TODD LAMMLE

CompTIA Network+ STUDY GUIDE

Fourth Edition

Covers 100% of exam objectives, including networking concepts, infrastructure, network operations, network security, networking troubleshooting and tools, and much more...

Includes interactive online learning environment and study tools with:

+ 2 custom practice exams
+ 100 electronic flashcards
+ Searchable key term glossary

CompTIA

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EXAM N10-007

SYBEX
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CompTIA® Network+® Study Guide

Fourth Edition

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About the Author

Todd Lammle, CompTIA Network+, CCSI, CCNA/CCNP, is the authority on network certification and internetworking. He is a world-renowned author, speaker, trainer, and consultant with more than 100 study guides in print. Todd has more than 30 years of experience working with LANs, WANs, and large licensed and unlicensed wireless networks and currently is working on a Cisco Security expert certification. He's president and CEO of Todd Lammle, LLC, a network-integration and training firm based in Colorado, Texas, and San Francisco, California. You can reach Todd through his website at `www.lammle.com/network±`.

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Becoming a CompTIA Certified IT Professional is Easy

It's also the best way to reach greater professional opportunities and rewards.

Why Get CompTIA Certified?

Growing Demand

Labor estimates predict some technology fields will experience growth of over 20% by the year 2020.* CompTIA certification qualifies the skills required to join this workforce.

Higher Salaries

IT professionals with certifications on their resume command better jobs, earn higher salaries, and have more doors open to new multi-industry opportunities.

Verified Strengths

91% of hiring managers indicate CompTIA certifications are valuable in validating IT expertise, making certification the best way to demonstrate your competency and knowledge to employers.**

Universal Skills

CompTIA certifications are vendor neutral—which means that certified professionals can proficiently work with an extensive variety of hardware and software found in most organizations.

Learn

Learn more about what the exam covers by reviewing the following:

- Exam objectives for key study points.
- Sample questions for a general overview of what to expect on the exam and examples of question format.
- Visit online forums, like LinkedIn, to see what other IT professionals say about CompTIA exams.

Certify

Purchase a voucher at a Pearson VUE testing center or at CompTIAstore.com.

- Register for your exam at a Pearson VUE testing center:
- Visit pearsonvue.com/CompTIA to find the closest testing center to you.
- Schedule the exam online. You will be required to enter your voucher number or provide payment information at registration.
- Take your certification exam.

Work

Congratulations on your CompTIA certification!

- Make sure to add your certification to your resume.
- Check out the CompTIA Certification Roadmap to plan your next career move.

Learn more: **Certification.CompTIA.org**

* Source: CompTIA 9th Annual Information Security Trends study: 500 U.S. IT and Business Executives Responsible for Security

** Source: CompTIA Employer Perceptions of IT Training and Certification

Introduction

If you're like most of us in the networking community, you probably have one or more network certifications. If that's you, you're very wise in choosing a CompTIA Network+ (N10-007) certification to proudly add to your repertoire because that achievement will make you all the more valuable as an employee. In these challenging economic times, keeping ahead of the competition—even standing out among your present colleagues—could make a big difference in whether you gain a promotion or possibly keep your job instead of being the one who gets laid off! Or maybe this is your first attempt at certification because you've decided to venture into a new career in information technology (IT). You've realized that getting into the IT sector is a good way to go because as the information age marches on, the demand for knowledgeable professionals in this dynamic field will only intensify dramatically.

Either way, certification is one of the best things you can do for your career if you are working in, or want to break into, the networking profession because it proves that you know what you're talking about regarding the subjects in which you're certified. It also powerfully endorses you as a professional in a way that's very similar to a physician being board certified in a certain area of expertise.

In this book, you'll find out what the Network+ exam is all about because each chapter covers a part of the exam. I've included some great review questions at the end of each chapter to help crystallize the information you learned and solidly prepare you to ace the exam.

A really cool thing about working in IT is that it's constantly evolving, so there are always new things to learn and fresh challenges to master. Once you obtain your Network+ certification and discover that you're interested in taking it further by getting into more complex networking (and making more money), the Cisco CCNA certification is definitely your next step; you can get the skinny on that and even more in-depth certifications on my blog at `www.lammle.com`.

NOTE For Network+ training with Todd Lammle, both instructor-led and online, please see `www.lammle.com/network+`.

What Is the Network+ Certification?

Network+ is a certification developed by the Computing Technology Industry Association (CompTIA) that exists to provide resources and education for the computer and technology community. This is the same body that developed the A+ exam for PC technicians.

The Network+ exam was designed to test the skills of network technicians with 18 to 24 months of experience in the field. It tests areas of networking technologies such as the definition of a protocol, the Open Systems Interconnection (OSI) model and its layers, and the concepts of network design and implementation—the minimum knowledge required for working on a network and some integral prerequisites for network design and implementation.

Why Become Network+ Certified?

Because CompTIA is a well-respected developer of vendor-neutral industry certifications, becoming Network+ certified proves you're competent in the specific areas covered by the Network+ objectives.

Four major benefits are associated with becoming Network+ certified:

Proof of Professional Achievement Networking professionals are pretty competitive when it comes to collecting more certifications than their peers. And because the Network+ certification broadly covers the entire field of networking, technicians want this certification a lot more than just Microsoft certifications—Network+ is a lot more prestigious and valuable. Because it's rare to gain something that's worth a lot with little effort, I'll be honest—preparing for the Network+ exam isn't exactly a lazy day at the beach. (However, beaches do happen to be really high on my personal list of great places to study!) And people in IT know that it isn't all that easy to pass the Network+ exam, so they'll definitely respect you more and know that you've achieved a certain level of expertise about vendor-independent, networking-related subjects.

Opportunity for Advancement We all like to get ahead in our careers—advancement results in more responsibility and prestige, and it usually means a fatter paycheck, greater opportunities, and added options. In the IT sector, a great way to make sure all that good stuff happens is by earning a lot of technology certifications, including Network+.

Fulfillment of Training Requirements Network+, because of its wide-reaching industry support, is recognized as a baseline of networking information. Some companies actually specify the possession of a Network+ certification as a job requirement before they'll even consider hiring you, or it may be specified as a goal to be met before your next review.

Customer Confidence As companies discover the CompTIA advantage, they will undoubtedly require qualified staff to achieve these certifications. Many companies outsource their work to consulting firms with experience working with security. Firms that have certified staff have a definite advantage over firms that don't.

How to Become Network+ Certified

As this book goes to press, Pearson VUE is the sole Network+ exam provider. The following is the necessary contact information and exam-specific details for registering. Exam pricing might vary by country or by CompTIA membership.

Vendor	Website	Phone Number
Pearson VUE	`www.pearsonvue.com/comptia`	US and Canada: 877-551-PLUS (7587)

When you schedule the exam, you'll receive instructions regarding appointment and cancellation procedures, ID requirements, and information about the testing center location. In addition, you'll receive a registration and payment confirmation letter. Exams can be scheduled up to six weeks out or as soon as the next day (or, in some cases, even the same day).

NOTE Exam prices and codes may vary based on the country in which the exam is administered. For detailed pricing and exam registration procedures, refer to CompTIA's website at `www.comptia.org`.

After you've successfully passed your Network+ exam, CompTIA will award you a certification. Within four to six weeks of passing the exam, you'll receive your official CompTIA Network+ certificate and ID card. (If you don't receive these within eight weeks of taking the test, contact CompTIA directly using the information found in your registration packet.)

Tips for Taking the Network+ Exam

Here are some general tips for taking your exam successfully:

- Bring two forms of ID with you. One must be a photo ID, such as a driver's license. The other can be a major credit card or a passport. Both forms must include a signature.
- Arrive early at the exam center so you can relax and review your study materials, particularly tables and lists of exam-related information. After you are ready to enter the testing room, you will need to leave everything outside; you won't be able to bring any materials into the testing area.
- Read the questions carefully. Don't be tempted to jump to an early conclusion. Make sure you know exactly what each question is asking.
- Don't leave any unanswered questions. Unanswered questions are scored against you. There will be questions with multiple correct responses. When there is more than one correct answer, a message at the bottom of the screen will prompt you to either "choose two" or "choose all that apply." Be sure to read the messages displayed to know how many correct answers you must choose.
- When answering multiple-choice questions you're not sure about, use a process of elimination to get rid of the obviously incorrect answers first. Doing so will improve your odds if you need to make an educated guess.
- On form-based tests (nonadaptive), because the hard questions will take the most time, save them for last. You can move forward and backward through the exam.

Who Should Read This Book?

You—if want to pass the Network+ exam, and pass it confidently! This book is chock-full of the exact information you need and directly maps to Network+ exam objectives, so if you use it to study for the exam, your odds of passing shoot way up.

And in addition to including every bit of knowledge you need to learn to pass the exam, I've included some really great tips and solid wisdom to equip you even further to successfully work in the real IT world.

What Does This Book Cover?

This book covers everything you need to know to pass the CompTIA Network+ exam. But in addition to studying the book, it's a good idea to practice on an actual network if you can.

Here's a list of the 20 chapters in this book:

Chapter 1, "Introduction to Networks" This chapter includes an introduction to what a network is and an overview of the most common physical network topologies you'll find in today's networks.

Chapter 2, "The Open Systems Interconnection Specifications" This chapter covers the OSI model, what it is, what happens at each of its layers, and how each layer works.

Chapter 3, "Networking Topologies, Connectors, and Wiring Standards" This chapter covers the various networking media and topologies, plus the cable types and properties used in today's networks.

Chapter 4, "The Current Ethernet Specifications" This chapter covers how a basic Ethernet LAN works and describes and categorizes the different Ethernet specifications.

Chapter 5, "Networking Devices" It's important for you to understand all the various devices used in today's networks, and this chapter will describe how hubs, routers, and switches and some other devices work within a network.

Chapter 6, "Introduction to the Internet Protocol" This is your introduction to the all-important IP protocol stack.

Chapter 7, "IP Addressing" This chapter will take up from where Chapter 6 left off and move into IP addressing. It also contains information about public versus private addressing and DHCP.

Chapter 8, "IP Subnetting, Troubleshooting IP, and Introduction to NAT" Beginning where Chapter 7 ends, we'll be tackling IP subnetting in this one. But no worries here—I've worked hard to make this not-so-popular-yet-vital topic as painless as possible.

Chapter 9, "Introduction to IP Routing" This is an introduction to routing that basically covers what routers do and how they do it. This chapter, along with Chapter 10 and Chapter 11, cover routing and switching in much more detail than what is necessary to meet the CompTIA Network+ objectives because this knowledge is so critical to grasp when working with today's networks.

Chapter 10, "Routing Protocols" This chapter goes into detail describing the protocols that run on routers and that update routing tables to create a working map of the network.

Chapter 11, "Switching and Virtual LANs" This chapter covers Layer 2 switching, the Spanning Tree Protocol (STP), and virtual LANs. I went deeper than needed for the exam with the routing chapters, and I'll cover switching and virtual LANs (which are also vital in today's corporate networks) more thoroughly as well.

Chapter 12, "Wireless Networking" Because wireless is so important for both home and business networks today, this chapter is loaded with all the information you need to be successful at wireless networking at home and work.

Chapter 13, "Authentication and Access Control" This is the first of three security chapters. There are tons of exam objectives about network security that are so important that I took three chapters to cover all of them. In this chapter, I'll introduce security, security filtering, tunneling, and user authentication.

Chapter 14, "Network Threats and Mitigation" This is probably the most fun of the three security chapters because I'll tell you all about security threats and how to stop them. The only way to get good at network security is to implement it, and this chapter shows you how.

Chapter 15, "Physical Security and Risk" This chapter's focus is on explaining basic firewalls, security devices, and device security.

Chapter 16, "Wide Area Networks" In this chapter, you get to learn all about things like Frame Relay, E1/T1, DSL, cable modems, and more. All of the CompTIA Network+ WAN objectives are covered in this chapter.

Chapter 17, "Troubleshooting Tools" This is also a fun chapter because, again, you can follow along and run all the commands yourself. And I repeat, it's a really good idea to run through all the commands in this chapter!

Chapter 18, "Software and Hardware Tools" This chapter introduces you to the network tools you will use to help you run your networks. Both software and hardware tools will be discussed.

Chapter 19, "Network Troubleshooting" In almost every chapter, I discuss how to verify and fix problems, but this chapter will really get into the nuts and bolts of detailed network troubleshooting and documentation.

Chapter 20, "Management, Monitoring, and Optimization" This last chapter will provide configuration-management documentation and covers wiring, logical diagrams, baselines, policies, and regulations.

What's Included in the Book

I've included several study tools throughout the book:

Assessment Test At the end of this introduction is an assessment test that you can use to check your readiness for the exam. Take this test before you start reading the book; it will help you determine the areas you might need to brush up on. The answers to the assessment test questions appear on a separate page after the last question of the test. Each answer includes an explanation and a note telling you the chapter in which the material appears.

Objective Map and Opening List of Objectives On the inside front cover of this book is a detailed exam objective map showing you where each of the exam objectives is covered in this book. In addition, each chapter opens with a list of the exam objectives it covers. Use these to see exactly where each of the exam topics is covered.

Exam Essentials Each chapter, just after the summary, includes a number of exam essentials. These are the key topics you should take from the chapter in terms of areas to focus on when preparing for the exam.

Written Lab Each chapter includes a written lab. These are short exercises that map to the exam objectives. Answers to these can be found in Appendix A.

Chapter Review Questions To test your knowledge as you progress through the book, there are review questions at the end of each chapter. As you finish each chapter, answer the review questions and then check your answers—the correct answers and explanations are in Appendix B. You can go back to reread the section that deals with each question you got wrong to ensure that you answer correctly the next time you're tested on the material.

Interactive Online Learning Environment and Test Bank

The interactive online learning environment that accompanies *CompTIA Network+ Study Guide: Exam N10-007* provides a test bank with study tools to help you prepare for the certification exam—and increase your chances of passing it the first time! The test bank includes the following tools:

Sample Tests All of the questions in this book are provided, including the assessment test, which you'll find at the end of this introduction, and the chapter tests that include the review questions at the end of each chapter. In addition, there are two practice exams. Use these questions to test your knowledge of the study guide material. The online test bank runs on multiple devices.

Flashcards Approximately 100 questions are provided in digital flashcard format (a question followed by a single correct answer). You can use the flashcards to reinforce your learning and provide last-minute test prep before the exam.

Other Study Tools A glossary of key terms from this book and their definitions are available as a fully searchable PDF.

NOTE

Go to `http://www.wiley.com/go/netplustestprep` to register and gain access to this interactive online learning environment and test bank with study tools.

How to Use This Book

If you want a solid foundation for the serious effort of preparing for the Network+ exam, then look no further because I've spent countless hours putting together this book with the sole intention of helping you pass it!

This book is loaded with valuable information, and you will get the most out of your study time if you understand how I put the book together. Here's a list that describes how to approach studying:

1. Take the assessment test immediately following this introduction. (The answers are at the end of the test, but no peeking!) It's okay if you don't know any of the answers—that's what this book is for. Carefully read over the explanations for any question you get wrong, and make note of the chapters where that material is covered.

2. Study each chapter carefully, making sure you fully understand the information and the exam objectives listed at the beginning of each one. Again, pay extra-close attention to any chapter that includes material covered in questions you missed on the assessment test.
3. Complete the written lab at the end of each chapter. Do *not* skip these written exercises because they directly map to the CompTIA objectives and what you've got to have nailed down to meet them.
4. Answer all the review questions related to each chapter. Specifically note any questions that confuse you, and study the corresponding sections of the book again. And don't just skim these questions—make sure you understand each answer completely.
5. Try your hand at the practice exams. Before you take your test, be sure to visit my website for questions, videos, audios, and other useful information.
6. Test yourself using all the electronic flashcards. This is a brand-new and updated flashcard program to help you prepare for the latest CompTIA Network+ exam, and it is a really great study tool.

I tell you no lies—learning every bit of the material in this book is going to require applying yourself with a good measure of discipline. So try to set aside the same time period every day to study, and select a comfortable and quiet place to do so. If you work hard, you will be surprised at how quickly you learn this material.

If you follow the steps listed here and study with the review questions, practice exams, electronic flashcards, and all the written labs, you would almost have to try to fail the CompTIA Network+ exam. However, studying for the Network+ exam is like training for a marathon—if you don't go for a good run every day, you're not likely to finish very well.

NOTE

This book covers everything about CompTIA Network+. For up-to-date information about Todd Lammle CompTIA boot camps, audio training, and training videos, please see `www.lammle.com/network+`.

Exam Objectives

Speaking of objectives, you're probably pretty curious about those, right? CompTIA asked groups of IT professionals to fill out a survey rating the skills they felt were important in their jobs, and the results were grouped into objectives for the exam and divided into five domains.

This table gives you the extent by percentage that each domain is represented on the actual examination.

Domain	% of Examination
1.0 Networking Concepts	23%
2.0 Infrastructure	18%
3.0 Network Operations	17%
4.0 Network Security	20%
5.0 Network Troubleshooting and Tools	22%
Total	100%

N10-007 Exam Objectives

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Assessment Test

1. What is the basic purpose of a local area network (LAN)?
   - **A.** To interconnect networks in several different buildings
   - **B.** To connect one or more computers together so they can share resources
   - **C.** To interconnect 2 to 10 routers
   - **D.** To make routers unnecessary

2. You need a topology that is easy to troubleshoot and scalable. Which would you use?
   - **A.** Bus
   - **B.** Star
   - **C.** Mesh
   - **D.** Ring

3. IP resides at which layer of the OSI model?
   - **A.** Application
   - **B.** Data Link
   - **C.** Network
   - **D.** Physical

4. Layer 2 of the OSI model is named __________ .
   - **A.** Application layer
   - **B.** Network layer
   - **C.** Transport layer
   - **D.** Data Link layer

5. Which RG rating of coax is used for cable modems?
   - **A.** RG-59
   - **B.** RG-58
   - **C.** RG-6
   - **D.** RG-8

6. Which UTP wiring uses four twisted wire pairs (eight wires) and is rated for 250 MHz?
   - **A.** Category 3 UTP
   - **B.** Category 5 STP
   - **C.** Category 5 UTP
   - **D.** Category 6 UTP

7. If you are running half-duplex Internet, which of the following is true? (Choose all that apply.)

   A. Your digital signal cannot transmit and receive data at the same time.

   B. Hosts use the CSMA/CD protocol to detect collisions.

   C. The physical connection consists of one wire pair.

   D. None of the above.

8. You need to connect a hub to a switch. You don't like this idea because you know that it will create congestion. What type of cable do you need to use to connect the hub to the switch?

   A. EtherIP

   B. Crossover

   C. Straight-through

   D. Cable Sense, Multiple Access

9. Your boss asks you why you just put in a requisition to buy a bunch of switches. He said he just bought you a bunch of hubs five years ago! Why did you buy the switches?

   A. Because each switch port is its own collision domain.

   B. The cable connecting devices to the hub wore out, and switches were cheaper than new cable.

   C. There were too many broadcast domains, and a switch breaks up broadcast domains by default.

   D. The hubs kept repeating signals but quit recognizing frames and data structures.

10. Which device would connect network segments together, creating separate collision domains for each segment but only a single broadcast domain?

    A. Hub

    B. Router

    C. Switch

    D. Modem

11. Most Application layer protocols use only UDP or TCP at the Transport layer. Which of the following could use both?

    A. TCP

    B. Microsoft Word

    C. Telnet

    D. DNS

12. HTTP, FTP, and Telnet work at which layer of the OSI model?

    A. Application

    B. Presentation

    C. Session

    D. Transport

13. IPv6 uses multiple types of addresses. Which of the following would describe an anycast address used by an IPv6 host?

    A. Communications are routed to the most distant host that shares the same address.

    B. Packets are delivered to all interfaces identified by the address. This is also called one-to-many addressing.

    C. This address identifies multiple interfaces, and the anycast packet is only delivered to one address. This address can also be called one-to-one-of-many.

    D. Anycast is a type of broadcast.

14. Which of the following IP addresses are not allowed on the Internet? (Choose all that apply.)

    A. 11.255.255.1

    B. 10.1.1.1

    C. 172.33.255.0

    D. 192.168.0.1

15. What is the subnetwork address for a host with the IP address 200.10.5.168/28?

    A. 200.10.5.156

    B. 200.10.5.132

    C. 200.10.5.160

    D. 200.10.5.0

    E. 200.10.5.255

16. If you wanted to verify the local IP stack on your computer, what would you do?

    A. Ping 127.0.0.0

    B. Ping 127.0.0.1

    C. Telnet 1.0.0.127

    D. Ping 169.5.3.10

    E. Telnet 255.255.255.255

17. The OSI model uses an encapsulation method to describe the data as it is encapsulated at each layer. What is the encapsulation named at the Data Link layer?

    A. Bits

    B. Packets

    C. Frames

    D. Data

    E. Segments

18. Where does a Data Link layer frame have to carry a Network layer packet if the packet is destined for a remote network?

    A. Router

    B. Physical medium

    C. Switch

    D. Another host

19. Which of the following are not distance vector routing protocols? (Choose all that apply.)

A. OSPF

B. RIP

C. RIPv2

D. IS-IS

20. Which of the following uses both distance vector and link state properties?

A. IGRP

B. OSPF

C. RIPv1

D. EIGRP

E. IS-IS

21. You need to break up broadcast domains in a Layer 2 switched network. What strategy will you use?

A. Implement a loop-avoidance scheme.

B. Create a flatter network structure using switches.

C. Create a VLAN.

D. Disable the spanning tree on individual ports.

22. Why do most switches run the Spanning Tree Protocol by default?

A. It monitors how the network is functioning.

B. It stops data from forwarding until all devices are updated.

C. It prevents switching loops.

D. It manages the VLAN database.

23. Which of the following describes MIMO correctly?

A. A protocol that requires acknowledgment of each and every frame

B. A data-transmission technique in which several frames are sent by several antennas over several paths and are then recombined by another set of antennas

C. A modulation technique that allows more than one data rate

D. A technique that packs smaller packets into a single unit, which improves throughput

24. Which two practices help secure your wireless access points from unauthorized access? (Choose all that apply.)

A. Assigning a private IP address to the AP

B. Changing the default SSID value

C. Configuring a new administrator password

D. Changing the mixed-mode setting to single mode

E. Configuring traffic filtering

25. IPSec is defined at what layer of the OSI model?
    - A. Network
    - B. Physical
    - C. Layer 4
    - D. Layer 7

26. You want your users to log in and authenticate before they can get onto your network. Which of the following services would you use?
    - A. RADIUS
    - B. DNS
    - C. Virtual Network Computing
    - D. Remote Desktop Protocol

27. Someone calls you and asks for your bank account number because the bank is having problems with your account. You give them this information and later find out that you were scammed. What type of attack is this?
    - A. Phishing
    - B. Calling scam
    - C. Analog scam
    - D. Trust-exploration attack
    - E. Man-in-the-middle attack
    - F. Rogue access point

28. Which of the following are types of denial-of-service attacks? (Choose all that apply.)
    - A. Ping of Death
    - B. Stacheldraht
    - C. SYN flood
    - D. Virus FloodSyn

29. You want to stop a hacker in their tracks. Which of the following devices are proactive in providing this service?
    - A. Access control list (ACL)
    - B. Content filtering
    - C. Security zones
    - D. Intrusion prevention system (IPS)
    - E. Network Address Translation
    - F. Virtual LANs

30. You connected your company to the Internet, and security is a concern. What should you install?

A. Higher-quality cables

B. Firewall

C. DNS

D. Switches

31. Which of the following are WAN protocols or technologies? (Choose all that apply.)

A. ATM

B. ISDN

C. MPLS

D. RIP

32. The rate at which the Frame Relay switch agrees to transfer data is referred to as ________ .

A. BE

B. FECN

C. CIR

D. BECN

33. Which two `arp` utility switches perform the same function?

A. `-g`

B. `-Z`

C. `-d`

D. `-a`

E. `-h`

F. `-b`

34. You need to purge and reload the remote NetBIOS name table cache. Which `nbtstat` utility switch will you use?

A. `-r`

B. `-R`

C. `/r`

D. `/R`

E. `-a`

F. `-A`

35. Which tool is used to attach ends to network cables?

A. Punch-down tool

B. Crimper

C. VLAN tool

D. Strippers

E. ARP tool

36. You are using a TDR. Which of the following actions can you do with this device? (Choose all that apply.)

A. Estimate cable lengths

B. Find splice and connector locations and their associated loss amounts

C. Display unused services

D. Define cable-impedance characteristics

37. Which of the following are considered cabling issues? (Choose all that apply.)

A. Crosstalk

B. Shorts

C. Open impedance mismatch

D. DNS configurations

38. You have just tested your theory of a problem to determine the cause. Based on the standard troubleshooting model, what is your next step?

A. Question the obvious.

B. Establish a theory of probable cause.

C. Establish a plan of action to resolve the problem and identify potential effects.

D. Verify full system functionality, and if applicable, implement preventative measures.

39. Which network performance optimization technique can delay packets that meet certain criteria to guarantee usable bandwidth for other applications?

A. Traffic shaping

B. Jitter control

C. Logical network mapping

D. Load balancing

E. Access lists

40. You need to optimize network traffic by spreading it across multiple connections. Which strategy should be used?

A. Load balancing

B. Traffic shaping

C. Adding VLANs

D. A 1 Gbps connection

E. Following the regulations

Answers to Assessment Test

1. B. LANs generally have a geographic scope of a single building or smaller. They can be simple (two hosts) to complex (with thousands of hosts). See Chapter 1 for more information.

2. B. Star topologies are the easiest to troubleshoot and can easily scale to large sizes. See Chapter 1 for more information.

3. C. IP is a Network layer protocol. Internet Explorer is an example of an Application layer protocol, Ethernet is an example of a Data Link layer protocol, and T1 can be considered a Physical layer protocol. See Chapter 2 for more information.

4. D. Layer 2 of the OSI model is the Data Link layer, which provides the physical transmission of the data and handles error notification, network topology, and flow control. See Chapter 2 for more information.

5. C. Cable modems use RG-6 coax cables. See Chapter 3 for more information.

6. D. To get the high data-transfer speed, like 1 Gbps, you need to use a wire standard that is highly rated, such as Category 5e or Category 6. See Chapter 3 for more information.

7. A, B, C. With half duplex, you are using one wire pair with a digital signal either transmitting or receiving (but not both at once). Carrier Sense Multiple Access with Collision Detection (CSMA/CD) helps packets that are transmitted simultaneously from different hosts share bandwidth evenly. See Chapter 4 for more information.

8. B. To connect two switches together or a hub to a switch, you need a crossover cable. See Chapter 4 for more information.

9. A. For the most part, switches are not cheap; however, one of the biggest benefits of using switches instead of hubs in your internetwork is that each switch port is actually its own collision domain. A hub creates one large collision domain. Switches still can't break up broadcast domains (do you know which devices do?). Hubs do not recognize frames and data structures but switches do. See Chapter 5 for more information.

10. C. A switch creates separate collision domains for each port but does not break up broadcast domains by default. See Chapter 5 for more information.

11. D. DNS uses TCP for zone exchanges between servers and UDP when a client is trying to resolve a hostname to an IP address. See Chapter 6 for more information.

12. A. HTTP, FTP, and Telnet use TCP at the Transport layer; however, they are all Application layer protocols, so the Application layer is the best answer for this question. See Chapter 6 for more information.

13. C. Anycast is a new type of communication that replaces broadcasts in IPv4. Anycast addresses identify multiple interfaces, which is the same as multicast; however, the big difference is that the anycast packet is delivered to only one address: the first one it finds defined in terms of routing distance. This address can also be called one-to-one-of-many. See Chapter 7 for more information.

14. B, D. The addresses in the ranges 10.0.0.0 through 10.255.255.255 and 172.16.0.0 through 172.31.255.255 as well as 192.168.0.0 through 192.168.255.255 are all considered private, based on RFC 1918. Use of these addresses on the Internet is prohibited so that they can be used simultaneously in different administrative domains without concern for conflict. See Chapter 7 for more detail on IP addressing and information on private IP addresses.

15. C. This is a pretty simple question. A /28 is 255.255.255.240, which means that our block size is 16 in the fourth octet. 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, and so on. The host is in the subnet 160. See Chapter 8 for more information.

16. B. To test the local stack on your host, ping the loopback interface of 127.0.0.1. See Chapter 8 for more information.

17. C. The Data Link layer is responsible for encapsulating IP packets into frames and for providing logical network addresses. See Chapter 9 for more information.

18. A. Packets specifically have to be carried to a router in order to be routed through a network. On your local computer, the IP address of this router is displayed as the gateway address. See Chapter 9 for more information.

19. A, D. RIP and RIPv2 are distance vector routing protocols. OSPF and IS-IS are link state. See Chapter 10 for more information.

20. D. EIGRP is called a hybrid routing protocol because it uses the characteristics of both distance vector and link state routing protocols. However, EIGRP can only be run on Cisco routers and is not vendor neutral. The new CompTIA objectives mention BGP as a hybrid routing protocol. See Chapter 10 for more information.

21. C. Virtual LANs break up broadcast domains in Layer 2 switched internetworks. See Chapter 11 for more information.

22. C. The Spanning Tree Protocol (STP) was designed to stop Layer 2 loops. All enterprise model switches have STP by default. See Chapter 11 for more information.

23. B. Part of the 802.11n wireless standard, MIMO sends multiple frames by several antennas over several paths; they are then recombined by another set of antennas to optimize throughput and multipath resistance. This is called spatial multiplexing. See Chapter 12 for more information.

24. B, C. At a minimum, you need to change the default SSID value on each AP and configure new usernames and passwords on the AP. See Chapter 12 for more information.

25. A. IPSec works at the Network layer of the OSI model (Layer 3) and secures all applications that operate above it (Layer 4 and above). Additionally, because it was designed by the IETF and designed to work with IPv4 and IPv6, it has broad industry support and is quickly becoming the standard for VPNs on the Internet. See Chapter 13 for more information.

26. A. RADIUS combines user authentication and authorization into one profile. See Chapter 13 for more information.

27. A. Social engineering, or phishing, refers to the act of attempting to illegally obtain sensitive information by pretending to be a credible source. Phishing usually takes one of two forms: an email or a phone call. See Chapter 14 for more information.

28. A, B, C. A denial-of-service (DoS) attack prevents users from accessing the system. All of the options are possible denial-of-service attacks except Virus FloodSyn. See Chapter 14 for more information.

29. D. Changing network configurations, terminating sessions, and deceiving the attacker are all actions that can be taken by an intrusion prevention system (IPS) device. These are all proactive approaches to security. See Chapter 15 for more information.

30. B. Firewalls help provide perimeter network security by allowing or denying connections and types of traffic in or out of the network. See Chapter 15 for more information.

31. A, B, C. Routing Information Protocol (RIP) is not a WAN protocol but a routing protocol used in local area connections. See Chapter 16 for more information.

32. C. The committed information rate (CIR) is the rate, in bits per second, at which the Frame Relay switch agrees to transfer data. See Chapter 16 for more information.

33. A, D. The `arp` utility's `-a` and `-g` switches perform the same function. They both show the current ARP cache. See Chapter 17 for more information.

34. B. To purge and reload the remote NetBIOS name cache, you must use `nbtstat -R`. Remember that the *R* must be uppercase, and it will not work correctly without the hyphen before it. See Chapter 17 for more information.

35. B. A wire crimper or crimper is used to attach ends onto different types of network cables. See Chapter 18 for more information.

36. A, B, D. Due to sensitivity to any variation and impedance to cabling, options A, B, and D are all reasons you'd use a time-domain reflectometer (TDR). See Chapter 18 for more information.

37. A, B, C. Because most of today's networks still consist of large amounts of copper cable, they can continue to suffer from the physical issues (the options are not a complete list) that have plagued all networks since the very beginning of networking. See Chapter 19 for more information.

38. C. Based on the standard troubleshooting model, the next step would be to establish a plan of action to resolve the problem and identify potential effects. See Chapter 19 for more information.

39. A. Traffic shaping, also known as packet shaping, is another form of bandwidth optimization. See Chapter 20 for more information.

40. A. Load balancing refers to a technique used to spread work out to multiple computers, network links, or other devices. You can load-balance work on servers by clustering servers so that multiple machines all provide the same service. See Chapter 20 for more information.

Chapter 1

Introduction to Networks

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.5 Compare and contrast the characteristics of network topologies, types, and technologies**

- Wired topologies
  - Logical vs. physical
  - Star
  - Ring
  - Mesh
  - Bus
  - CAN
  - SAN

You'd have to work pretty hard these days to find someone who would argue when we say that our computers have become invaluable to us personally and professionally. Our society has become highly dependent on the resources they offer and on sharing them with each other. The ability to communicate with others—whether they're in the same building or in some faraway land—completely hinges on our capacity to create and maintain solid, dependable networks.

And those vitally important networks come in all shapes and sizes—ranging from small and simple to humongous and super complicated. But whatever their flavor, they all need to be maintained properly, and to do that well, you have to understand networking basics. The various types of devices and technologies that are used to create networks, as well as how they work together, is what this book is about, and I'll go through this critical information one step at a time with you. Understanding all of this will not only equip you with a rock-solid base to build on as you gain IT knowledge and grow in your career, it will also arm you with what you'll need to ace the Network+ certification exam!

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

First Things First: What's a Network?

The dictionary defines the word *network* as "a group or system of interconnected people or things." Similarly, in the computer world, the term *network* means two or more connected computers that can share resources such as data and applications, office machines, an Internet connection, or some combination of these, as shown in Figure 1.1.

FIGURE 1.1 A basic network

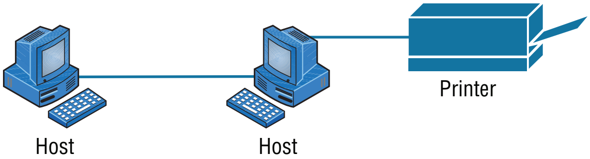


Figure 1.1 shows a really basic network made up of only two host computers connected; they share resources such as files and even a printer hooked up to one of the hosts. These

two hosts "talk" to each other using a computer language called *binary code*, which consists of lots of 1s and 0s in a specific order that describes exactly what they want to "say."

Next, I'm going to tell you about local area networks, how they work, and even how we can connect LANs together. Then, later in this chapter, I'll describe how to connect remote LANs together through something known as a wide area network.

The Local Area Network

Just as the name implies, a *local area network (LAN)* is usually restricted to spanning a particular geographic location such as an office building, a single department within a corporate office, or even a home office.

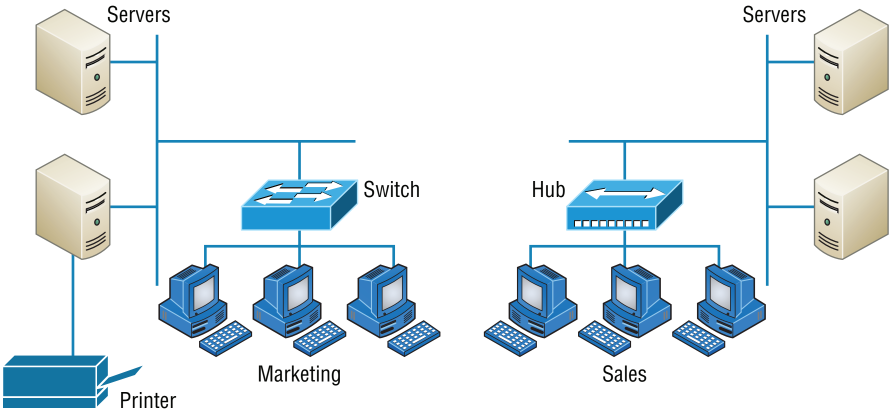
Back in the day, you couldn't put more than 30 workstations on a LAN, and you had to cope with strict limitations on how far those machines could actually be from each other. Because of technological advances, all that's changed now, and we're not nearly as restricted in regard to both a LAN's size and the distance a LAN can span. Even so, it's still best to split a big LAN into smaller logical zones known as *workgroups* to make administration easier.

NOTE

The meaning of the term *workgroup* in this context is slightly different than when the term is used in contrast to domains. In that context, a workgroup is a set of devices with no security association with one another (whereas in a domain they do have that association). In this context, we simply mean they physically are in the same network segment.

In a typical business environment, it's a good idea to arrange your LAN's workgroups along department divisions; for instance, you would create a workgroup for Accounting, another one for Sales, and maybe another for Marketing—you get the idea. Figure 1.2 shows two separate LANs, each as its own workgroup.

FIGURE 1.2 Two separate LANs (workgroups)



First, don't stress about the devices labeled *hub* and *switch*—these are just connectivity devices that allow hosts to physically connect to resources on an LAN. Trust me; I'll describe them to you in much more detail in Chapter 5, "Networking Devices."

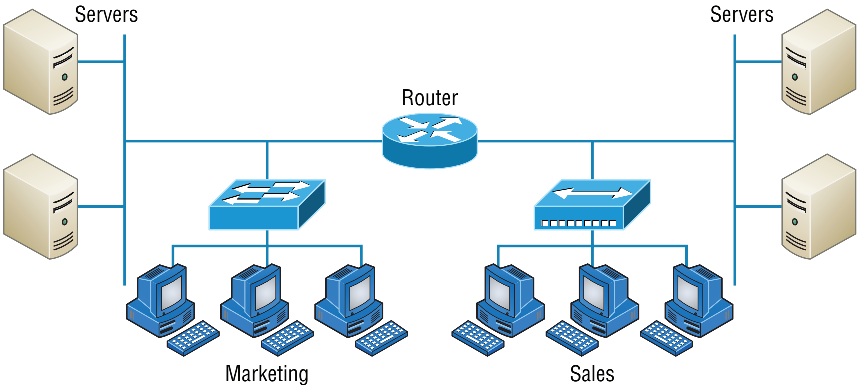
Anyway, back to the figure. Notice that there's a Marketing workgroup and a Sales workgroup. These are LANs in their most basic form. Any device that connects to the Marketing LAN can access the resources of the Marketing LAN—in this case, the servers and printer.

There are two problems with this:

- You must be physically connected to a workgroup's LAN to get the resources from it.
- You can't get from one LAN to the other LAN and use its server data and printing resources remotely.

This is a typical network issue that's easily resolved by using a cool device called a *router* to connect the two LANs, as shown in Figure 1.3.

FIGURE 1.3 A router connects LANs.



Nice—problem solved! Even though you can use routers for more than just connecting LANs, the router shown in Figure 1.3 is a great solution because the host computers from the Sales LAN can get to the resources (server data and printers) of the Marketing LAN, and vice versa.

Now, you might be thinking that we really don't need the router—that we could just physically connect the two workgroups with a type of cable that would allow the Marketing and Sales workgroups to hook up somehow. Well, we could do that, but if we did, we would have only one big, cumbersome workgroup instead of separate workgroups for Marketing and Sales, and that kind of arrangement just isn't practical for today's networks.

This is because with smaller, individual-yet-connected groups, the users on each LAN enjoy much faster response times when accessing resources, and administrative tasks are a lot easier, too. Larger workgroups run more slowly because there's a legion of hosts within them that are all trying to get to the same resources simultaneously. So the router shown in Figure 1.3, which separates the workgroups while still allowing access between them, is a really great solution!

NOTE Don't focus too much on the network connectivity devices like the hubs, routers, and switches I've mentioned so far in this chapter yet. We'll thoroughly cover them all later, in Chapter 5. Right now, I really want you to prioritize your understanding of the concepts that I'm presenting here, so at this point, all you need to know is that hubs and switches are devices that connect other devices together into a network and routers connect networks together.

So let me define the other terms I've used so far: *workstations*, *servers*, and *hosts*.

Common Network Components

There are a lot of different machines, devices, and media that make up our networks. Let's talk about three of the most common:

- Workstations
- Servers
- Hosts

Workstations

Workstations are often seriously powerful computers that run more than one central processing unit (CPU) and whose resources are available to other users on the network to access when needed. With this much power, you might think I am describing a server—not quite because there is an important difference between these devices that I'll cover in the next section. Workstations are often employed as systems that end users use on a daily basis. Don't confuse workstations with client machines, which can be workstations but not always. People often use the terms *workstation* and *client* interchangeably. In colloquial terms, this isn't a big deal; we all do it. But technically speaking, they are different. A *client machine* is any device on the network that can ask for access to resources like a printer or other hosts from a server or powerful workstation.

NOTE The terms *workstation*, *client*, and *host* can sometimes be used interchangeably. Computers have become more and more powerful and the terms have become somewhat fuzzy because hosts can be clients, workstations, servers, and more! The term *host* is used to describe pretty much anything that takes an IP address.

Servers

Servers are also powerful computers. They get their name because they truly are "at the service" of the network and run specialized software known as the network operating system to maintain and control the network.

In a good design that optimizes the network's performance, servers are highly specialized and are there to handle one important labor-intensive job. This is not to say that a single server can't do many jobs, but more often than not, you'll get better performance if you dedicate a server to a single task. Here's a list of common dedicated servers:

File Server Stores and dispenses files

Mail Server The network's post office; handles email functions

Print Server Manages printers on the network

Web Server Manages web-based activities by running Hypertext Transfer Protocol (HTTP) for storing web content and accessing web pages

Fax Server The "memo maker" that sends and receives paperless faxes over the network

Application Server Manages network applications

Telephony Server Handles the call center and call routing and can be thought of as a sophisticated network answering machine

Proxy Server Handles tasks in the place of other machines on the network, particularly an Internet connection.

NOTE See how the name of each kind of server indicates what it actually does—how it serves the network? This is an excellent way to remember them.

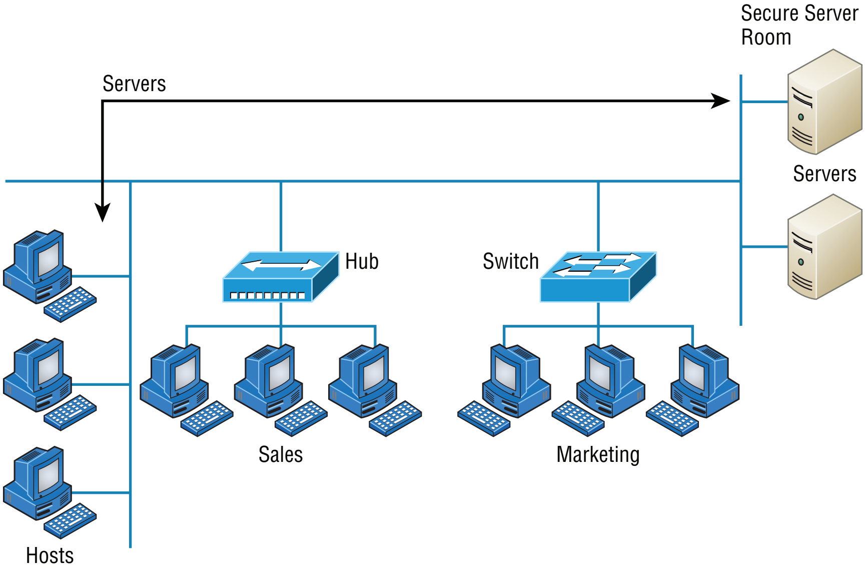
As I said, servers are usually dedicated to doing one specific important thing within the network. Not always, though—sometimes they have more than one job. But whether servers are designated for one job or are network multitaskers, they can maintain the network's data integrity by backing up the network's software and providing redundant hardware (for fault tolerance). And no matter what, they all serve a number of client machines.

Back in Figure 1.2, I showed you an example of two really simple LAN networks. I want to make sure you know that servers must have considerably superior CPUs, hard-drive space, and memory—a lot more than a simple client's capacity—because they serve many client machines and provide any resources they require. Because they're so important, you should always put your servers in a very secure area. My company's servers are in a locked server room because not only are they really pricey workhorses, they also store huge amounts of important and sensitive company data, so they need to be kept safe from any unauthorized access.

In Figure 1.4, you can see a network populated with both workstations and servers. Also notice that the hosts can access the servers across the network, which is pretty much the general idea of having a network in the first place!

You probably picked up on the fact that there are more workstations here than servers, right? Think of why that is. If you answered that it's because one server can provide resources to what can sometimes be a huge number of individual users at the same time but workstations don't, you nailed it!

FIGURE 1.4 A network populated with servers and workstations



Hosts

This can be kind of confusing because when people refer to hosts, they really can be referring to almost any type of networking devices—including workstations and servers. But if you dig a bit deeper, you'll find that usually this term comes up when people are talking about resources and jobs that have to do with Transmission Control Protocol/Internet Protocol (TCP/IP). The scope of possible machines and devices is so broad because, in TCP/IP-speak, *host* means any network device with an IP address. Yes, you'll hear IT professionals throw this term around pretty loosely; for the Network+ exam, stick to the definition being network devices, including workstations and servers, with IP addresses.

Here's a bit of background: The name *host* harks back to the Jurassic period of networking when those dinosaurs known as *mainframes* were the only intelligent devices able to roam the network. These were called *hosts* whether they had TCP/IP functionality or not. In that bygone age, everything else in the network-scape was referred to as *dumb terminals* because only mainframes—hosts—were given IP addresses. Another fossilized term from way back then is *gateways*, which was used to talk about any Layer 3 machines like routers. We still use these terms today, but they've evolved a bit to refer to the many intelligent devices populating our present-day networks, each of which has an IP address. This is exactly the reason you hear *host* used so broadly.

Wide Area Network

There are legions of people who, if asked to define a *wide area network (WAN)*, just couldn't do it. Yet most of them use the big dog of all WANs—the Internet—every day!

With that in mind, you can imagine that WAN networks are what we use to span large geographic areas and truly go the distance. Like the Internet, WANs usually employ both routers and public links, so that's generally the criteria used to define them.

NOTE WANs are so important that I have dedicated an entire chapter to them: Chapter 16, "Wide Area Networks."

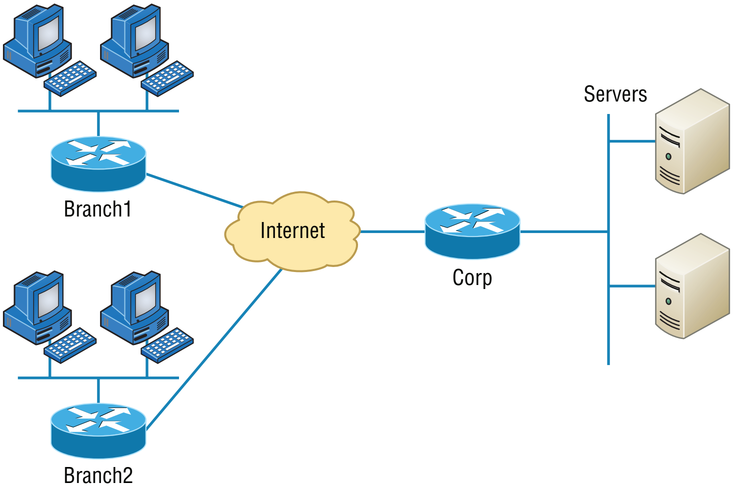
Here's a list of some of the important ways that WANs are different from LANs:

- WANs usually need a router port or ports.
- WANs span larger geographic areas and/or can link disparate locations.
- WANs are usually slower.
- We can choose when and how long we connect to a WAN. A LAN is all or nothing—our workstation is connected to it either permanently or not at all, although most of us have dedicated WAN links now.
- WANs can utilize either private or public data transport media such as phone lines.

We get the word *Internet* from the term *internetwork*. An internetwork is a type of LAN and/or WAN that connects a bunch of networks, or *intranets*. In an internetwork, hosts still use hardware addresses to communicate with other hosts on the LAN. However, they use logical addresses (IP addresses) to communicate with hosts on a different LAN (other side of the router).

And *routers* are the devices that make this possible. Each connection into a router is a different logical network. Figure 1.5 demonstrates how routers are employed to create an internetwork and how they enable our LANs to access WAN resources.

FIGURE 1.5 An internetwork



The Internet is a prime example of what's known as a *distributed WAN*—an internetwork that's made up of a lot of interconnected computers located in a lot of different places. There's another kind of WAN, referred to as *centralized*, that's composed of a main, centrally located computer or location that remote computers and devices can connect to. A good example is remote offices that connect to a main corporate office, as shown in Figure 1.5.

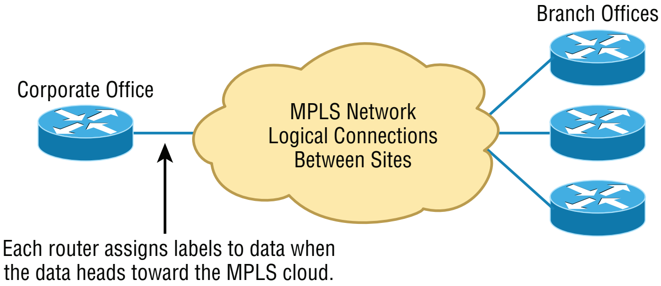
MPLS

Multiprotocol Label Switching (MPLS) will be defined clearly in Chapter 16, but for the objectives of the CompTIA Network+ exam, this chapter will define the actual layout of what is one of the most popular WAN protocols in use today. MPLS has become one of the most innovative and flexible networking technologies on the market, and it has some key advantages over other WAN technologies:

- Physical layout flexibility
- Prioritizing of data
- Redundancy in case of link failure
- One-to-many connection

MPLS is a switching mechanism that imposes labels (numbers) to data and then uses those labels to forward data when it arrives at the MPLS network, as shown in Figure 1.6.

FIGURE 1.6 Multiprotocol Label Switching layout


Branch Offices
Corporate Office
MPLS Network
Logical Connections
Between Sites
Each router assigns labels to data when
the data heads toward the MPLS cloud.

The labels are assigned on the edge of the MPLS network, and forwarding inside the MPLS network (cloud) is done solely based on labels through virtual links instead of physical links. Prioritizing data is a huge advantage; for example, voice data could have priority over basic data based on the labels. And since there are multiple paths for the data to be forwarded through the MPLS cloud, there's even some redundancy provided as well.

Network Architecture: Peer-to-Peer or Client-Server?

We've developed networking as a way to share resources and information, and how that's achieved directly maps to the particular architecture of the network operating system software. There are two main network types you need to know about: peer-to-peer and client-server. And by the way, it's really tough to tell the difference just by looking at a diagram or even by checking out live video of the network humming along. But the differences between peer-to-peer and client-server architectures are pretty major. They're not just physical; they're logical differences. You'll see what I mean in a bit.

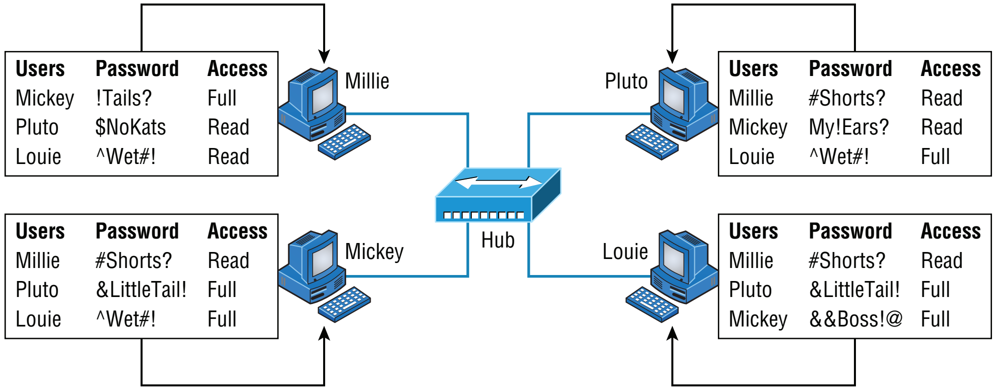
Peer-to-Peer Networks

Computers connected together in *peer-to-peer networks* do not have any central, or special, authority—they're all *peers*, meaning that when it comes to authority, they're all equals. The authority to perform a security check for proper access rights lies with the computer that has the desired resource being requested from it.

It also means that the computers coexisting in a peer-to-peer network can be client machines that access resources and server machines and provide those resources to other computers. This actually works pretty well as long as there isn't a huge number of users on the network, if each user backs things up locally, and if your network doesn't require much security.

If your network is running Windows, Mac, or Unix in a local LAN workgroup, you have a peer-to-peer network. Figure 1.7 gives you a snapshot of a typical peer-to-peer network. Keep in mind that peer-to-peer networks definitely present security-oriented challenges; for instance, just backing up company data can get pretty sketchy!

FIGURE 1.7 A peer-to-peer network



Users	Password	Access
Mickey	!Tails?	Full
Pluto	$NoKats	Read
Louie	^Wet#!	Read

Users	Password	Access
Millie	#Shorts?	Read
Mickey	My!Ears?	Read
Louie	^Wet#!	Full

Users	Password	Access
Millie	#Shorts?	Read
Pluto	&LittleTail!	Full
Louie	^Wet#!	Full

Users	Password	Access
Millie	#Shorts?	Read
Pluto	&LittleTail!	Full
Mickey	&&Boss!@	Full

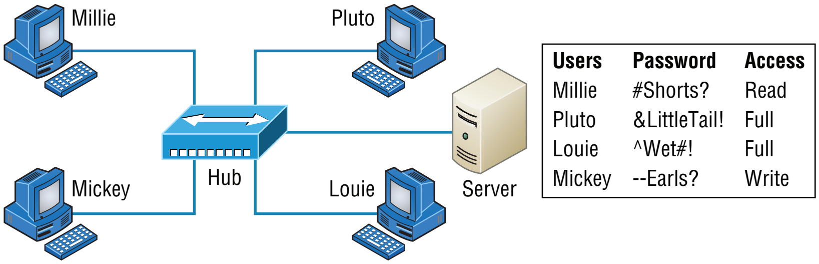
Since it should be clear by now that peer-to-peer networks aren't all sunshine, backing up all your critical data may be tough, but it's vital! Haven't all of us forgotten where we've put an important file? And then there's that glaring security issue to tangle with. Because security is not centrally governed, each and every user has to remember and maintain a list of users and passwords on each and every machine. Worse, some of those all-important passwords for the same users change on different machines—even for accessing different resources. What a mess!

Client-Server Networks

Client-server networks are pretty much the polar opposite of peer-to-peer networks because in them, a single server uses a network operating system for managing the whole network. Here's how it works: A client machine's request for a resource goes to the main server, which responds by handling security and directing the client to the desired resource. This happens instead of the request going directly to the machine with the desired resource, and it has some serious advantages. First, because the network is much better organized and doesn't depend on users remembering where needed resources are, it's a whole lot easier to find the files you need because everything is stored in one spot—on that special server. Your security also gets a lot tighter because all usernames and passwords are on that specific server, which is never ever used as a workstation. You even gain scalability—client-server networks can have legions of workstations on them. And surprisingly, with all those demands, the network's performance is actually optimized—nice!

Check out Figure 1.8, which shows a client-server network with a server that has a database of access rights, user accounts, and passwords.

FIGURE 1.8 A client-server network



Users	Password	Access
Millie	#Shorts?	Read
Pluto	&LittleTail!	Full
Louie	^Wet#!	Full
Mickey	--Earls?	Write

Many of today's networks are hopefully a healthy blend of peer-to-peer and client-server architectures, with carefully specified servers that permit the simultaneous sharing of resources from devices running workstation operating systems. Even though the supporting machines can't handle as many inbound connections at a time, they still run the server service reasonably well. And if this type of mixed environment is designed well, most networks benefit greatly by having the capacity to take advantage of the positive aspects of both worlds.

Physical Network Topologies

Just as a topographical map is a type of map that shows the shape of the terrain, the *physical topology* of a network is also a type of map. It defines the specific characteristics of a network, such as where all the workstations and other devices are located and the precise arrangement of all the physical media such as cables. On the other hand, the *logical topologies* we covered earlier delineate exactly how data moves through the network. Now, even though these two topologies are usually a lot alike, a particular network can actually have physical and logical topologies that are very different. Basically, what you want to remember is that a network's physical topology gives you the lay of the land and the logical topology shows how a digital signal or data navigates through that layout.

Here's a list of the topologies you're most likely to run into these days:

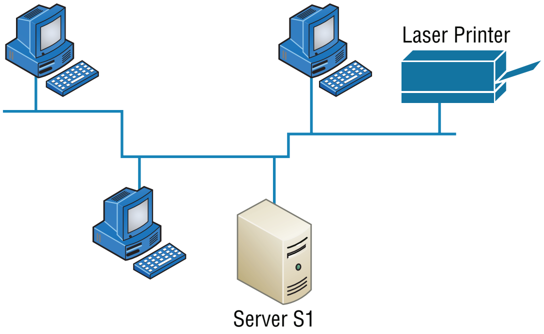
- Bus
- Star
- Ring
- Mesh
- Point-to-point
- Point-to-multipoint
- Hybrid

Bus Topology

This type of topology is the most basic one of the bunch, and it really does sort of resemble a bus, but more like one that's been in a wreck! Anyway, the *bus topology* consists of two distinct and terminated ends, with each of its computers connecting to one unbroken cable running its entire length. Back in the day, we used to attach computers to that main cable with wire taps, but this didn't work all that well so we began using drop cables in their place. If we were dealing with 10Base2 Ethernet, we would slip a "T" into the main cable anywhere we wanted to connect a device to it instead of using drop cables.

Figure 1.9 depicts what a typical bus network's physical topology looks like.

FIGURE 1.9 A typical bus network's physical topology



Even though all the computers on this kind of network see all the data flowing through the cable, only the one computer, which the data is specifically addressed to, actually *gets* the data. Some of the benefits of using a bus topology are that it's easy to install and it's not very expensive, partly because it doesn't require as much cable as the other types of physical topologies. But it also has some drawbacks: For instance, it's hard to troubleshoot, change, or move, and it really doesn't offer much in the way of fault tolerance because everything is connected to that single cable. This means that any fault in the cable would basically bring the whole network down!

NOTE

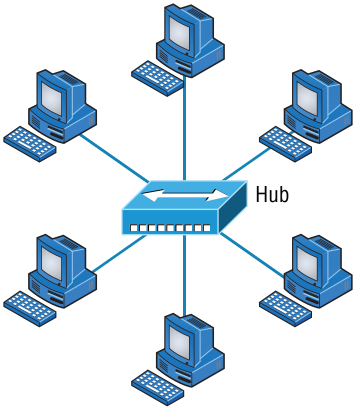
By the way, *fault tolerance* is the capability of a computer or a network system to respond to a condition automatically, often resolving it, which reduces the impact on the system. If fault-tolerance measures have been implemented correctly on a network, it's highly unlikely that any of that network's users will know that a problem ever existed at all.

Star Topology

A star topology's computers are connected to a central point with their own individual cables or wireless connections. You'll often find that central spot inhabited by a device like a hub, a switch, or an access point.

Star topology offers a lot of advantages over bus topology, making it more widely used even though it obviously requires more physical media. One of its best features is that because each computer or network segment is connected to the central device individually, if the cable fails, it only brings down the machine or network segment related to the point of failure. This makes the network much more fault tolerant as well as a lot easier to troubleshoot. Another great thing about a star topology is that it's a lot more scalable—all you have to do if you want to add to it is run a new cable and connect to the machine at the core of the star. In Figure 1.10, you'll find a great example of a typical star topology.

FIGURE 1.10 Typical star topology with a hub



Although it is called a *star* topology, it also looks a lot like a bike wheel with spokes connecting to the hub in the middle of the wheel and extending outward to connect to the rim. And just as with that bike wheel, it's the hub device at the center of a star topology network that can give you the most grief if something goes wrong with it. If that central hub happens to fail, down comes the whole network, so it's a very good thing hubs don't fail often!

Just as it is with pretty much everything, a star topology has its pros and cons. But the good news far outweighs the bad, which is why people often opt for star topology. And here's a list of benefits you gain by going with it:

- New stations can be added or moved easily and quickly.
- A single cable failure won't bring down the entire network.
- It's relatively easy to troubleshoot.

And here are the disadvantages to using a star topology:

- The total installation cost can be higher because of the larger number of cables, even though prices are becoming more competitive.
- It has a single point of failure—the hub or other central device.

There are two more sophisticated implementations of a star topology. The first is called a *point-to-point link*, where you have not only the device in the center of the spoke acting as a hub but also the device on the other end, which extends the network. This is still a star-wired topology, but as I'm sure you can imagine, it gives you a lot more scalability!

Another refined version is the wireless version, but to understand this variety well, you've got to have a solid grasp of all the capabilities and features of any devices populating the wireless star topology. No worries, though—I'll be covering wireless access points later on in Chapter 12, "Wireless Networking." For now, it's good enough for you to know that access points are pretty much just wireless hubs or switches that behave like their wired counterparts. Basically, they create a point-by-point connection to endpoints and other wireless access points.

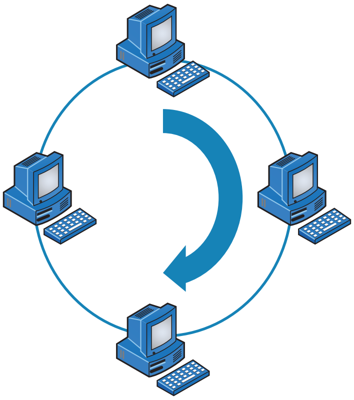
Ring Topology

In this type of topology, each computer is directly connected to other computers within the same network. Looking at Figure 1.11, you can see that the network's data flows from computer to computer back to the source, with the network's primary cable forming a ring. The problem is, the *ring topology* has a lot in common with the bus topology because if you want to add to the network, you have no choice but to break the cable ring, which is likely to bring down the entire network!

This is one big reason that ring topology isn't very popular—you just won't run into it a lot as I did in the 1980s and early 1990s. It's also pricey because you need several cables to connect each computer, it's really hard to reconfigure, and as you've probably guessed, it's not fault tolerant.

But even with all that being said, if you work at an ISP, you may still find a physical ring topology in use for a technology called SONET or some other WAN technology. However, you just won't find any LANs in physical rings anymore.

FIGURE 1.11 A typical ring topology

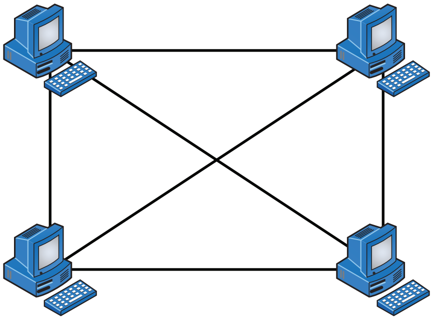


Mesh Topology

In this type of topology, you'll find that there's a path from every machine to every other one in the network. That's a lot of connections—in fact, the *mesh topology* wins the prize for "most physical connections per device"! You won't find it used in LANs very often, if ever, these days, but you will find a modified version of it known as a *hybrid mesh* used in a restrained manner on WANs, including the Internet.

Often, hybrid mesh topology networks will have quite a few connections between certain places to create redundancy (backup). And other types of topologies can sometimes be found in the mix, too, which is another reason it's dubbed *hybrid*. Just remember that it isn't a full-on mesh topology if there isn't a connection between all devices in the network. And understand that it's fairly complicated. Figure 1.12 gives you a great picture of just how much only four connections can complicate things!

FIGURE 1.12 A typical mesh topology



You can clearly see that everything gets more and more complex as both the wiring and the connections multiply. For each *n* locations or hosts, you end up with $n(n–1)/2$

connections. This means that in a network consisting of only four computers, you have 4(4–1)/2, or 6 connections. And if that little network grows to, say, a population of 10 computers, you'll then have a whopping 45 connections to cope with! That's a huge amount of overhead, so only small networks can really use this topology and manage it well. On the bright side, you get a really nice level of fault tolerance, but mesh still isn't used in corporate LANs anymore because they were so complicated to manage.

NOTE A full mesh physical topology is least likely to have a collision, which happens when the data from two hosts trying to communicate simultaneously "collides" and gets lost.

This is also the reason you'll usually find the hybrid version in today's WANs. In fact, the mesh topology is actually pretty rare now, but it's still used because of the robust fault tolerance it offers. Because you have a multitude of connections, if one goes on the blink, computers and other network devices can simply switch to one of the many redundant connections that are up and running. And clearly, all that cabling in the mesh topology makes it a very pricey implementation. Plus, you can make your network management much less insane than it is with mesh by using what's known as a *partial mesh topology* solution instead, so why not go that way? You may lose a little fault tolerance, but if you go the partial mesh route, you still get to use the same technology between all the network's devices. Just remember that with partial mesh, not all devices will be interconnected, so it's very important to choose the one's that will be very wisely.

Point-to-Point Topology

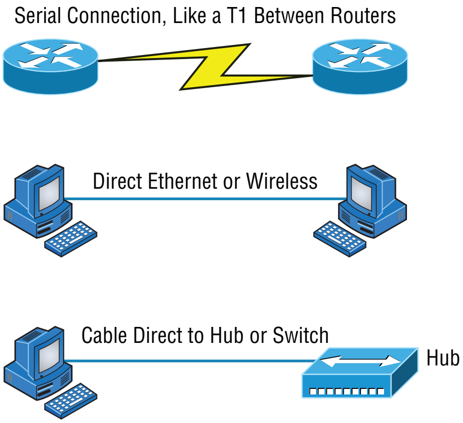
As its name implies, in a *point-to-point* topology you have a direct connection between two routers or switches, giving you one communication path. The routers in a point-to-point topology can be linked by a serial cable, making it a physical network, or if they're located far apart and connected only via a circuit within a Frame Relay or MPLS network, it's a logical network instead.

Figure 1.13 illustrates three examples of a typical T1, or WAN, point-to-point connection.

What you see here is a lightning bolt and a couple of round things with a bunch of arrows projecting from them, right? Well, the two round things radiating arrows represent our network's two routers, and that lightning bolt represents a WAN link. These symbols are industry standard, and I'll be using them throughout this book, so it's a good idea to get used to them!

Okay—so part two of the diagram shows two computers connected by a cable—a point-to-point link. By the way, this should remind you of something we just went over. Remember peer-to-peer networks? Good! I hope you also remember that a big drawback to peer-to-peer network sharing is that it's not very scalable. With this in mind, you probably won't be all that surprised that even if both machines have a wireless point-to-point connection, this network still won't be very scalable.

FIGURE 1.13 Three point-to-point connections


Serial Connection, Like a T1 Between Routers
Direct Ethernet or Wireless
Cable Direct to Hub or Switch
Hub

You'll usually find point-to-point networks within many of today's WANs, and as you can see in part three of Figure 1.13, a link from a computer to a hub or switch is also a valid point-to-point connection. A common version of this setup consists of a direct wireless link between two wireless bridges that's used to connect computers in two different buildings together.

Point-to-Multipoint Topology

Again as the name suggests, a *point-to-multipoint* topology consists of a succession of connections between an interface on one router and multiple destination routers—one point of connection to multiple points of connection. Each of the routers and every one of their interfaces involved in the point-to-multipoint connection are part of the same network.

Figure 1.14 shows a WAN and demonstrates a point-to-multipoint network. You can clearly see a single, corporate router connecting to multiple branches.

FIGURE 1.14 A point-to-multipoint network, example 1

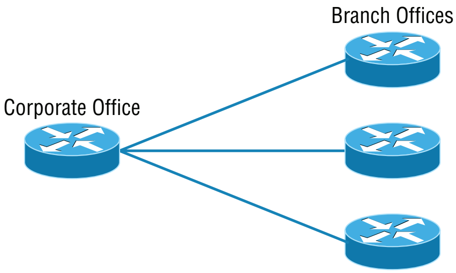
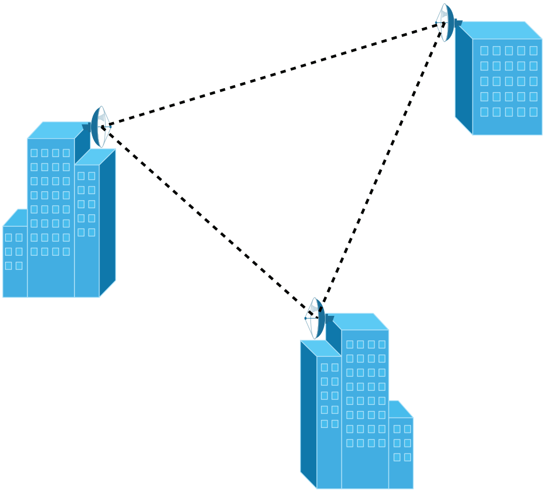


Figure 1.15 shows another prime example of a point-to-multipoint network: a college or corporate campus.

FIGURE 1.15 A point-to-multipoint network, example 2

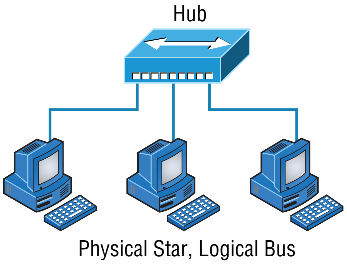


Hybrid Topology

I know I just talked about the hybrid network topology in the section about mesh topology, but I didn't give you a mental picture of it in the form of a figure. I also want to point out that *hybrid topology* means just that—a combination of two or more types of physical or logical network topologies working together within the same network.

Figure 1.16 depicts a simple hybrid network topology; it shows a LAN switch or hub in a star topology configuration that connects to its hosts via a bus topology.

FIGURE 1.16 A simple hybrid network



Topology Selection, Backbones, and Segments

Now that you're familiar with many different types of network topologies, you're ready for some tips on selecting the right one for your particular network. You also need to know about backbones and segments, which I'll cover in the very last part of this chapter.

Real World Scenario

They're Just Cables, Right?

Wrong! Regardless of the type of network you build, you need to start thinking about quality at the bottom and work up.

Think of it as if you were at an electronics store buying the cables for your home theater system. You've already spent a bunch of time and money getting the right components to meet your needs. Because you've probably parted with a hefty chunk of change, you might be tempted to cut corners, but why would you stop now and connect all your high-quality devices together with the cable equivalent of twine? No, you're smarter than that–you know that picking out the exact cables that will maximize the sound and picture quality of your specific components can also protect them!

It's the same thing when you're faced with selecting the physical media for a specific network. You just don't want to cut corners here because this is the backbone of the network and you definitely don't want to be faced with going through the costly pain of replacing this infrastructure once it's been installed. Doing that will cost you a lot more than taking the time to wisely choose the right cables and spending the money it takes to get them in the first place. The network downtime alone can cost a company a bundle! Another reason for choosing the network's physical media well is that it's going to be there for a good 5 to 10 years. This means two things: It better be solid quality, and it better be scalable because that network is going to grow and change over the years.

Selecting the Right Topology

As you now know, not only do you have a buffet of network topologies to choose from, but each one also has pros and cons to implementing it. But it really comes down to that well-known adage "Ask the right questions." First, how much cash do you have? How much fault tolerance and security do you really need? Also, is this network likely to grow like a weed—will you need to quickly and easily reconfigure it often? In other words, how scalable does your network need to be?

For instance, if your challenge is to design a nice, cost-effective solution that involves only a few computers in a room, getting a wireless access point and some wireless network cards is definitely your best way to go because you won't need to part with the cash for a bunch of cabling and it's super easy to set up. Alternatively, if you're faced with coming up with a solid design for a growing company's already-large network, you're probably good to go with using a wired star topology because it will nicely allow for future changes. Remember, a star topology really shines when it comes to making additions to the network, moving things around, and making any kind of changes happen quickly, efficiently, and cost effectively.

If, say, you're hired to design a network for an ISP that needs to be up and running 99.9 percent of the time with no more than eight hours a year allowed downtime, well, you need Godzilla-strength fault tolerance. Do you remember which topology gives that up the best? (Hint: Internet.) Your primo solution is to go with either a hybrid or a partial mesh topology. Remember that partial mesh leaves you with a subset of $n(n-1)/2$ connections to maintain—a number that could very well blow a big hole in your maintenance budget!

Here's a list of things to keep in mind when you're faced with coming up with the right topology for the right network:

- Cost
- Ease of installation
- Ease of maintenance
- Fault-tolerance requirement
- Security requirement

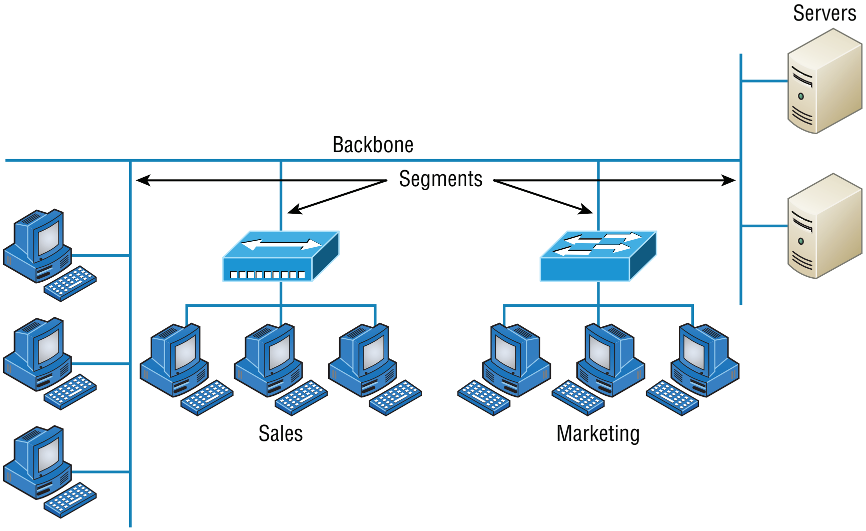
The Network Backbone

Today's networks can get pretty complicated, so we need to have a standard way of communicating with each other intelligibly about exactly which part of the network we're referencing. This is the reason we divide networks into different parts called *backbones* and *segments*.

Figure 1.17 illustrates a network and shows which part is the backbone and which parts are segments.

You can see that the network backbone is actually kind of like our own. It's what all the network segments and servers connect to and what gives the network its structure. As you can imagine, being such an important nerve center, the backbone must use some kind of seriously fast, robust technology—often Gigabit Ethernet. And to optimize network performance—its speed and efficiency—it follows that you would want to connect all of the network's servers and segments directly to the network's backbone.

FIGURE 1.17 Backbone and segments on a network



Network Segments

When we refer to a segment, we can mean any small section of the network that may be connected to, but isn't actually a piece of, the backbone. The network's workstations and servers organized into segments connect to the network backbone, which is the common connecting point for all segments; you can see this by taking another look at Figure 1.17, which displays four segments.

CAN

A campus area network (CAN) refers to a network that encompasses several buildings. It comprises the part of the network where data, services and connectivity to the outside world is provided to those who work in the corporate office or headquarters.

SAN

Classic Storage area networks (SANs) are comprised of high-capacity storage devices that are connected by a high-speed private network (separate from the LAN) using a storage-specific switch. This storage information architecture addresses the collection of data, management of data, and use of data. These networks are typically fiber networks.

Summary

This chapter created a solid foundation for you to build your networking knowledge on as you go through this book.

In it, you learned what, exactly, a network is, and you got an introduction to some of the components involved in building one—routers, switches, and hubs—as well as the jobs they do in a network.

You also learned that the components required to build a network aren't all you need. Understanding the various types of network connection methods, like peer-to-peer and client-server, is also vital.

Further, you learned about the various types of logical and physical network topologies and the features and drawbacks of each. I wrapped up the chapter with a short discussion about network backbones and segments and equipped you with the right questions to ask yourself to ensure that you come up with the right network topology for your networking needs.

Exam Essentials

Know your network topologies. Know the names and descriptions of the topologies. Be aware of the difference between physical networks (what humans see) and logical networks (what the equipment "sees").

Know the advantages and disadvantages of the topologies. It is important to know what each topology brings to the table. Knowing the various characteristics of each topology comes in handy during troubleshooting.

Understand the terms *LAN* and *WAN*. You need to understand when you would use a LAN and when you would use a WAN. A LAN is used to connect a group of hosts together, and a WAN is used to connect various LANs together.

Written Lab

You can find the answers to the written labs in Appendix A.

1. What are the three basic LAN topologies?
2. What common WAN topology often results in multiple connections to a single site (leading to a high degree of fault tolerance) and has one-to-many connections?
3. What is the term for a device that shares its resources with other network devices?
4. What network model draws a clear distinction between devices that share their resources and devices that do not?
5. Which network topology or connection type can be implemented with only two endpoints?
6. What device is generally implemented as a star topology?
7. What does MPLS stand for?
8. What does WAN stand for?
9. Will a computer that shares no resources most likely be connected to the backbone or to a segment?
10. Which LAN topology is characterized by all devices being daisy-chained together with the devices at each end being connected to only one other device?

Review Questions

You can find the answers to the review questions in Appendix B.

1. You need a network that provides centralized authentication for your users. Which of the following logical topologies should you use?

   A. VLANs

   B. Peer-to-peer

   C. Client-server

   D. Mesh

2. You need a topology that is scalable to use in your network. Which of the following will you install?

   A. Bus

   B. Ring

   C. Star

   D. Mesh

3. Which of the following physical topologies has the most connections and is the least popular for LANs?

   A. Bus

   B. Start

   C. Ring

   D. Mesh

4. In a physical star topology, what happens when a workstation loses its physical connection to another device?

   A. The ring is broken, so no devices can communicate.

   B. Only that workstation loses its ability to communicate.

   C. That workstation and the device it's connected to lose communication with the rest of the network.

   D. No devices can communicate because there are now two unterminated network segments.

5. Which type of WAN technology uses labels, which enables priority of voice though the network?

   A. VPN

   B. T1

   C. MPLS

   D. LAN

   E. Bus

6. What is a logical grouping of network users and resources called?
   - A. WAN
   - B. LAN
   - C. MPLS
   - D. Host

7. Which of the following is a concern when using peer-to-peer networks?
   - A. Where to place the server
   - B. Whose computer is least busy and can act as the server
   - C. The security associated with such a network
   - D. Having enough peers to support creating such a network

8. Which of the following is an example of when a point-to-multipoint network is called for?
   - A. When a centralized office needs to communicate with many branch offices
   - B. When a full mesh of WAN links is in place
   - C. When multiple offices are daisy-chained to one another in a line
   - D. When there are only two nodes in the network to be connected

9. Which of the following is an example of a LAN?
   - A. Ten buildings interconnected by Ethernet connections over fiber-optic cabling
   - B. Ten routers interconnected by Frame Relay circuits
   - C. Two routers interconnected with a T1 circuit
   - D. A computer connected to another computer so they can share resources

10. Which of the following is a disadvantage of the star topology?
    - A. When a single port on the central concentrating device fails, the entire network loses connectivity.
    - B. When the central concentrating device experiences a complete failure, all attached devices lose connectivity to the rest of the network.
    - C. In a star topology, a more expensive type of host must be used compared to the host used when implementing a physical bus.
    - D. It is more difficult to add stations and troubleshoot than with other topologies.

11. What is a difference between a LAN and a WAN?
    - A. WANs require a router.
    - B. WANs cover larger geographical areas.
    - C. WANs can utilize either private or public data transport.
    - D. All of the above.

12. Which of the following provides the most physical layout flexibility in a very large, geographically dispersed enterprise network?

    A. Bus topology

    B. LAN switch

    C. Star topology

    D. MPLS cloud network

13. In what type of network are all computers considered equal and do not share any central authority?

    A. Peer-to-peer

    B. Client-server

    C. Physical topology

    D. None of the above

14. What advantage does the client-server architecture have over peer-to-peer?

    A. Easier maintenance

    B. Greater organization

    C. Tighter security

    D. All of the above

15. Which of the following is an example of a hybrid network?

    A. Ethernet switch

    B. Ring topology

    C. Bus topology

    D. Star topology

16. You have a network with multiple LANs and want to keep them separate but still connect them together so they can all get to the Internet. Which of the following is the best solution?

    A. Use static IP addresses.

    B. Add more hubs.

    C. Implement more switches.

    D. Install a router.

17. Which type of topology has the greatest number of physical connections?

    A. Point-to-multipoint

    B. Star

    C. Point-to-point

    D. Mesh

18. What type of topology gives you a direct connection between two routers so that there is one communication path?

    A. Point-to-point

    B. Star

    C. Bus

    D. Straight

19. Which network topology is a combination of two or more types of physical or two or more types of logical topologies?

    A. Point-to-multipoint

    B. Hybrid

    C. Bus

    D. Star

20. When designing a network and deciding which type of network topology to use, which item(s) should be considered? (Select all that apply.)

    A. Cost

    B. Ease of installation

    C. Ease of maintenance

    D. Fault tolerance requirements

Chapter 2

The Open Systems Interconnection Specifications

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.2 Explain devices, applications, protocols, and services at their appropriate OSI layers**

- Layer 1 – Physical
- Layer 2 – Data link
- Layer 3 – Network
- Layer 4 – Transport
- Layer 5 – Session
- Layer 6 – Presentation
- Layer 7 – Application

In this chapter, we're going to analyze the Open Systems Interconnection (OSI) model. I'll thoroughly describe each part to you in detail because it's imperative for you to grasp the OSI model's key concepts. Once solidly equipped with this vital foundation, you'll be set to move on and build your own personal storehouse of networking knowledge.

The OSI model has seven hierarchical layers that were developed to enable different networks to communicate reliably between disparate systems.

Because this book is centering upon all things Network+, it's crucial for you to understand the OSI model as CompTIA sees it, so I'll present each of its seven layers in that light.

I'll also provide you with an introduction to *encapsulation*, which is the process of encoding data as it goes down the OSI stack.

NOTE To find Todd Lammle CompTIA videos and questions, please see `www.lammle.com/network+`.

Internetworking Models

In the very first networks, the computers involved could communicate only with other computers made by the same manufacturer. For example, companies ran either a complete DECnet solution or an IBM solution—not both together. In the late 1970s, the *Open Systems Interconnection (OSI) reference model* was created by the International Organization for Standardization (ISO) to break through this barrier.

The OSI model was meant to help vendors create interoperable network devices and software in the form of protocols, or standards, so that different vendors' networks could become compatible and work together. Like world peace, it'll probably never happen completely, but it's still a great goal.

The OSI model is the primary architectural model for networks. It describes how data and network information are communicated from an application on one computer through the network media to an application on another computer. The OSI reference model breaks this approach into layers.

Let's move on and explore this layered approach as well as how you can utilize its key concepts to troubleshoot internetworks.

The Layered Approach

Basically, a *reference model* is a conceptual blueprint of how communications should take place. It addresses all the processes required for effective communication and divides these processes into logical groupings called *layers*. When a communication system is designed in this manner, it's known as *layered architecture*.

Think of it like this: Say you and some friends want to start a company. One of the first things you'll do is sit down and think through what tasks must be done, who will do them, the order in which they will be done, and how they relate to each other. Ultimately, you might group these tasks into departments. Let's say you decide to have a customer service department, an inventory department, and a shipping department. Each of your departments has its own unique tasks, keeping its staff members busy and requiring them to focus only on their own duties.

In this scenario, I'm using departments as a metaphor for the layers in a communication system. For things to run smoothly, the staff of each department has to trust and rely heavily on the others to do their jobs and competently handle their unique responsibilities. During your planning sessions, you'll probably take notes, recording the entire process to facilitate later discussions about standards of operation that will serve as your business blueprint or reference model.

Once your business is launched, each department leader will need to develop practical methods to implement their assigned tasks using the specific part of the business model's blueprint that relates to their branch. These practical methods, or protocols, must be compiled into a standard operating procedures manual and followed closely. The procedures in your manual will have been included for different reasons and have varying degrees of importance and implementation. If you form a partnership or acquire another company, it will be crucial for its business protocols to either match or be compatible with yours.

Similarly, software developers can use a reference model to understand computer communication processes and see exactly what must be accomplished on any one layer and how. In other words, if I need to develop a protocol for a certain layer, I only need to focus on that specific layer's functions. I don't need to be concerned with those of any other layer because different protocols will be in place to meet the different layer's needs. The technical term for this idea is *binding*. The communication processes that are related to each other are bound, or grouped together, at a particular layer.

Advantages of Reference Models

The OSI model is hierarchical, and I'd like to point out that the same beneficial characteristics can actually apply to any layered model. Understand that the central purpose of the OSI, and all networking models, is to allow different vendors' networks to interoperate smoothly.

This short list depicts some of the most important advantages we gain by using the OSI layered model:

- The OSI model divides network communication processes into smaller and simpler components, thus aiding component development, design, and troubleshooting.
- It allows multiple-vendor development through the standardization of network components.

- It encourages industry standardization by defining the specific functions that occur at each layer of the model.
- It allows various types of network hardware and software to communicate.
- It prevents changes in one layer from affecting other layers, facilitating development and making application programming much easier.

The OSI Reference Model

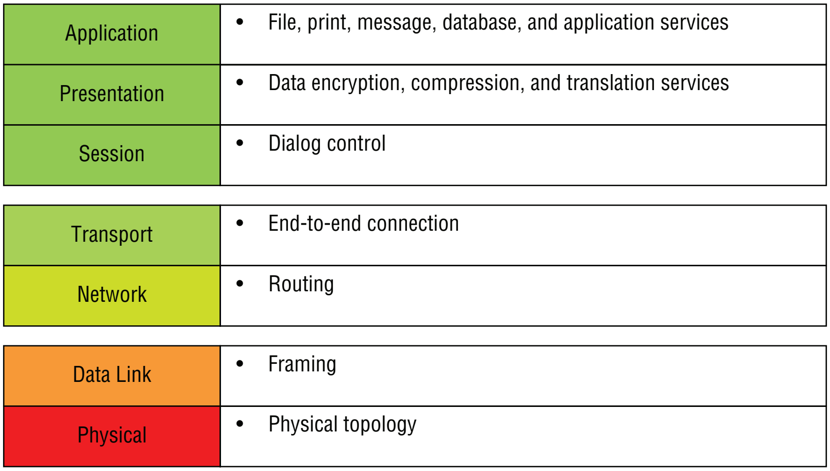
One of the greatest functions of the OSI specifications is to assist in data transfer between disparate hosts regardless if they're Unix, Windows, or Mac based.

But keep in mind that the OSI model isn't a physical model; it's a conceptual and comprehensive yet fluid set of guidelines, which application developers utilize to create and implement applications that run on a network. It also provides a framework for creating and implementing networking standards, devices, and internetworking schemes. The OSI model has seven layers:

- Application (Layer 7)
- Presentation (Layer 6)
- Session (Layer 5)
- Transport (Layer 4)
- Network (Layer 3)
- Data Link (Layer 2)
- Physical (Layer 1)

Figure 2.1 summarizes the functions that occur at each layer of the OSI model. With this in mind, you're ready to delve into what takes place at each layer in detail.

FIGURE 2.1 Layer functions

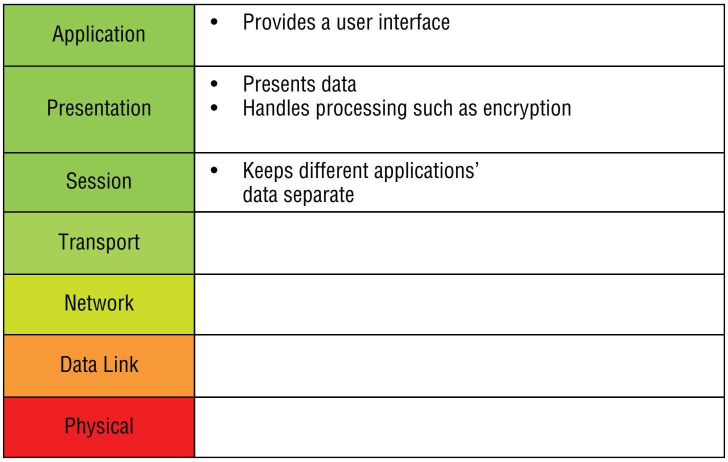


Application	• File, print, message, database, and application services
Presentation	• Data encryption, compression, and translation services
Session	• Dialog control
Transport	• End-to-end connection
Network	• Routing
Data Link	• Framing
Physical	• Physical topology

NOTE Some people like to use the mnemonic Please Do Not Throw Sausage Pizza Away to remember the seven layers (starting at Layer 1 and moving up to Layer 7). I didn't make that up!

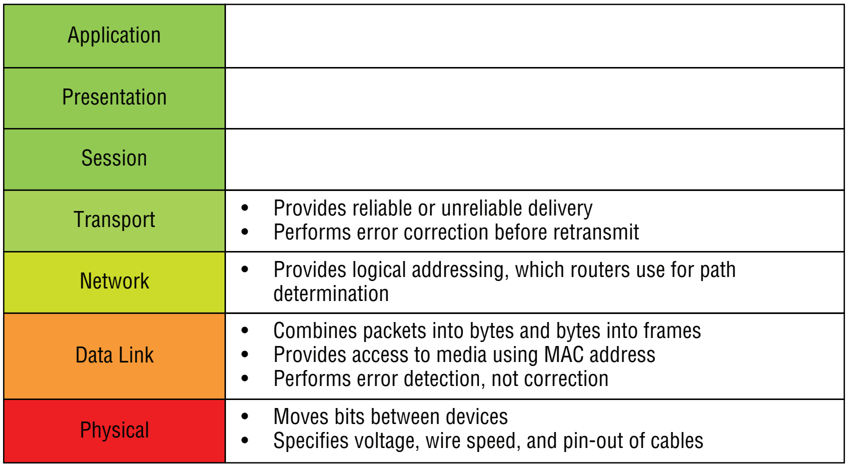
The OSI's seven layers are divided into two groups. The top three layers define the rules of how the applications working within host machines communicate with each other as well as with end users. The bottom four layers define how the actual data is transmitted from end to end. Figure 2.2 shows the top three layers and their functions, and Figure 2.3 shows the four lower layers and their functions.

FIGURE 2.2 The upper layers



Application	• Provides a user interface
Presentation	• Presents data • Handles processing such as encryption
Session	• Keeps different applications' data separate
Transport	
Network	
Data Link	
Physical	

FIGURE 2.3 The lower layers



Application	
Presentation	
Session	
Transport	• Provides reliable or unreliable delivery • Performs error correction before retransmit
Network	• Provides logical addressing, which routers use for path determination
Data Link	• Combines packets into bytes and bytes into frames • Provides access to media using MAC address • Performs error detection, not correction
Physical	• Moves bits between devices • Specifies voltage, wire speed, and pin-out of cables

Looking at Figure 2.2, it's clear that actual users interact with the computer at the Application layer. It's also apparent that the upper layers are responsible for applications communicating between hosts. Remember that none of the upper layers "know" anything about networking or network addresses. That's the responsibility of the four bottom layers.

Figure 2.3 illustrates that the four bottom layers define how data is transferred through physical media, switches, and routers. These bottom layers also determine how to rebuild a data stream from a transmitting host to a destination host's application.

Okay—so let's start at the Application layer and work our way down the stack.

The Application Layer

The *Application layer* of the OSI model marks the spot where users actually communicate or interact with the computer. Technically, users communicate with the network stack through application processes, interfaces, or APIs that connect the application in use to the operating system of the computer. The Application layer chooses and determines the availability of communicating partners along with the resources necessary to make their required connections. It coordinates partnering applications and forms a consensus on procedures for controlling data integrity and error recovery. The Application layer comes into play only when it's apparent that access to the network will be needed soon. Take the case of Internet Explorer (IE). You could uninstall every trace of networking components from a system, such as TCP/IP, the network card, and so on, and you could still use IE to view a local HTML document without a problem. But things would definitely get messy if you tried to do something like view an HTML document that had to be retrieved using HTTP or nab a file with FTP or TFTP because IE responds to requests like those by attempting to access the Application layer. So what's happening is that the Application layer acts as an interface between the application program—which isn't part of the layered structure—and the next layer down by providing ways for the application to send information down through the protocol stack. In other words, IE doesn't reside within the Application layer—it interfaces with Application layer protocols when it needs to deal with remote resources.

The Application layer is also responsible for identifying and establishing the availability of the intended communication partner and determining whether sufficient resources for the requested communication exist.

These tasks are important because computer applications sometimes require more than just desktop resources. Often, they unite communicating components from more than one network application. Prime examples are file transfers and email as well as enabling remote access, network-management activities, and client-server processes like printing and information location. Many network applications provide services for communication over enterprise networks, but for present and future internetworking, the need is fast developing to reach beyond the limitations of current physical networking.

NOTE

It's important to remember that the Application layer acts as an interface between application programs. For instance, Microsoft Word doesn't *reside* at the Application layer, it *interfaces* with the Application layer protocols. Later in Chapter 6, "Introduction to the Internet Protocol," I'll tell you all about key programs or processes that actually do reside at the Application layer, like FTP and TFTP.

The Presentation Layer

The *Presentation layer* gets its name from its purpose: it presents data to the Application layer and is responsible for data translation and code formatting.

A successful data-transfer technique is to adapt the data into a standard format before transmission. Computers are configured to receive this generically formatted data and then convert it back into its native format for reading—for example, from EBCDIC to ASCII. By providing translation services, the Presentation layer ensures that the data transferred from one system's Application layer can be read and understood by the Application layer on another system.

The OSI has protocol standards that define how standard data should be formatted. Tasks like data compression, decompression, encryption, and decryption are all associated with this layer. Some Presentation layer standards are even involved in multimedia operations.

The Session Layer

The *Session layer* is responsible for setting up, managing, and then tearing down sessions between Presentation layer entities. This layer also provides dialog control between devices, or nodes. It coordinates communication between systems and serves to organize their communication by offering three different modes: *simplex*, *half duplex*, and *full duplex*. To sum up, the Session layer basically keeps applications' data separate from other applications' data. For a good example, the Session layer allows multiple web browser sessions on your desktop at the same time.

The Transport Layer

The *Transport layer* segments and reassembles data into a data stream. Services located in the Transport layer handle data from upper-layer applications and unite it onto the same data stream. They provide end-to-end data transport services and can establish a logical connection between the sending host and destination host on an internetwork.

The Transport layer is responsible for providing the mechanisms for multiplexing upper-layer applications, establishing virtual connections, and tearing down virtual circuits. It also hides the many and sundry details of any network-dependent information from the higher layers, facilitating data transfer.

We'll cover Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) thoroughly in Chapter 6, but if you're already familiar with them, you know that they both work at the Transport layer. You also know that TCP is a reliable service and UDP is not. These two protocols give application developers more options because they have a choice between them when they're working with TCP/IP protocols.

NOTE

The term *reliable networking* relates to the Transport layer and means that acknowledgments, sequencing, and flow control will be used.

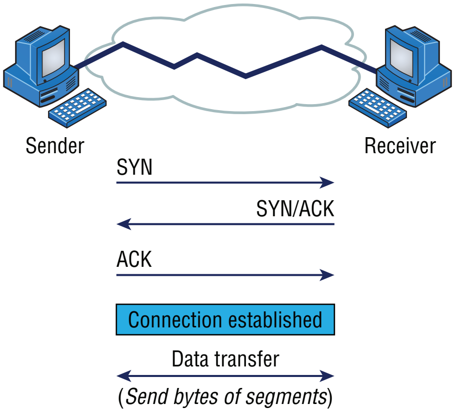
The Transport layer can be connectionless or connection-oriented, but it's especially important for you to really understand the connection-oriented portion of the Transport layer. So let's take some time to delve into the connection-oriented (reliable) protocol of the Transport layer now.

Connection-Oriented Communication

Before a transmitting host starts to send segments down the model, the sender's TCP process contacts the destination's TCP process to establish a connection. The resulting creation is known as a *virtual circuit*. This type of communication is called *connection-oriented*. During this initial *handshake*, the two TCP processes also agree on the amount of information that will be sent in either direction before the respective recipient's TCP sends back an acknowledgment. With everything agreed on in advance, the path is paved for reliable communication to take place.

Figure 2.4 depicts a typical reliable session taking place between sending and receiving systems. Both of the hosts' application programs begin by notifying their individual operating systems that a connection is about to be initiated. The two operating systems communicate by sending messages over the network confirming that the transfer is approved and that both sides are ready for it to take place. After all of this required synchronization occurs, a connection is fully established and the data transfer begins. This virtual circuit setup is called *overhead*.

FIGURE 2.4 Establishing a connection-oriented session



While the information is being transferred between hosts, the two machines periodically check in with each other, communicating through their protocol software to ensure that all is going well and that data is being received properly.

Let me sum up the steps in the connection-oriented session—the three-way handshake—pictured in Figure 2.4:

1. The first "connection agreement" segment is a request for synchronization.
2. The next segments acknowledge the request and establish connection parameters—the rules—between hosts. These segments request that the receiver's sequencing is synchronized here as well so that a bidirectional connection is formed.
3. The final segment is also an acknowledgment. It notifies the destination host that the connection agreement has been accepted and that the connection has been established. Data transfer can now begin.

I know I went into a lot of detail about this connection setup, and I did that so you would have a really clear picture of how it works. You can refer to this entire process as "the three-way handshake" I already mentioned, known as SYN, SYN/ACK, ACK or synchronize, synchronize-acknowledgment, acknowledgment.

That sounds pretty simple, but things don't always flow so well. Sometimes congestion can occur during a transfer because a high-speed computer is generating data traffic a lot faster than the network can handle transferring it. A bunch of computers simultaneously sending datagrams through a single gateway or to a destination can also clog things up. In the latter case, a gateway or destination can become congested even though no single source caused the problem. Either way, the problem is like a freeway bottleneck—too much traffic for too small a capacity. It's not usually one car that's the problem; it's that there are just too many cars on that particular route.

Flow Control

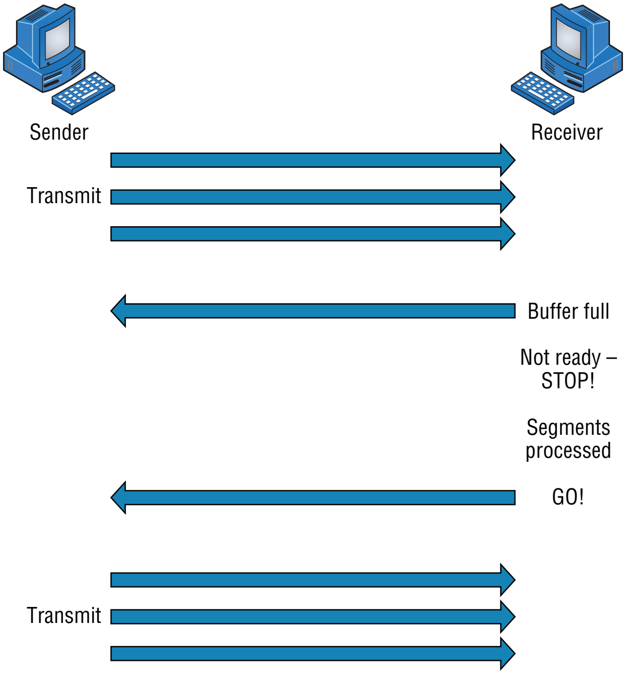
Data integrity is ensured at the Transport layer by maintaining *flow control* and by allowing users to request reliable data transport between systems. Flow control provides a means for the receiver to govern the amount of data sent by the sender. It prevents a sending host on one side of the connection from overflowing the buffers in the receiving host—an event that can result in lost data. Reliable data transport employs a connection-oriented communications session between systems, and the protocols involved ensure that the following will be achieved:

1. The segments delivered are acknowledged back to the sender upon their reception.
2. Any segments not acknowledged are retransmitted.
3. Segments are sequenced back into their proper order upon arrival at their destination.
4. A manageable data flow is maintained in order to avoid congestion, overloading, and data loss.

Okay, so what happens when a machine receives a flood of datagrams too quickly for it to process? It stores them in a memory section called a *buffer*. But this buffering tactic can only solve the problem if the datagrams are part of a small burst. If not, and the datagram deluge continues, a device's memory will eventually be exhausted, its flood capacity will be exceeded, and it will react by discarding any additional datagrams that arrive like a dam spilling over!

This sounds pretty bad, and it would be if it weren't for the transport function network flood-control systems that actually work really well. But how? Well, instead of just dumping resources and allowing data to be lost, the transport can issue a "not ready" indicator to the sender, or source, of the flood, as shown in Figure 2.5. This mechanism works kind of like a stoplight, signaling the sending device to stop transmitting segment traffic to its overwhelmed peer. After the peer machine's receiver processes the segments abounding in its memory reservoir (its buffer), it sends out a "ready" transport indicator. When the machine waiting to transmit the rest of its datagrams receives this "go" indictor, it resumes its transmission.

FIGURE 2.5 Transmitting segments with flow control



During fundamental, reliable, connection-oriented data transfer, datagrams are delivered to the receiving host in exactly the same sequence they're transmitted. So if any data segments are lost, duplicated, or damaged along the way, a failure notice is transmitted. This error is corrected by making sure the receiving host acknowledges it has received each and every data segment, and in the correct order.

To summarize, a service is considered connection-oriented if it has the following characteristics:

- A virtual circuit is set up (such as a three-way handshake).
- It uses sequencing.
- It uses acknowledgments.
- It uses flow control.

Windowing

Ideally, data throughput happens quickly and efficiently. And as you can imagine, it would be slow if the transmitting machine had to wait for an acknowledgment after sending each segment. But because time is available *after* the sender transmits the data segment and *before* it finishes processing acknowledgments from the receiving machine, the sender uses the break as an opportunity to transmit more data. The quantity of data segments (measured in bytes) that the transmitting machine is allowed to send without receiving an acknowledgment is represented by something called a *window*.

NOTE Windows are used to control the amount of outstanding, unacknowledged data segments.

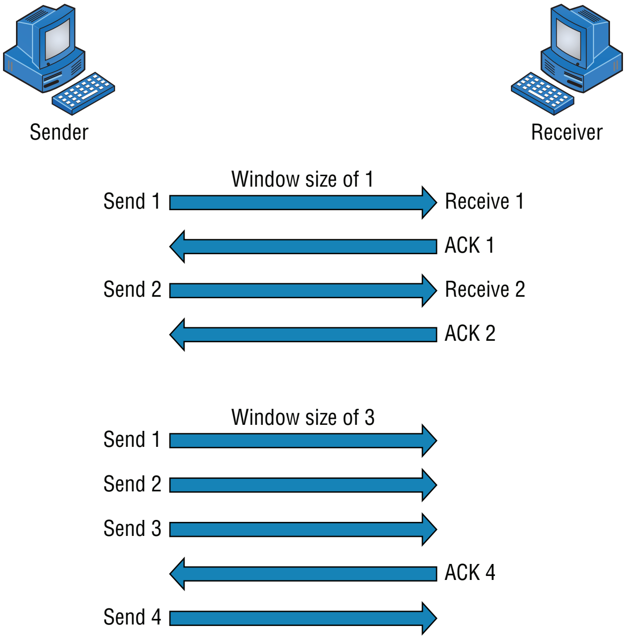
It's important to understand that the size of the window controls how much information is transferred from one end to the other. Although some protocols quantify information by observing the number of packets, TCP/IP measures it by counting the number of bytes.

Figure 2.6 illustrates two window sizes—one set to 1 and one set to 3. In this simplified example, both the sending and receiving machines are workstations.

When you've configured a window size of 1, the sending machine waits for an acknowledgment for each data segment it transmits before transmitting another. If you've configured a window size of 3, the sending machine is allowed to transmit three data segments before an acknowledgment is received. In reality, the window size actually delimits the amount of bytes that can be sent at a time.

NOTE If a receiving host fails to receive all the segments that it should acknowledge, the host can improve the communication session by decreasing the window size.

FIGURE 2.6 Windowing



Acknowledgments

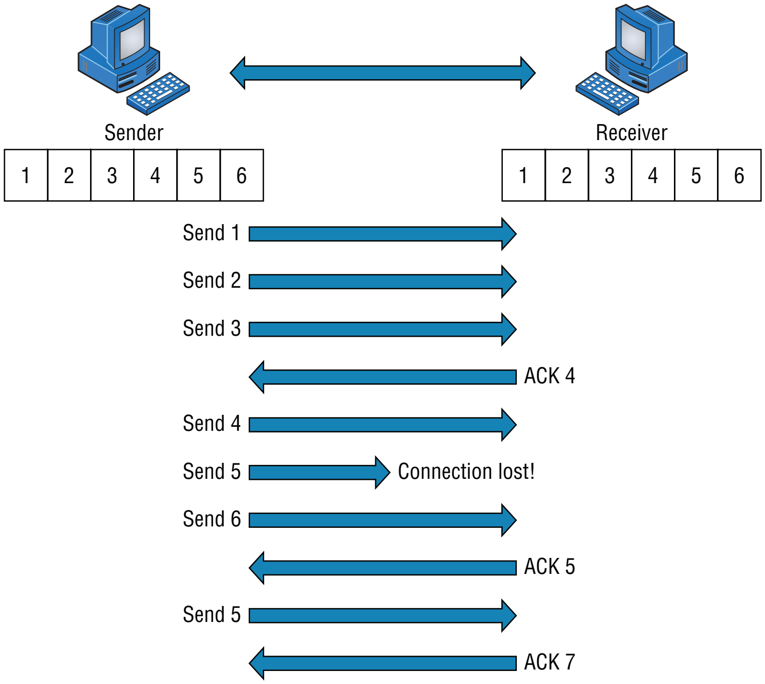
Reliable data delivery ensures the integrity of a data stream being sent from one machine to the other through a fully functional data link. It guarantees that the data won't be duplicated or lost. This is achieved through something called *positive acknowledgment with retransmission*—a technique that requires a receiving machine to communicate with the transmitting source by sending an acknowledgment message back to the sender when it receives data. The sender documents each segment it sends and waits for this acknowledgment before sending the next segment. When it sends a segment, the transmitting machine starts a timer and retransmits if it expires before an acknowledgment is returned from the receiving end.

In Figure 2.7, the sending machine transmits segments 1, 2, and 3. The receiving node acknowledges it has received them by requesting segment 4. When it receives the acknowledgment, the sender then transmits segments 4, 5, and 6. If segment 5 doesn't make it to the destination, the receiving node acknowledges that event with a request for the segment to be re-sent. The sending machine will then resend the lost segment and wait for an acknowledgment, which it must receive in order to move on to the transmission of segment 7.

The Transport layer doesn't need to use a connection-oriented service. That choice is up to the application developer. It's safe to say that if you're connection-oriented, meaning that you've created a virtual circuit, you're using TCP. If you aren't setting up a virtual circuit, then you're using UDP and are considered connectionless.

NOTE Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are protocols that work at the Transport layer and will be covered in detail in Chapter 6.

FIGURE 2.7 Transport layer reliable delivery



Devices Used in an Internetwork

The following network devices operate at all seven layers of the OSI model:

- Network management stations (NMSs)
- Web and application servers
- Gateways (not default gateways)
- Network hosts

Several devices operate primarily at the Physical layer of the OSI model. These devices manipulate mainly the physical aspects of a network data stream—things like voltages, signal direction, and signal strength. The following four devices are the most popular and will be detailed in Chapter 5, "Networking Devices":

- Network interface cards (NICs)
- Transceivers
- Repeaters
- Hubs

The Network Layer

The *Network layer* manages logical device addressing, tracks the location of devices on the network, and determines the best way to move data. This means that the Network layer must transport traffic between devices that aren't locally attached. Routers are Layer 3 devices that are specified at the Network layer and provide the routing services within an internetwork.

It happens like this: First, when a packet is received on a router interface, the destination IP address is checked. If the packet isn't destined for that particular router, the router looks up the destination network address in the routing table. Once the router chooses an exit interface, the packet is sent to that interface to be framed and sent out on the local network. If the router can't find an entry for the packet's destination network in the routing table, the router drops the packet.

Two types of packets are used at the Network layer:

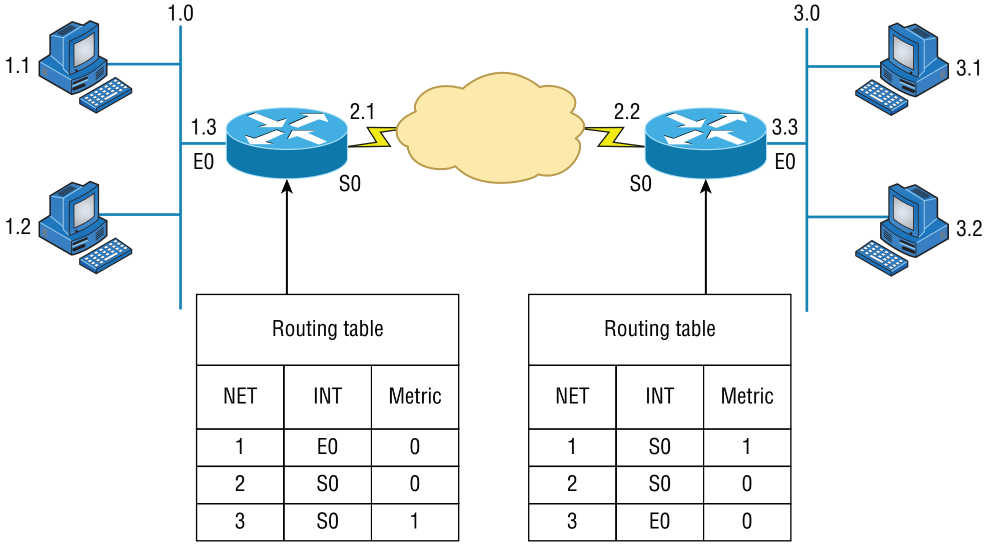
Data Packets These are used to transport user data through the internetwork. Protocols used to support data traffic are called *routed protocols*. Two examples of routed protocols are Internet Protocol (IP) and Internet Protocol version 6 (IPv6), which you'll learn all about coming up in Chapter 7, "IP Addressing."

Route-Update Packets These are used to update neighboring routers about the networks connected to all routers within the internetwork. Protocols that send route-update packets are called routing protocols, and some common ones are Routing Information Protocol (RIP), RIPv2, Enhanced Interior Gateway Routing Protocol (EIGRP), and Open Shortest Path First (OSPF). Route-update packets are used to help build and maintain routing tables on each router.

Figure 2.8 pictures a routing table. The routing table used by a router includes the following information:

Network Addresses These are protocol-specific network addresses. A router must maintain a routing table for individual routing protocols because each routing protocol keeps track of a network that includes different addressing schemes, like IP and IPv6. Think of it as a street sign in each of the different languages spoken by the residents who live on a particular street. If there were American, Spanish, and French folks on a street named Cat, the sign would read Cat/Gato/Chat.

FIGURE 2.8 Routing table used in a router



Routing table

NET	INT	Metric
1	E0	0
2	S0	0
3	S0	1

Routing table

NET	INT	Metric
1	S0	1
2	S0	0
3	E0	0

Interface This is the exit interface a packet will take when destined for a specific network.

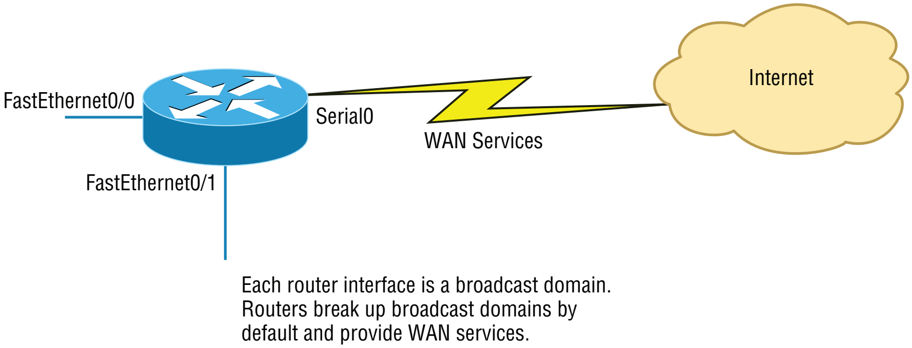
Metric This value equals the distance to the remote network. Different routing protocols use different ways of computing this distance. I'll cover routing protocols in Chapter 9, "Introduction to IP Routing." For now, just know that some routing protocols, namely RIP, use something called a *hop count*—the number of routers a packet passes through en route to a remote network. Other routing protocols alternatively use bandwidth, delay of the line, and even something known as a tick count, which equals 1/18 of a second, to make routing decisions.

Routers break up broadcast domains, which means that by default, broadcasts aren't forwarded through a router. This is a good thing because it reduces traffic on the network. Routers also break up collision domains, but this can be accomplished using Layer 2 (Data Link layer) switches as well.

NOTE Broadcast and collision domains will be covered in detail in Chapter 5. For now, just remember that routers break up broadcast domains and switches break up collision domains.

Because each interface in a router represents a separate network, it must be assigned unique network identification numbers, and each host on the network connected to that router must use the same network number. Figure 2.9 demonstrates how a router works within an internetwork.

FIGURE 2.9 A router in an internetwork



Each router interface is a broadcast domain. Routers break up broadcast domains by default and provide WAN services.

Here are some key points about routers that you really should commit to memory:

- Routers, by default, won't forward any broadcast or multicast packets.
- Routers use the logical address in a Network layer header to determine the next-hop router to forward the packet to.
- Routers can use access lists, created by an administrator, to control security on the types of packets that are allowed to enter or exit an interface.
- Routers can provide Layer 2 bridging functions if needed and can simultaneously route through the same interface.
- Layer 3 devices (routers, in this case) provide connections between virtual LANs (VLANs).
- Routers can provide quality of service (QoS) for specific types of network traffic.

NOTE

A router can also be referred to as a Layer 3 switch. These terms are interchangeable.

The Data Link Layer

The *Data Link layer* provides the physical transmission of the data and handles error notification, network topology, and flow control. This means the Data Link layer ensures that messages are delivered to the proper device on a LAN using hardware (MAC) addresses and translates messages from the Network layer into bits for the Physical layer to transmit.

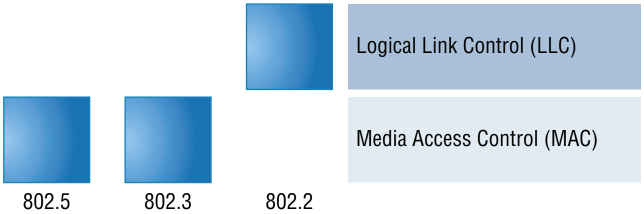
The Data Link layer formats the message into pieces, each called a *data frame*, and adds a customized header containing the destination and source hardware addresses. This added information forms a sort of capsule that surrounds the original message in much the same way that engines, navigational devices, and other tools were attached to the lunar modules of the Apollo project. These various pieces of equipment were useful only during certain stages of flight and were stripped off the module and discarded when their designated stage was complete. This is a great analogy for data traveling through networks because it works very similarly.

It's important for you to understand that routers, which work at the Network layer, don't care about where a particular host is located. They're only concerned about where networks are located and the best way to reach them—including remote ones. Routers are totally obsessive when it comes to networks, and in this instance, obsession is a good thing! The Data Link layer is responsible for the unique identification of each device that resides on a local network.

For a host to send packets to individual hosts on a local network as well as transmit packets between routers, the Data Link layer uses hardware addressing. Each time a packet is sent between routers, it's framed with control information at the Data Link layer. However, that information is stripped off at the receiving router, and only the original packet is left completely intact. This framing of the packet continues for each hop until the packet is finally delivered to the correct receiving host. It's important to understand that the packet itself is never altered along the route; it's only encapsulated with the type of control information required for it to be properly passed on to the different media types.

Figure 2.10 shows the Data Link layer with the Ethernet and Institute of Electrical and Electronics Engineers (IEEE) specifications. When you check it out, notice that the IEEE 802.2 standard is not only used in conjunction with the other IEEE standards, it also adds functionality to those standards.

FIGURE 2.10 Data Link layer



The IEEE Ethernet Data Link layer has two sublayers:

Media Access Control (MAC) Defines how packets are placed on the media. Contention media access is "first come, first served" access, where everyone shares the same bandwidth—hence the name. Physical addressing is defined here, as are logical topologies. What's a logical topology? It's the signal path through a physical topology. Line discipline, error notification (not correction), ordered delivery of frames, and optional flow control can also be used at this sublayer.

Logical Link Control (LLC) Responsible for identifying Network layer protocols and then encapsulating them, an LLC header tells the Data Link layer what to do with a packet once a frame is received. It works like this: A host receives a frame and looks in the LLC header to find out where the packet is destined—say, the IP protocol at the Network layer. The LLC can also provide flow control and sequencing of control bits.

Project 802

One of the major components of the Data Link layer is the result of the IEEE's 802 subcommittees and their work on standards for local area and metropolitan area networks (LANs/MANs). The committee met in February 1980, so they used the 80 from 1980 and the 2 from the second month to create the name Project 802. The designation for an 802 standard always includes a dot (.) followed by either a single or a double digit. These numeric digits specify particular categories within the 802 standard. These standards are listed in the following table.

Standard	Topic
802.1	LAN/MAN Management (and Media Access Control Bridges)
802.2	Logical Link Control
802.3	CSMA/CD (Ethernet)
802.4	Token Passing Bus
802.5	Token Passing Ring
802.6	Distributed Queue Dual Bus (DQDB) Metropolitan Area Network (MAN)
802.7	Broadband Local Area Networks
802.8	Fiber-Optic LANs and MANs
802.9	Isochronous LANs
802.10	LAN/MAN Security
802.11	Wireless LAN
802.12	Demand Priority Access Method
802.15	Wireless Personal Area Network
802.16	Wireless Metropolitan Area Network (also called WiMAX)
802.17	Resilient Packet Ring

NOTE

From this list in the sidebar, “Project 802”, you just need to remember that 802.3 calls out anything having to do with Ethernet and 802.11 is anything wireless.

The Physical Layer

Finally, we’re hitting bottom. Well, not in a bad way—we’ve now arrived at the *Physical layer*, which does two important things: it sends bits and receives bits. Bits come only in values of 1 or 0—a Morse code with numerical values. The Physical layer communicates directly with the various types of actual communication media. Different kinds of media represent these bit values in different ways. Some use audio tones, and others employ *state transitions*—changes in voltage from high to low and low to high. Specific protocols are needed for each type of media to describe the proper bit patterns to be used, how data is encoded into media signals, and the various qualities of the physical media’s attachment interface.

The Physical layer specifies the electrical, mechanical, procedural, and functional requirements for activating, maintaining, and deactivating a physical link between end systems. This layer is also where you identify the interface between the *data terminal equipment (DTE)* and the *data communication equipment (DCE)*. (Some older phone company employees still call DCE data circuit-terminating equipment.) The DCE is usually located at the customer, whereas the DTE is the attached device. The services available to the DTE are most often accessed via the DCE device, which is a modem or *channel service unit/data service unit (CSU/DSU)*.

The Physical layer’s connectors and different physical topologies are defined by the standards, allowing disparate systems to communicate.

Finally, the Physical layer specifies the layout of the transmission media, otherwise known as its topology. A physical topology describes the way the cabling is physically laid out, as opposed to the logical topology that we just talked about in the section “The Data Link Layer.” The various physical topologies include bus, star, ring, and mesh and were described in Chapter 1, “Introduction to Networks.”

Introduction to Encapsulation

When a host transmits data across a network to another device, the data goes through *encapsulation*: It’s wrapped with protocol information at each layer of the OSI model. Each layer communicates only with its peer layer on the receiving device.

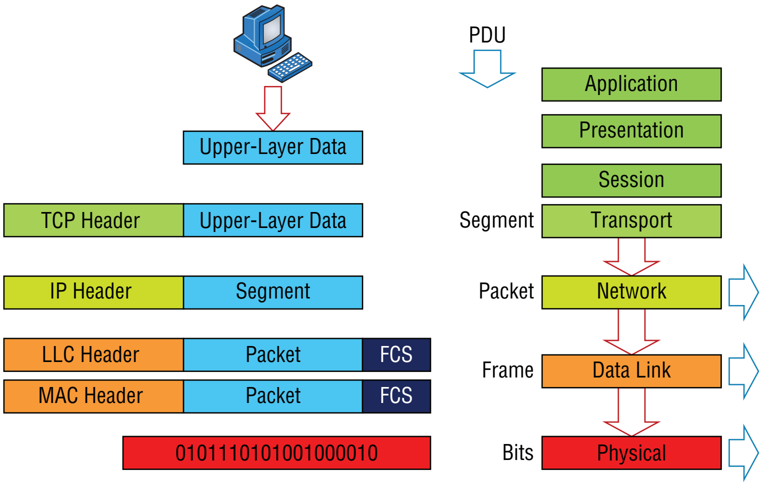
To communicate and exchange information, each layer uses *Protocol Data Units (PDUs)*. These hold the control information attached to the data at each layer of the model. They’re usually attached to the header in front of the data field but can also be in the trailer, or end, of it.

At a transmitting device, the data-encapsulation method works like this:

1. User information is converted to data for transmission on the network.
2. Data is converted to segments, and a reliable connection is set up between the transmitting and receiving hosts.
3. Segments are converted to packets or datagrams, and a logical address is placed in the header so each packet can be routed through an internetwork. A packet carries a segment of data.
4. Packets or datagrams are converted to frames for transmission on the local network. Hardware (Ethernet) addresses are used to uniquely identify hosts on a local network segment. Frames carry packets.
5. Frames are converted to bits, and a digital encoding and clocking scheme is used.

Figure 2.11 shows how user data is encapsulated at a transmitting host.

FIGURE 2.11 Data encapsulation



After you learn more foundational material about networking in the next few chapters, I'll come back to the encapsulation method and discuss it in a lot more detail in Chapter 6.

Modulation Techniques

In networks, modulation is the process of varying one or more properties of a waveform, called the *carrier signal*, with a signal that typically contains information to be transmitted.

Modulation of a waveform transforms a baseband (Ethernet or wireless) message signal into a passband signal (a passband [a band-pass filtered signal] is the range of frequencies or wavelengths that can pass through a filter without being attenuated). In current networks, modulation takes a digital or analog signal and puts it in another signal that can be physically transmitted.

A modulator is a device that performs modulation of a signal and a demodulator is a device that performs demodulation, the inverse of modulation. We typically just call these modems (from **mo**dulator–**dem**odulator), which can perform both operations.

The purpose of digital modulation is to transfer a digital bit stream over an analog bandpass channel. (A good example would be data transmitting over the public switched telephone network, where a bandpass filter limits the frequency range to 300–3400 Hz, or over a limited radio frequency band.) The purpose of an analog modulation is to transfer an analog baseband (or lowpass) signal (for example, an audio signal, wireless network, or TV signal) over an analog bandpass channel at a different frequency.

Analog and digital modulation use something called frequency-division multiplexing (FDM), where several low-pass information signals are transferred simultaneously over the same shared physical network, using separate passband channels (several different frequencies).

The digital baseband modulation methods found in our Ethernet networks, and also known as line coding, are used to transfer a digital bit stream over a baseband channel. Baseband means that the signal being modulated used the complete available bandwidth.

Time-division multiplexing (TDM) is a method of transmitting and receiving many independent signals over a common signal path by means of synchronized network devices at each end of the transmission line so that each signal appears on the line only a fraction of time in an alternating pattern. The receiving end demultiplexes the signal back to its original form.

Summary

You're now armed with a ton of fundamental information. You're set to build on it and are well on your way to certification.

Let's take a minute to go over what you've learned in this chapter. We started by discussing internetworking models and the advantages of having them. I then discussed the OSI model—the seven-layer model used to help application developers design applications that can run on any type of system or network. Each layer has its special jobs and select responsibilities within the model to ensure that solid, effective communications do, in fact, occur. I provided you with complete details of each layer and discussed how you need to view the specifications of the OSI model.

I also discussed the encapsulation method used in networking. Encapsulation is a highly important concept to understand, and I'll continue to discuss it throughout this book.

This chapter finished with a brief introduction to modulation of digital and analog signals.

Exam Essentials

Remember the OSI layers. You absolutely must remember and understand the seven layers of the OSI model as well as what function each layer provides. The Application, Presentation, and Session layers are upper layers and are responsible for communicating from a user interface to an application. The Transport layer provides segmentation, sequencing, and virtual circuits. The Network layer provides logical network addressing and routing through an internetwork. The Data Link layer provides framing and placing of data on the network medium. The Physical layer is responsible for taking 1s and 0s and encoding them into a digital signal for transmission on the network segment.

Know the sublayers of the Data Link layer. In addition to the OSI layers, knowing the only layer that has sublayers and the functions of those sublayers is extremely important. The Data Link layer has two sublayers: LLC and MAC. The LLC sublayer is responsible primarily for the multiplexing of Network layer protocols. The MAC sublayer is responsible for physical addressing and determining the appropriate time to place data on the network.

Know the devices that operate at each layer of the OSI model. Hubs and repeaters see only bits, making them Layer 1 devices. Because all networking devices have physical connectivity to the network, they all operate at Layer 1, but hubs and repeaters operate only at this layer, whereas other devices work in higher layers. Nevertheless, we generally consider that a device operates at the highest layer it supports; that layer's functionality is the main reason we implement the device on the network. For example, switches and bridges are considered Layer 2 devices because they understand and make decisions based on Layer 2 addresses. Routers are Layer 3 devices for a similar reason; they deal with Layer 3 addresses. Networking devices, such as workstations that run applications, are said to operate at the Application layer (or you may hear that they operate at all layers) because they must include Application layer protocols that offer services to networked applications.

Written Lab

You can find the answers to the written labs in Appendix A.

1. Which layer chooses and determines the availability of communicating partners along with the resources necessary to make the connection, coordinates partnering applications, and forms a consensus on procedures for controlling data integrity and error recovery?

2. Which layer is responsible for converting frames from the Data Link layer into electrical signals?

3. At which layer is routing implemented, enabling connections and path selection between two end systems?

4. Which layer defines how data is formatted, presented, encoded, and converted?

5. Which layer is responsible for creating, managing, and terminating sessions between applications?

6. Which layer manages the transmission of data across a physical link and is primarily concerned with physical addressing and the ordered delivery of frames?

7. Which layer is used for reliable communication between end nodes over the network and provides mechanisms for establishing, maintaining, and terminating virtual circuits as well as controlling the flow of information?

8. Which layer provides logical addressing that routers use for path determination?

9. Which layer specifies voltage, wire speed, and connector pin-outs and moves bits between devices?

10. Which layer combines bits into bytes and bytes into frames and uses MAC addressing?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Host 1 sent a SYN packet to Host 2. What will Host 2 send in response?

   A. ACK

   B. NAK

   C. SYN/ACK

   D. SYN/NAK

   E. SYN

2. TCP and UDP reside at which layer of the OSI model?

   A. 1

   B. 2

   C. 3

   D. 4

3. Which layer of the OSI model provides an entry point for programs to access the network infrastructure?

   A. Application

   B. Transport

   C. Network

   D. Physical

4. You are connected to a server on the Internet and you click a link on the server and receive a time-out message. What layer could be the source of this message?

   A. Application

   B. Transport

   C. Network

   D. Physical

5. Which layer of the OSI model is responsible for code and character-set conversion as well as recognizing data formats?

   A. Application

   B. Presentation

   C. Session

   D. Network

6. At which layers of the OSI model do bridges, hubs, and routers primarily operate, respectively?

   A. Physical, Physical, Data Link

   B. Data Link, Data Link, Network

C. Data Link, Physical, Network

D. Physical, Data Link, Network

7. Which layer of the OSI model is responsible for converting data into signals appropriate for the transmission medium?

A. Application

B. Network

C. Data Link

D. Physical

8. A receiving host has failed to receive all the segments that it should acknowledge. What can the host do to improve the reliability of this communication session?

A. Send a different source port number.

B. Restart the virtual circuit.

C. Decrease the sequence number.

D. Decrease the window size.

9. Which Layer 1 devices can be used to enlarge the area covered by a single LAN segment? (Choose two.)

A. Firewall

B. NIC

C. Hub

D. Repeater

E. RJ-45 transceiver

10. Segmentation of a data stream happens at which layer of the OSI model?

A. Physical

B. Data Link

C. Network

D. Transport

11. When data is encapsulated, which is the correct order?

A. Data, frame, packet, segment, bits

B. Segment, data, packet, frame, bits

C. Data, segment, packet, frame, bits

D. Data, segment, frame, packet, bits

12. What are two purposes for segmentation with a bridge? (Choose two.)

A. To add more broadcast domains

B. To create more collision domains

C. To add more bandwidth for users

D. To allow more broadcasts for users

13. Acknowledgments, sequencing, and flow control are characteristic of which OSI layer?
    A. Layer 2
    B. Layer 3
    C. Layer 4
    D. Layer 7

14. Which of the following is true regarding sequencing and acknowledgments? (Choose all that apply.)
    A. The segments delivered are acknowledged back to the sender upon their reception.
    B. If a segment is not received, the virtual circuit must be restarted from the beginning at a slower transmit interval.
    C. Any segments not acknowledged are retransmitted.
    D. Segments are sequenced back into their proper order upon arrival at their destination.
    E. All segments are retransmitted on time slot intervals.

15. What is the purpose of flow control?
    A. To ensure that data is retransmitted if an acknowledgment is not received
    B. To reassemble segments in the correct order at the destination device
    C. To provide a means for the receiver to govern the amount of data sent by the sender
    D. To regulate the size of each segment

16. At which layer of the OSI model would you find IP?
    A. Transport
    B. Network
    C. Data Link
    D. Physical

17. Of the following, which is the highest layer in the OSI model?
    A. Transport
    B. Session
    C. Network
    D. Presentation

18. Routers perform routing at which OSI layer?
    A. Physical
    B. Data Link
    C. Network
    D. Transport
    E. Application

19. Which of the following mnemonic devices can you use to remember the first letter of the name of each layer of the OSI model in the proper order?

A. All People Seem To Need Processed Data.

B. Always Should People Never Threaten Dog Police.

C. Please Do Not Throw Sausage Pizza Away.

D. All Day People Should Try New Professions.

20. Which IEEE standard specifies the protocol for CSMA/CD?

A. 802.2

B. 802.3

C. 802.5

D. 802.11

Chapter 3

Networking Topologies, Connectors, and Wiring Standards

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **2.0 Infrastructure**

✓ **2.1 Given a scenario, deploy the appropriate cabling solution.**

- Media types
  - Copper
  - UTP
  - STP
  - Coaxial
  - Fiber
  - Single-mode
  - Multimode
- Plenum vs. PVC
- Connector types
- Copper
  - RJ-45
  - RJ-11
  - BNC
  - DB-9
  - DB-25
  - F-type

- Fiber
  - LC
  - ST
  - SC
  - APC
  - UPC
  - MTRJ
- Transceivers
  - SFP
  - GBIC
  - SFP+
  - QSFP
- Characteristics of fiber transceivers
  - Bidirectional
  - Duplex
- Termination points
  - 66 block
  - 110 block
  - Patch panel
  - Fiber distribution panel
- Copper cable standards
  - Cat 3
  - Cat 5
  - Cat 5e
  - Cat 6
  - Cat 6A
  - Cat 7
  - RG-6
  - RG-59
- Copper termination standards
  - TIA/EIA 568a
  - TIA/EIA 568b
  - Crossover
  - Straight-through

The idea of connecting a bunch of computers together hasn't changed a whole lot since the mid-1980s, but how we go about doing that certainly has. Like everything else, the technologies and devices we create our networks with have evolved dramatically and will continue to do so in order to keep up with the ever-quickening pace of life and the way we do business.

When you connect computers together to form a network, you want error-free, blazingly fast communication, right? Although "error-free" and reality don't exactly walk hand in hand, keeping lapses in communication to a minimum and making that communication happen really fast is definitely possible. But it isn't easy, and understanding the types of media and network topologies used in networking today will go far in equipping you to reach these goals; so will being really knowledgeable about the array of components and devices used to control network traffic.

All of these networking ingredients are going to be the focus of this chapter. In it, I'll cover different types of networking media, discuss common topologies and devices, and compare the features that they all bring into designing a solid network that's as problem free and turbo charged as possible.

NOTE To find Todd Lammle CompTIA videos and questions, please see `www.lammle.com/network+`.

Physical Media

A lot of us rely on wireless networking methods that work using technologies like radio frequency and infrared, but even wireless depends on a physical media backbone in place somewhere. And the majority of installed LANs today communicate via some kind of cabling, so let's take a look at the three types of popular cables used in modern networking designs:

- Coaxial
- Twisted-pair
- Fiber optic

Coaxial Cable

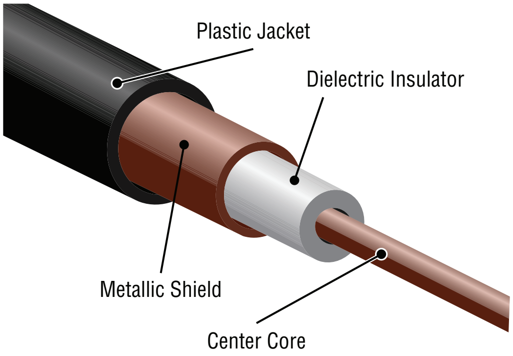
Coaxial cable, referred to as *coax*, contains a center conductor made of copper that's surrounded by a plastic jacket with a braided shield over it. A plastic such as polyvinyl chloride (PVC) or fluoroethylenepropylene (FEP, commonly known as Teflon) covers this metal shield. The Teflon-type covering is frequently referred to as a *plenum-rated coating*, and it's definitely expensive but often mandated by local or municipal fire code when cable is hidden in walls and ceilings. Plenum rating applies to all types of cabling and is an approved replacement for all other compositions of cable sheathing and insulation like PVC-based assemblies.

The difference between plenum and non-plenum cable comes down to how each is constructed and where you can use it. Many large multistory buildings are designed to circulate air through the spaces between the ceiling of one story and the floor of the next; this space between floors is referred to as the *plenum*. And it just happens to be a perfect spot to run all the cables that connect the legions of computers that live in the building. Unless there's a fire—if that happens, the non-plenum cable becomes a serious hazard because its insulation gives off poisonous smoke that gets circulated throughout the whole building. Plus, non-plenum cables can actually become "wicks" for the fire, helping it quickly spread from room to room and floor to floor—yikes!

Because it's a great goal to prevent towering infernos, the National Fire Protection Association (NFPA) demands that cables run within the plenum have been tested and guaranteed as safe. They must be fire retardant and create little or no smoke and poisonous gas when burned. This means you absolutely can't use a non-plenum-type cable in the plenum, but it doesn't mean you can't use it in other places where it's safe. And because it's a lot cheaper, you definitely want to use it where you can.

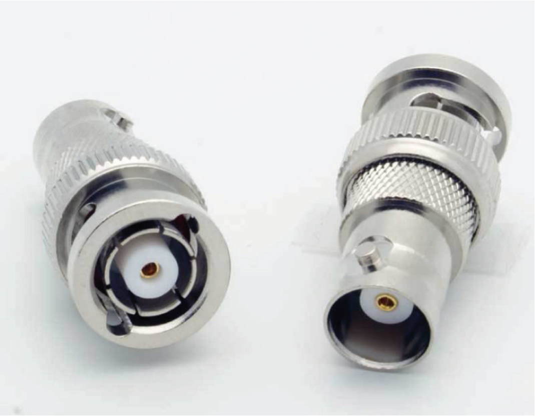
Thin Ethernet, also referred to as *Thinnet* or 10Base2, is a thin coaxial cable. It is basically the same as thick coaxial cable except it's only about 5 mm, or 2/10″, diameter coaxial cable. Thin Ethernet coaxial cable is Radio Grade 58, or just RG-58. Figure 3.1 shows an example of thinnet. This connector resembles the coaxial connector used for cable TV, which is called an *F-type connector.*

FIGURE 3.1 A stripped-back thinnet cable



Oh, by the way, if you use Thinnet cable, you've got to use *BNC* connectors to attach stations to the network, as shown in Figure 3.2, and you have to use 50 ohm terminating resistors at each end of the cable in order to achieve the proper performance.

FIGURE 3.2 Male and female BNC connectors



NOTE

You don't have to know much about most coax cable types in networks anymore, especially the thinnet and thicknet types of coaxial cable. Thicknet was known as RG-8 and was about 1/2″ in diameter, also requiring 50 ohm terminating resistors on each end of the cable. Nowadays, we use 75 ohm coax for cable TV; using coax in the Ethernet LAN world is pretty much a thing of the past, but we do use them for high-bandwidth runs in our data centers. RG-6, or CATV coax, is used in our broadband world.

You can attach a BNC connector to the cable with a crimper that looks like a weird pair of pliers and has a die to crimp the connector. A simple squeeze crimps the connector to the cable. You can also use a screw-on connector, but I avoid doing that because it's not very reliable.

You can use a BNC coupler to connect two male connectors together or two female connectors together.

Table 3.1 lists some specifications for the different types of coaxial cable, but understand that we use only RG-59 and RG-6 in today's world.

F-type

The F connector, or F-type connector, is a form of coaxial connector that is used for cable TV. It has an end that screws to tighten the connector to the interface. It resembles the RG-58 mentioned earlier in this section.

TABLE 3.1 Coaxial cable specifications

RG Rating	Popular Name	Ethernet Implementation	Type of Cable
RG-58 U	N/A	None	Solid copper
RG-58 A/U	Thinnet	10Base2	Stranded copper
RG-8	Thicknet	10Base5	Solid copper
RG-59	Cable television Low cost, short distance	N/A	Solid copper
RG-6	Cable television, cable modems Longer distances than RG-59; some power implementations	N/A	Solid copper
RG-62	ARCnet (obsolete)	N/A	Solid/stranded

NOTE

An advantage of using coax cable is the braided shielding that provides resistance to electronic pollution like *electromagnetic interference (EMI)*, *radio frequency interference (RFI)*, and other types of stray electronic signals that can make their way onto a network cable and cause communication problems.

Twisted-Pair Cable

Twisted-pair cable consists of multiple individually insulated wires that are twisted together in pairs. Sometimes a metallic shield is placed around them, hence the name *shielded twisted-pair (STP)*. Cable without outer shielding is called *unshielded twisted-pair (UTP)*, and it's used in twisted-pair Ethernet (10BaseT, 100BaseTX, 1000BaseTX) networks.

Ethernet Cable Descriptions

Ethernet cable types are described using a code that follows this format: *N* <*Signaling*> *X*. The *N* refers to the signaling rate in megabits per second. <*Signaling*> stands for the signaling type—either baseband or broadband—and the *X* is a unique identifier for a specific Ethernet cabling scheme.

Here's a common example: 100Base*X*. The 100 tells us that the transmission speed is 100 Mb, or 100 megabits. The *X* value can mean several different things; for example, a *T* is short for *twisted-pair*. This is the standard for running 100-megabit Ethernet over two pairs (four wires) of Category 5, 5e, or 6 UTP.

So why are the wires in this cable type twisted? Because when electromagnetic signals are conducted on copper wires in close proximity—like inside a cable—it causes interference called *crosstalk*. Twisting two wires together as a pair minimizes interference and even protects against interference from outside sources. This cable type is the most common today for the following reasons:

- It's cheaper than other types of cabling.
- It's easy to work with.
- It allows transmission rates that were impossible 10 years ago.

UTP cable is rated in these categories:

Category 1 Two twisted wire pairs (four wires). It's the oldest type and is only voice grade—it isn't rated for data communication. People refer to it as plain old telephone service (POTS). Before 1983, this was the standard cable used throughout the North American telephone system. POTS cable still exists in parts of the Public Switched Telephone Network (PSTN) and supports signals limited to the 1 MHz frequency range.

NOTE *Category* is often shortened to *Cat.* Today, any cable installed should be a minimum of Cat 5e because some cable is now certified to carry bandwidth signals of 350 MHz or beyond. This allows unshielded twisted-pair cables to exceed speeds of 1 Gbps—fast enough to carry broadcast-quality video over a network.

Category 2 Four twisted wire pairs (eight wires). It handles up to 4 Mbps, with a frequency limitation of 10 MHz, and is now obsolete.

Category 3 Four twisted wire pairs (eight wires) with three twists per foot. This type can handle transmissions up to 16 MHz. It was popular in the mid-1980s for up to 10 Mbps Ethernet, but it's now limited to telecommunication equipment and, again, is obsolete for networks.

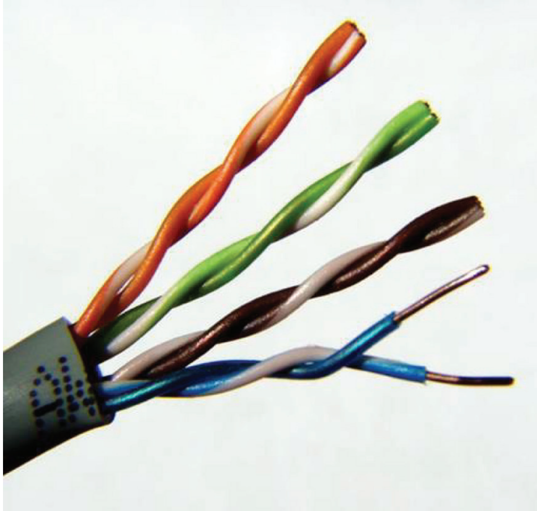
Category 4 Four twisted wire pairs (eight wires), rated for 20 MHz; also obsolete.

Category 5 Four twisted wire pairs (eight wires), used for 100BaseTX (two pair wiring) and rated for 100 MHz. But why use Cat 5 when you can use Cat 5e for the same price? I am not sure you can even buy plain Cat 5 anymore!

Category 5e (Enhanced) Four twisted wire pairs (eight wires), recommended for 1000BaseT (four pair wiring) and rated for 100 MHz but capable of handling the disturbance on each pair that's caused by transmitting on all four pairs at the same time—a feature that's needed for Gigabit Ethernet. Any category below 5e shouldn't be used in today's network environments.

Figure 3.3 shows a basic Cat 5e cable with the four wire pairs twisted to reduce crosstalk.

FIGURE 3.3 Cat 5e UTP cable



Category 6 Four twisted wire pairs (eight wires), used for 1000BaseTX (two pair wiring) and rated for 250 MHz. Cat 6 became a standard back in June 2002. You would usually use it as riser cable to connect floors together. If you're installing a new network in a new building, there's no reason to use anything but Category 6 UTP cabling as well as running fiber runs between floors.

Category 6A (Augmented) Basic Category 6 cable has a reduced maximum length when used for 10GBaseT; however, Category 6A cable, or Augmented Category 6, is characterized to 500 MHz and has improved crosstalk characteristics, which allows 10GBaseT to be run for up to 100 meters. The most important point is a performance difference between Electronic Industries Alliance and Telecommunications Industry Association (EIA/TIA) component specifications for the NEXT (near-end crosstalk) transmission parameter. Running at a frequency of 500 MHz, an ISO/IEC Cat 6A connector provides double the power (3db) of a Cat 6A connector that conforms with the EIA/TIA specification. Note that 3 dB equals a 100 percent increase of a near-end crosstalk noise reduction. This is our future cable indeed!

Category 7 While not recognized by the TIA/EIA, category 7 cable, Cat 7, allows 10 Gigabit Ethernet over 100 m of copper cabling. The cable contains four twisted copper wire pairs, just like the earlier standards. As of 2017, there is no equipment that has connectors supporting the Class F (Category 7) channel.

Connecting UTP

BNC connectors won't fit very well on UTP cable, so you need to use a *registered jack (RJ)* connector, which you're familiar with because most telephones connect with them. The connector used with UTP cable is called RJ-11 for phones that use four wires; RJ-45 has four pairs (eight wires), as shown in Figure 3.4.

FIGURE 3.4 RJ-11 and RJ-45 connectors

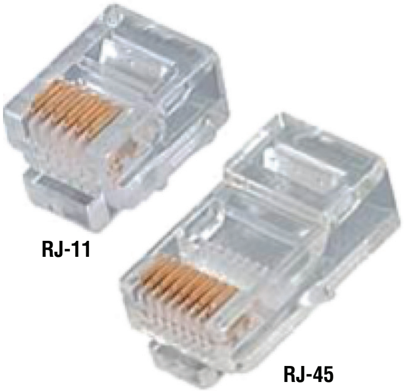
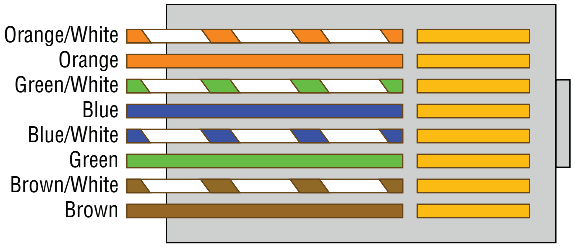


Figure 3.5 shows the pin-outs used in a typical RJ-45 connector. Looking from the bottom of the connector, pin 1 would be on the left.

FIGURE 3.5 The pin-outs in an RJ-45 Connector, T568B standard



Most of the time, UTP uses RJ connectors, and you use a crimper to attach them to a cable, just as you would with BNC connectors. The only difference is that the die that holds the connector is a different shape. Higher-quality crimping tools have interchangeable dies for both types of cables. We don't use RJ-11 for local area networks (LANs), but we do use them for our home Digital Subscriber Line (DSL) connections.

RJ-11 uses two wire pairs, and RJ-45 uses four wire pairs.

There's one other type of copper connector called the RJ-48c, which looks exactly like an RJ-45 connector. This plug is very similar to the RJ-45 in that it has four wire pairs, but they are wired differently and used for different circumstances.

RJ-45 is mainly used in LANs with short distances (typically up to 100 meters), where the RJ-48c wiring type would be used with a T1 connection, which is a long-distance wide area network (WAN). In addition, to protect the signal in an RJ-48c, the wires are typically shielded, whereas the RJ-45 uses unshielded wiring.

Real World Scenario

Category 5e Cabling Tips

If you want data rates faster than 10 Mbps over UTP, ensure that all components are rated to deliver this and be really careful when handling all components. If you yank on Cat 5e cable, it will stretch the number of twists inside the jacket, rendering the Cat 5e label on the outside of the cable invalid. Also, be certain to connect and test all four pairs of wire. Although today's wiring usually uses only two pairs (four wires), the standard for Gigabit Ethernet over UTP requires that all four pairs (eight wires) be in good condition.

Also be aware that a true Cat 5e cabling system uses rated components from end to end, patch cables from workstation to wall panel, cable from wall panel to patch panel, and patch cables from patch panel to hub. So if any components are missing, or if the lengths don't match the Category 5e specification, you just don't have a Category 5e cabling installation. And certify that the entire installation is Category 5e compliant. I've got to warn you that doing this requires some pretty pricey test equipment to make the appropriate measurements!

Fiber-Optic Cable

Because fiber-optic cable transmits digital signals using light impulses rather than electricity, it's immune to EMI and RFI. Anyone who's seen a network's UTP cable run down an elevator shaft would definitely appreciate this fiber feature. Fiber cable allows light impulses to be carried on either a glass or a plastic core. Glass can carry the signal a greater distance, but plastic costs less. Whichever the type of core, it's surrounded by a glass or plastic cladding with a different refraction index that reflects the light back into the core. Around this is a layer of flexible plastic buffer that can be wrapped in an armor coating that's usually Kevlar, which is then sheathed in PVC or plenum.

The cable itself comes in either single-mode fiber (SMF) or multimode fiber (MMF); the difference between them is in the number of light rays (the number of signals) they can carry. Multimode fiber is most often used for shorter-distance applications and single-mode fiber for spanning longer distances.

Although fiber-optic cable may sound like the solution to many problems, it has its pros and cons just like the other cable types.

Here are the pros:

- It's completely immune to EMI and RFI.
- It can transmit up to 40 kilometers (about 25 miles).

And here are the cons:

- It's difficult to install.
- It's more expensive than twisted-pair.
- Troubleshooting equipment is more expensive than twisted-pair test equipment.
- It's harder to troubleshoot.

Single-Mode Fiber

Single-mode fiber-optic cable (SMF) is a very high-speed, long-distance media that consists of a single strand—sometimes two strands—of glass fiber that carries the signals. Light-emitting diodes (LEDs) and laser are the light sources used with SMF. The light source is transmitted from end to end and pulsed to create communication. This is the type of fiber cable employed to span really long distances because it can transmit data 50 times farther than multimode fiber at a faster rate.

Clearly, because the transmission media is glass, the installation of SMF can be a bit tricky. Yes, there are outer layers protecting the glass core, but the cable still shouldn't be crimped or pinched around any tight corners.

Multimode Fiber

Multimode fiber-optic cable (MMF) also uses light to communicate a signal, but with it, the light is dispersed on numerous paths as it travels through the core and is reflected back. A special material called *cladding* is used to line the core and focus the light back onto it. MMF provides high bandwidth at high speeds over medium distances (up to about 3,000 feet), but beyond that it can be really inconsistent. This is why MMF is most often used within a smaller area of one building; SMF can be used between buildings.

MMF is available in glass or in a plastic version that makes installation a lot easier and increases the installation's flexibility.

APC vs. UPC

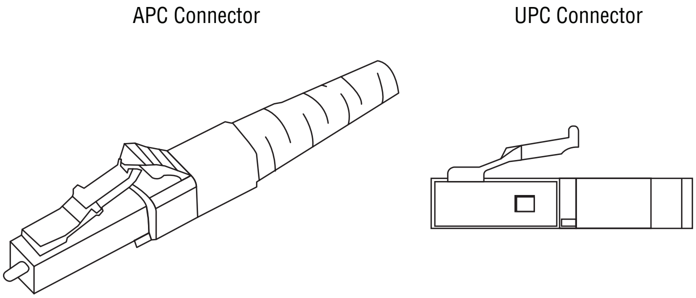
The choice between Angled Physical Contact (APC) and ultra Physical Contact (UPC) can make a pretty big difference on how your network will perform.

The ultra-polished connector looks like what you'd expect to find in a fiber-optic end. The cut is perfectly straight, as shown in Figure 3.6.

The angle-polished connector looks like Figure 3.6. Notice the perfectly cut angle, which seems odd, but there is a reason for this and it's a good one!

With the UPC, the light is reflected back down to the core of the fiber cable, which causes a loss of db called a return loss because the angled connector causes the light to reflect back into the cladding—the thick sides of the glass instead of the core. But the APC doesn't cause nearly as much db loss when using this type of connector. Very cool design indeed!

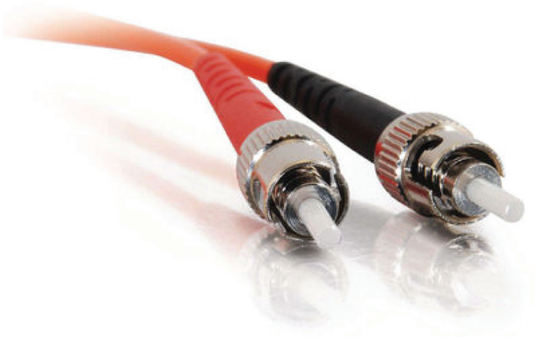
FIGURE 3.6 UPC and APC connectors



Fiber-Optic Connectors

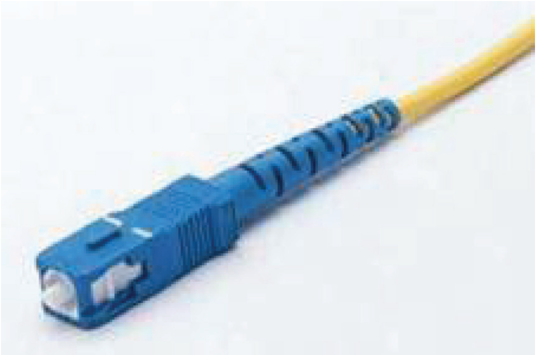
A whole bunch of different types of connectors are available to use with fiber-optic cables, but the two most popular are the *straight tip (ST)* and the *subscriber (or square) connector (SC)*. The ST fiber-optic connector (developed by AT&T) is one of the most widely used fiber-optic connectors; it uses a BNC attachment mechanism similar to Thinnet's that makes connections and disconnections fairly frustration free. In fact, this is the feature that makes this connector so popular. Figure 3.7 shows an example of an ST connector. Notice the BNC attachment mechanism.

FIGURE 3.7 An example of an ST connector



The SC connector is another type of fiber-optic connector. As you can see in Figure 3.8, SC connectors are *latched*—a mechanism holds the connector in securely and prevents it from falling out.

FIGURE 3.8 A sample SC connector



SC connectors work with both single-mode and multimode optical fibers and will last for around 1,000 matings. They're being used more now but still aren't nearly as popular as ST connectors for LAN connections.

Another type of connector I want to mention is the FC connector, or field assembly connector, also called the ferrule connector, which isn't very popular. It's still used in telecommunications and measurement equipment with single-mode lasers, but the SC is a way more popular fiber end. The only reason I mention it here is that it is an exam objective; other than that you probably won't ever see it in production. These look identical to ST connectors.

You can also get a fiber coupler in order to connect an ST to an SC connector, for example, but you will lose a lot of your power (db) if you do so.

Fiber Distribution Panel

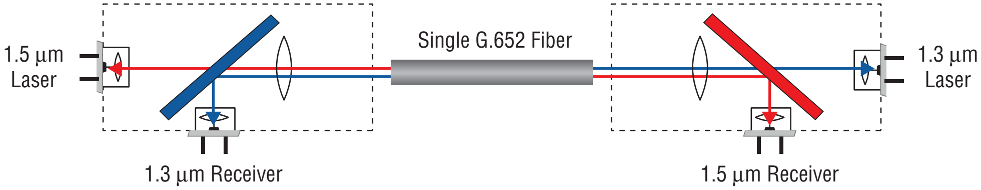
Fiber distribution panels (FDP) are termination and distribution systems for fiber optic cable facilities. It consists of a cable management tray and a splice drawer. They are designed for central offices, remote offices and LANs using fiber optic facilities.

Fiber-Optic Transceivers

Fiber-optic transceivers can be either unidirectional (simplex) or bidirectional (duplex). Let's look at both standards:

Bidirectional Bidirectional communication is possible if the cable used is following the EEE 802.3ah 1000BASE-BX10-D and 1000BASE-BX10-U standards. The communication over a single strand of fiber is achieved by separating the transmission wavelength of the two devices, as depicted in Figure 3.9.

FIGURE 3.9 Bidirectional communication



Small Form Factor Fiber-Optic Connectors

Another cool fiber-optic connector is the *small form factor (SFF)* connector, which allows more fiber-optic terminations in the same amount of space than its standard-sized counterparts. The two most popular versions are the *mechanical transfer registered jack (MT-RJ or MTRJ)*, designed by AMP, and the *Local Connector (LC)*, designed by Lucent.

Real World Scenario

Should I Use Copper or Fiber?

If your data runs are measured in miles, fiber optic is your cable of choice because copper just can’t give you more than about 1,500 feet without electronics regenerating the signal. The standards limit UTP to a pathetic 328 feet.

Another good reason to opt for fiber is if you require high security because it doesn’t create a readable magnetic field. Although fiber-optic technology was initially super expensive and nasty to work with, it’s now commonly used for Gigabit or 10 GB Internet backbones.

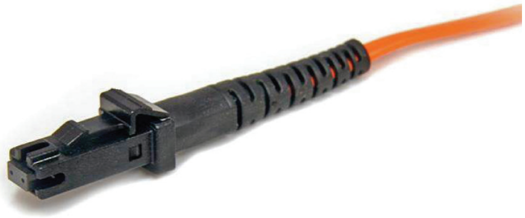
Ethernet running at 10 Mbps over fiber-optic cable to the desktop is designated 10BaseFL; the 100 Mbps version of this implementation is 100BaseFX. The *L* in the 10 Mbps version stands for *link*. Other designations are *B* for *backbone* and *P* for *passive.*

The MT-RJ fiber-optic connector was the first small form factor fiber-optic connector to be widely used, and it’s only one-third the size of the SC and ST connectors it most often replaces. It offers these benefits:

- Small size
- TX and RX strands in one connector
- Keyed for single polarity
- Pre-terminated ends that require no polishing or epoxy
- Easy to use

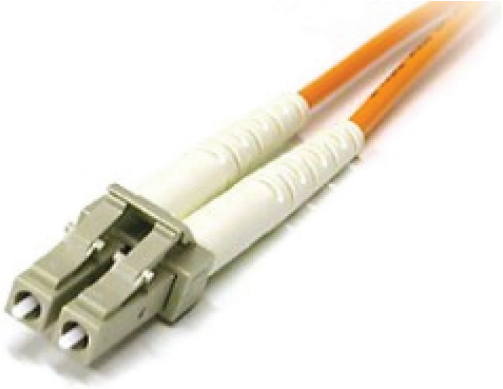
Figure 3.10 shows an example of an MT-RJ fiber-optic connector.

FIGURE 3.10 A sample MT-RJ fiber-optic connector



LC is a newer style of SFF fiber-optic connector that's pulling ahead of the MT-RJ. It's especially popular for use with Fibre-Channel adapters (FCs) and is a standard used for fast storage area networks and Gigabit Ethernet adapters. Figure 3.11 depicts an example of the LC connector.

FIGURE 3.11 A sample LC fiber-optic connector



It has similar advantages to MT-RJ and other SFF-type connectors but it's easier to terminate. It uses a ceramic insert just as standard-sized fiber-optic connectors do.

Transceivers

A transceiver is a device comprised of both a transmitter and a receiver, which are combined and share common circuitry or a single housing. The term applies to wireless communications devices such as cellular telephones, cordless telephone sets, hand held two-way radios, and mobile two-way radios. Occasionally, the term is used in reference to transmitter and receiver devices in cable or optical fiber systems.

SFP+ The small form-factor pluggable (SFP) is a compact, hot-pluggable optical module transceiver used for both telecommunication and data communications applications. The SFP+ transceiver is an enhanced version of the SFP that supports data rates up to 16 Gbit/s.

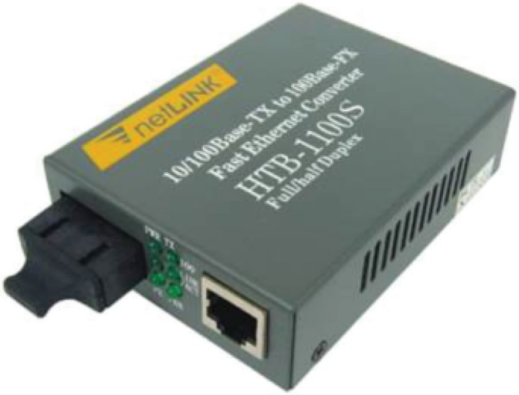
QSFP The Quad Small Form-factor Pluggable (QSFP) is another compact, hot-pluggable transceiver used for data communications applications. It interfaces networking hardware (such as servers and switches) to a fiber optic cable or active or passive electrical copper connection. It allows data rates from 4x1 Gb/s for QSFP and 4x10 Gbit/s for QSFP+ and to the highest rate of 4x28 Gbit/s known as QSFP28 used for 100 Gbit/s links.

Media Converters

Sometimes, you'll need to convert from one media type to another. Maybe you need to go from one mode of fiber to another mode, or in an even more extreme case, you need to go from fiber to Ethernet. If you're faced with situations like these, you'll need to be familiar with some of the more common media converters:

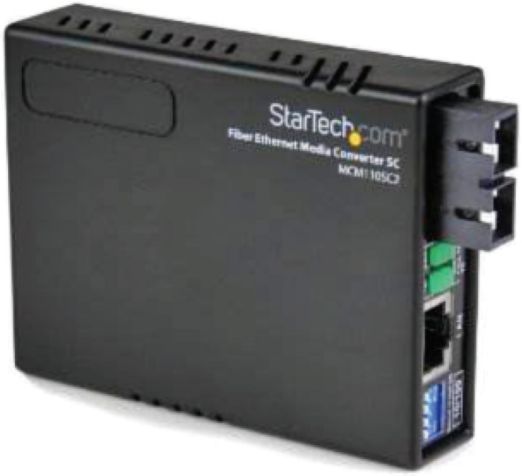
Single-Mode Fiber to Ethernet These devices accept a fiber connector and an Ethernet connector and convert the signal from Ethernet and single-mode fiber (see Figure 3.12).

FIGURE 3.12 Single-mode fiber to Ethernet



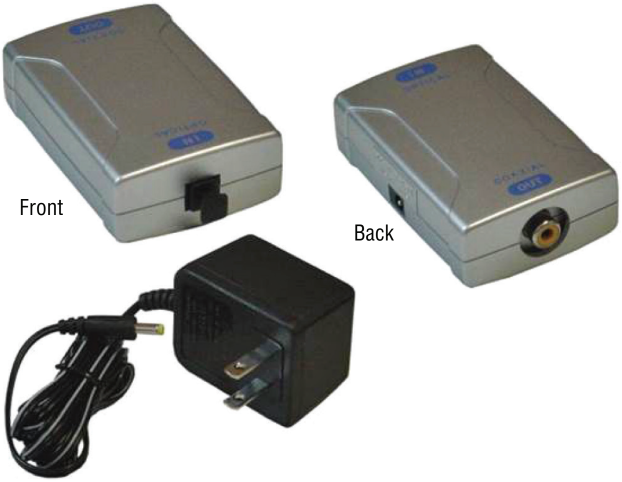
Multimode Fiber to Ethernet These devices accept a fiber connector and an Ethernet connector and convert the signal from Ethernet and multi-mode fiber (see Figure 3.13).

FIGURE 3.13 Multimode fiber to Ethernet



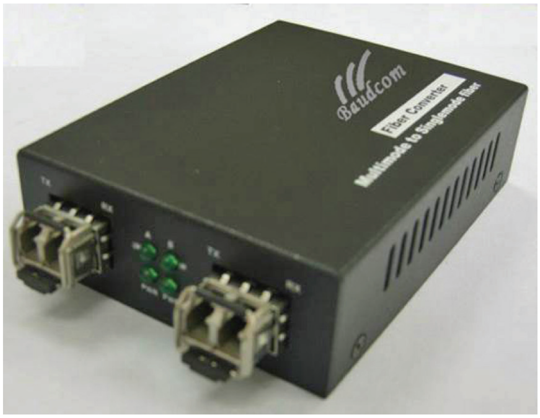
Fiber to Coaxial These devices accept a fiber connector and a coaxial connector and convert digital signals from optical to coax (see Figure 3.14).

FIGURE 3.14 Fiber to coaxial



Single-Mode to Multimode Fiber These devices accept a single-mode fiber connector and a multimode fiber connector and convert the signals between the two (see Figure 3.15).

FIGURE 3.15 Single-mode to multimode fiber



Serial Cables

Except for multimode fiber, all the cable varieties I've talked about so far are considered serial cable types. In network communications, *serial* means that one bit after another is sent out onto the wire or fiber and interpreted by a network card or other type of interface on the other end.

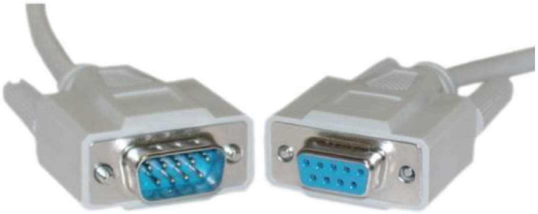
Each 1 or 0 is read separately and then combined with others to form data. This is very different from parallel communication, where bits are sent in groups and have to be read together to make sense of the message they represent. A good example of a parallel cable is an old printer cable—which has been replaced by USB, as I'll get to in a minute.

RS-232

Recommended Standard 232 (RS-232) was a cable standard commonly used for serial data signals connecting the DTE and the DCE, such as a computer's serial port to an external modem.

Figure 3.16 shows an example of one of the many types of RS-232 cables. These cables normally connect to a connector on the device called a *DB-9*.

FIGURE 3.16 RS-232 cable ends



Because laptops don't even come with these types of connectors anymore, they've pretty much been replaced by things like USB, Thunderbolt, and FireWire.

DB-25

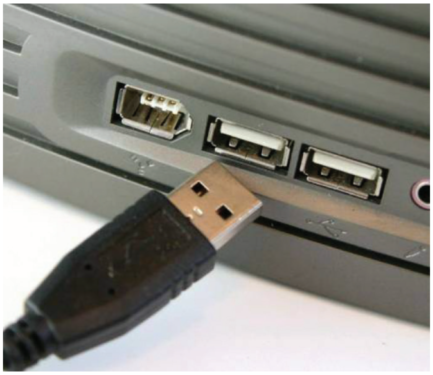
Now here's a connector that has been around for a while! The D series of connectors was invented by ITT Cannon in 1952, and the *D* was followed by *A*, *B*, *C*, *D*, or *E*, which described the shell size, then the numbers of pins or sockets. DB-25 tells us we have 25 pins in a "B" size shell. RS-232 devices usually used the DB-25 connector, but today we don't use RS-232 or DB-25, and we rarely use a DB-9, which used to be used for Cisco console cables but has mostly been replaced by USB.

Universal Serial Bus

Universal Serial Bus (USB) is now the built-in serial bus du jour of most motherboards. You usually get a maximum of 4 external USB interfaces, but add-on adapters can take that up to as many as 16 serial interfaces. USB can actually connect a maximum of 127 external devices, and it's a much more flexible peripheral bus than either serial or parallel.

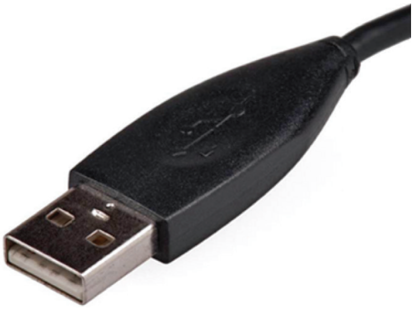
We use USB to connect printers, scanners, and a host of other input devices like keyboards, joysticks, and mice. When connecting USB peripherals, you've got to connect them either directly to one of the USB ports on the PC or to a USB hub that is connected to one of those USB ports. You can get a picture of this in Figure 3.17.

FIGURE 3.17 A USB port



Hubs can be chained together to provide multiple USB connections, but even though you can connect up to 127 devices, it's really not practical to go there. Each device has a USB plug, shown in Figure 3.18.

FIGURE 3.18 A USB plug



Cable Properties

The reason we use so many different types of cables in a network is that each type has its own set of properties that specifically make it the best to use for a particular area or purpose. Different types vary in transmission speeds, distance, duplex, noise immunity, and frequency, and I'll cover each of these next.

Transmission Speeds

Based on the type of cable or fiber you choose and the network that it's installed in, network administrators can control the speed of a network to meet the network's traffic demands.

Admins usually permit, or would like to have, transmission speeds of up to 10 Gbps or higher on the core areas of their networks that connect various network segments. In the distribution and access areas, where users connect to switches, it's typically 100 Mbps per connection, but transmission speeds are creeping up because the traffic demand is getting higher.

Distance

Deciding factors used in choosing what cable type to use often come down to the topology of a network and the distance between its components. Some network technologies can run much farther than others without communication errors, but all network communication technologies are prone to *attenuation*—the degradation of a signal due to the medium itself and the distance signals have to travel. Some cable types suffer from attenuation more than others. For instance, any network using twisted-pair cable should have a maximum segment length of only 328 feet (100 meters).

Duplex

All communications are either half duplex or full duplex. The difference is whether the communicating devices can "talk" and "listen" at the same time.

During half-duplex communication, a device can either send communication or receive communication, but not both at the same time. Think walkie-talkie—when you press the button on the walkie-talkie, you turn the speaker off and you can't hear anything the other side is saying.

In full-duplex communication, both devices can send and receive communication at the same time. This means that the effective throughput is doubled and communication is much more efficient. Full duplex is typical in most of today's switched networks. I'll discuss both full and half duplex in more detail in Chapter 4, "The Current Ethernet Specifications."

Noise Immunity (Security, EMI)

Any time electrons are pushed through two wires next to each other, a magnetic current is created. And we can create a current in the wires. This is good because without *magnetic flux*, we wouldn't be using computers—the power that surges through them is a result of it. The bad news is that it also creates two communications issues.

First, because the wire is creating a current based on the 1s and 0s coursing through it, with the right tools in hand, people can read the message in the wire without cutting it or even removing the insulation. You've heard of this—it's called *tapping* the wire, and it's clearly a valid security concern. In ancient history, high-security installations like the Pentagon actually encased communication wires in lead shielding to prevent them from being tapped. STP wires make tapping a little harder, but not hard enough.

The best way to solve the magnetic-flux problem caused by electricity is to not use these wires at all. As I said, fiber-optic cables carry the signal as light on a glass or a really pure plastic strand, and light is not susceptible to magnetic flux, making fiber optics a whole lot harder to tap. It's still not impossible—you can do it at the equipment level, but you have to actually cut and then repair the cable to do that, which isn't likely to go unnoticed.

The second magnetic-flux issue comes from the outside in instead of from the inside out. Because wires can take on additional current if they're near any source of magnetism, you've got to be really careful where you run your cables. You can avoid EMI by keeping copper cables away from all powerful magnetic sources like electric motors, speakers, amplifiers, fluorescent light ballasts, and so on. Just keep them away from anything that can generate a magnetic field!

Frequency

Each cable type has a specified maximum frequency that gives you the transmission bandwidth it can handle. Cat 5e cable is tested to 100 MHz maximum frequency and can run 1 Gbps signals for relatively short distances. That's maxing it out, but it's still good for connecting desktop hosts at high speeds. On the other hand, Cat 6 is a 250 MHz cable that can handle 1 Gbps data flow all day long with ease. Cat 6 has a lot more twists and thicker cables, so it's best used when connecting floors of a building.

NOTE Although a signal is measured as bandwidth, the capacity to carry the signal in a cable is measured as frequency.

Wiring Standards

Ethernet cabling is an important thing to understand, especially if you're planning to work on any type of LAN. There are different types of wiring standards available:

- T568A
- T568B
- Straight-through
- Crossover
- Rolled/rollover

We will look into each one of these, and then I'll end this discussion with some examples for you.

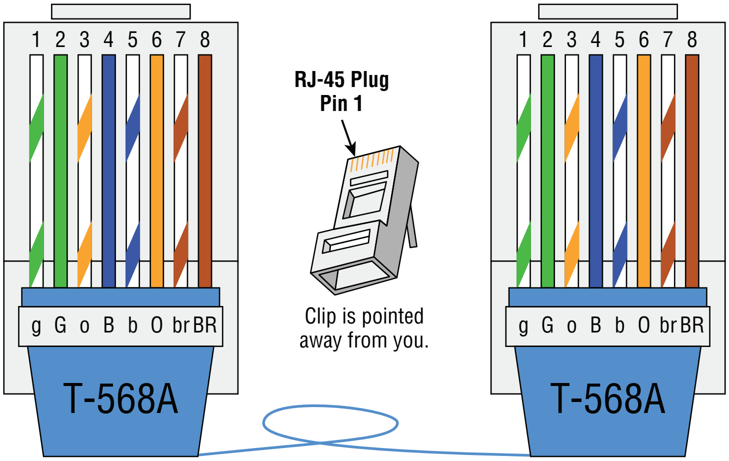
T568A vs. T568B

If you look inside a network cable, you'll find four pairs of wires twisted together to prevent crosstalk; they're also twisted like this to help prevent EMI and tapping. The same pins have to be used on the same colors throughout a network to receive and transmit, but how do you decide which color wire goes with which pin? The good news is that you don't have to decide—at least not completely.

Two wiring standards have surfaced that have been agreed on by over 60 vendors, including AT&T, 3Com, and Cisco, although there isn't 100 percent agreement. In other words, over the years, some network jacks have been pinned with the T568A standard and some have used the T568B standard, which can cause a bit of confusion if you don't know what you're looking at in your network.

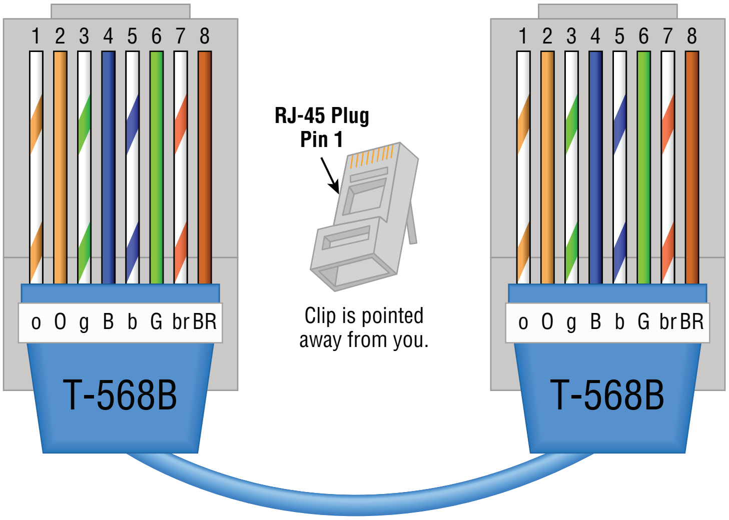
T568A By looking at Figure 3.19, you can see that the green pair is used for pins 1 and 2 but the orange pair is split to pins 3 and 6, separated by the blue pair.

FIGURE 3.19 T568A wired standard



T568B Now take a look at Figure 3.20. The orange pair is pins 1 and 2 and the green pair is pins 3 and 6, again separated by the blue pair.

FIGURE 3.20 T568B wired standard



Note that the only difference between T568A and T568B is that pairs 2 and 3 (orange and green) are swapped. Also, you can use a UTP coupler in order to connect two RJ-45 connectors together to lengthen a cable or in order to make a straight-through cable into a crossover, and vice versa.

If you're thinking, "What's the difference, and why does it matter?" the answer is the position of four wires on one side of the cable—that's it!

If you're installing new cabling to each cubicle and/or office, you need to make sure to connect all eight pins—and use Cat 5e or Cat 6. Voice over IP (VoIP) uses all eight pins, and it's really common to have voice and data on the same wire at the same time in today's networks. Pins 4, 5, 7, and 8 are used in both standards. They are needed for 1000BaseT, PoE, and specialized versions of 100 Mbps networks.

This only leaves the wire pairs to connect to pins 1, 2, 3, and 6 for data. Remember, if we connect the green-white, green, orange-white, and orange wires to pins 1, 2, 3, and 6, respectively, on both sides of the cable, we're using the T568A standard and creating the kind of straight-through cable that's regularly implemented as a regular *patch cable* for most networks. On the other hand, if we switch from pin 1 to pin 3 and from pin 2 to pin 6 on one side only, we've created a *crossover cable* for most networks. Let's take a look.

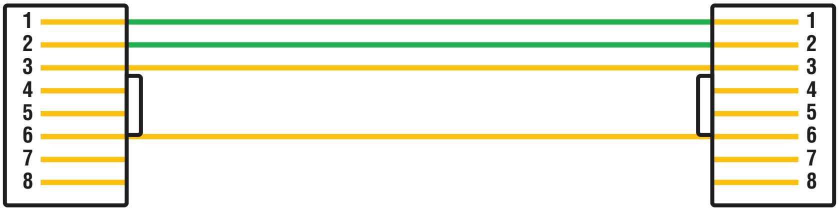
Straight-Through Cable

The straight-through cable is used to connect a host to a switch or hub or a router to a switch or hub.

No worries—I'll tell you all about devices like switches, hubs, and routers in detail in Chapter 5, "Networking Devices."

Four wires are used in straight-through cable to connect 10/100 Ethernet devices. It's really pretty simple to do this; Figure 3.21 depicts the four wires used in a straight-through Ethernet cable.

FIGURE 3.21 Straight-through Ethernet cable



Notice that only pins 1, 2, 3, and 6 are used. Connect 1 to 1, 2 to 2, 3 to 3, and 6 to 6 and you'll be up and networking in no time. Just remember that this would be a 10/100 Ethernet-only cable, so it wouldn't work with 1000 Mbps Ethernet, voice, Token Ring, ISDN, and so on.

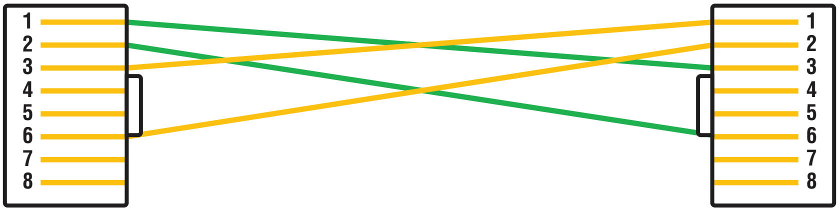
Crossover Cable

The same four wires are used in this cable, and just as with the straight-through cable, you simply connect the different pins together. Crossover cables can be used to connect these devices:

- Switch to switch
- Hub to hub
- Host to host
- Hub to switch
- Router direct to host

Take a look at Figure 3.22, which demonstrates how each of the four wires are used in a crossover Ethernet cable.

FIGURE 3.22 Crossover Ethernet cable



Okay—did you notice that instead of connecting 1 to 1, 2 to 2, and so on, we connected pins 1 to 3 and 2 to 6 on each side of the cable? A crossover cable is typically used to connect two switches together, but it can also be used to test communications between two workstations directly, bypassing the switch.

A crossover cable is used only in Ethernet UTP installations. You can connect two workstation NICs or a workstation and a server NIC directly with it.

If you are trying to match the straight-through and crossover cables with the T568A and T568B standard, here is how it would look:

T568A+T568A = straight-through

T568B+T568B = straight-through

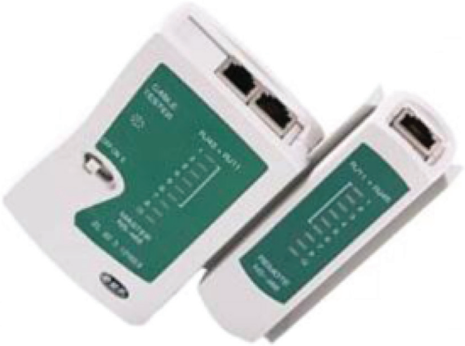
T568A+T568B = crossover

You're going to find out a lot more about how important it is to label basically everything. But for now, make sure to label a crossover cable as what it is so that no one tries to use it as a workstation patch cable. If they do that, the workstation won't be able to communicate with the hub and the rest of the network!

It's really cool that you can carry a crossover cable with you in your tool bag along with your laptop—then, if you want to ensure that a server's NIC is functioning correctly, you can just connect your laptop directly to the server's NIC using your handy crossover cable. You should be able to log in to the server if both NICs are configured correctly.

Use a cable tester to make sure that what you're dealing with is in fact a crossover cable. The tester can also tell you if there's a problem with the cable. Figure 3.23 shows an inexpensive cable tester for UTP.

FIGURE 3.23 An inexpensive cable tester



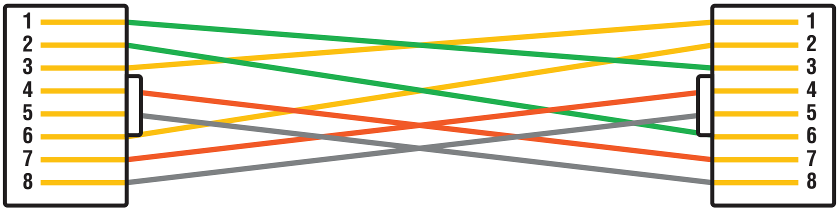
This cost-effective little tool will tell you beyond a shadow of a doubt if you have a straight-through or crossover cable—or even if there's a problem with the cable.

UTP Gigabit Wiring (1000BaseT)

In the previous examples of 10BaseT and 100BaseT UTP wiring, only two wire pairs were used, but that's just not good enough for Gigabit UTP transmission.

1000BaseT UTP wiring (Figure 3.24) requires four wire pairs and uses more advanced electronics so that each and every pair in the cable can transmit simultaneously. Even so, gigabit wiring is almost identical to my earlier 10/100 example, except that we'll use the other two pairs in the cable.

FIGURE 3.24 UTP gigabit crossover Ethernet cable



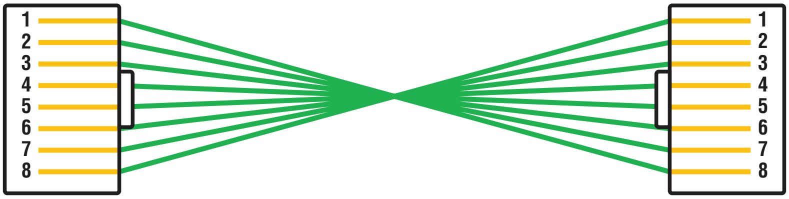
For a straight-through cable it's still 1 to 1, 2 to 2, and so on up to pin 8.

Rolled/Rollover Cable

Although *rolled cable* isn't used to connect any Ethernet connections together, you can use a rolled Ethernet cable to connect a host EIA-TIA 232 interface to a router console serial communication (COM) port.

If you have a Cisco router or switch, you would use this cable to connect your PC, Mac, or a device like an iPad to the Cisco hardware. Eight wires are used in this cable to connect serial devices, although not all eight are used to send information, just as in Ethernet networking. Figure 3.25 shows the eight wires used in a rolled cable.

FIGURE 3.25 Rolled Ethernet cable



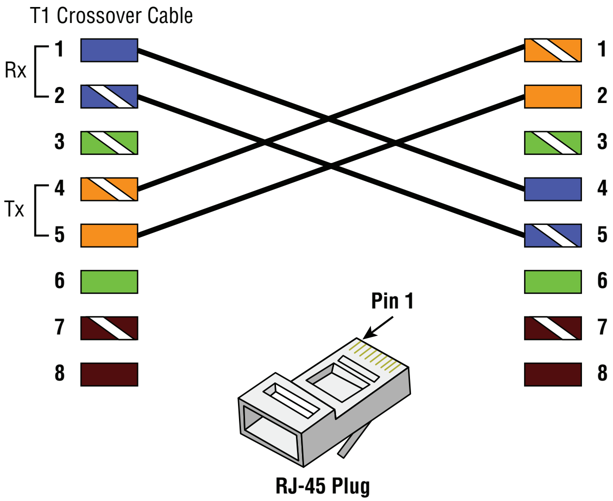
These are probably the easiest cables to make because you just cut the end off on one side of a straight-through cable, turn it over, and put it back on—with a new connector, of course!

T1 Crossover Cable

In Chapter 16 you'll be introduced to a device called the CSU/DSU. This device may be your connection to the Internet for the enterprise. The type of cable you use to connect to this device from your router depends on the interface types that are available on the router.

The router may connect with several types of serial cables if a T1 connection is not built into it. If a T1 connection is built into the router, you will use an Ethernet cable. Figure 3.26 shows a T1 crossover cable connected to a RJ-45 connector.

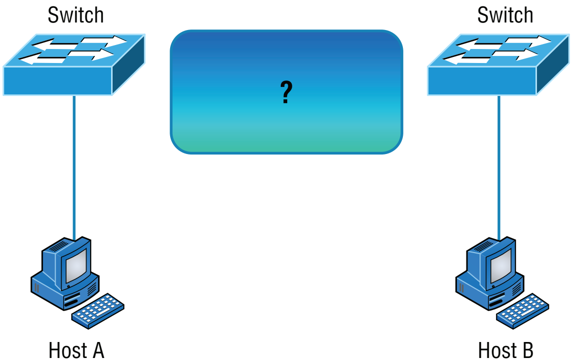
FIGURE 3.26 A T1 crossover cable



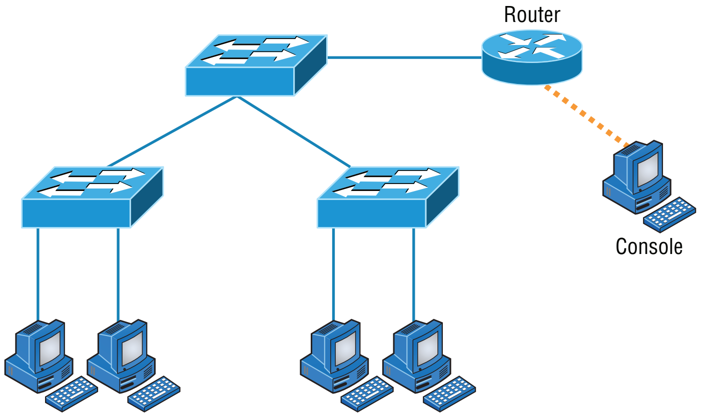
In rare instances you may need to run a cable between two CSU/DSUs. In that case you would need a T1 crossover cable. A T1 cable uses pairs 1 and 2, so to connect two T1 CSU/DSU devices back-to-back requires a crossover cable that swaps these pairs. Specifically, pins 1, 2, 4, and 5 are connected to 4, 5, 1, and 2, respectively.

Test Your Cable Understanding

You've taken a look at the various RJ-45 UTP cables. With that in mind, what cable is used between the switches in the following image?



For host A to ping host B, you need a crossover cable to connect the two switches together. But what types of cables are used in the network shown in the following image?



In the second example, there are a variety of cables in use. For the connection between the switches, we'd clearly use a crossover cable like the one you saw in the earlier example. The trouble is, here we have a console connection that uses a rolled cable. Plus, the connection from the router to the switch is a straight-through cable, which is also what's running between the hosts to the switches.

Installing Wiring Distributions

By now, you're probably getting the idea that there are a lot more components in the average computer networks than meets the eye, right? If this isn't exactly a news bulletin to you, then you either already are, or have been, involved in the initial installation of a network. If the latter describes you, you probably will be, or already are, involved in the purchase and installation of the components that will connect the computers throughout your organization's building. And it may also be up to you to verify that all of the network components have been installed properly and tested. So, let's go over each of these components and the process of verifying their proper installation.

MDF/IDF

The main distribution frame (MDF) is a wiring point that's generally used as a reference point for telephone lines. It's also considered the WAN termination point. It's installed in the building as part of the prewiring, and the internal lines are connected to it. After that, all that's left is to connect the external (telephone company) lines to the other side to complete the circuit. Often, another wire frame called an intermediate distribution frame (IDF) is located in an equipment or telecommunications room. It's connected to the MDF and is used to provide greater flexibility for the distribution of all the communications lines to the building. It's typically a sturdy metal rack designed to hold the bulk of cables coming from all over the building!

25 Pair

A *25-pair cable* consists of 25 individual pairs of wires all inside one common insulating jacket. It's not generally used for data cabling, just for telephone cabling, and especially for backbone and cross-connect cables because it reduces the cable clutter significantly. This type of cable is often referred to as a *feeder cable* because it supplies signal to many connected pairs.

66 Block

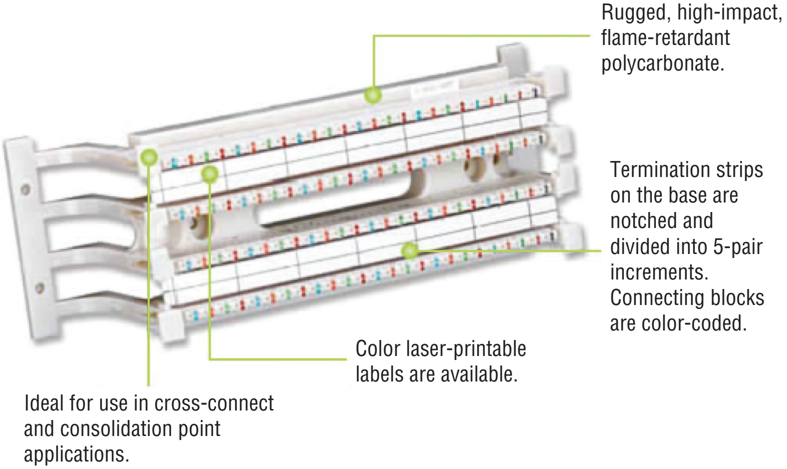
If you know what a *66 block* is, either you're really old or you work in an old building since they came out in 1962 and can really only be used for old analog telephone connections. This uses the 25-pair cable I just mentioned and is a standard termination block containing 50 rows, which created an industry standard for easy termination of voice cabling.

110 Block

A newer type of wiring distribution point called a *110 block* has replaced most telephone wire installations and is also used for computer networking. On one side, wires are punched down; the other side has RJ-11 (for phone) or RJ-45 (for network) connections.

You'll find 110 blocks in sizes from 25 to more than 500 wire pairs, and some are capable of carrying 1 Gpbs connections when used with Category 6 cables. The hitch is that using Cat 6 with the 110 block is really difficult because of the size of the Cat 6 wiring. Figure 3.27 shows a 110 block and describes each section used in the 110 block.

FIGURE 3.27 A 110 block


Rugged, high-impact, flame-retardant polycarbonate.
Termination strips on the base are notched and divided into 5-pair increments. Connecting blocks are color-coded.
Color laser-printable labels are available.
Ideal for use in cross-connect and consolidation point applications.

Demarc/Demarc Extension

The *demarc* (short for demarcation) is the last point of responsibility for the service provider. It's often at the MDF in your building connection, especially if your building is large, but it's usually just an RJ-45 jack that your channel service unit/data service unit (CSU/DSU) connects from your router to wide area network (WAN) connections. I'll thoroughly cover CSU/DSUs in Chapter 16, "Wide Area Networks."

When troubleshooting, network admins often test for connectivity on both sides of the demarc to determine if the problem is internal or external. The length of copper or fiber that begins after the demarc but still doesn't reach all the way up to your office is referred to as a *demarc extension*.

Smart Jack

A *smart jack*, also called a network interface device (NID) or network interface unit (NIU), is owned by the PSTN and is a special network interface that's often used between the service provider's network and the internal network. You can't physically test to an actual demarc because it's just an RJ-45 jack, but the service provider may install an NID that has power and can be looped for testing purposes.

The smart-jack device may also provide for code and protocol conversion, making the signal from the service provider usable by the devices on the internal network like the CSU/DSU.

Real World Scenario

Above and Beyond the Network+!

If you have a Cisco router that is having a problem—such as a serial WAN connection issue—and you're using a serial port on your router to connect to a port on a CSU/DSU, type this at the enabled Cisco router console or Telnet port:

```
config t
int s0/0
loopback
```

At this point, your interface will come up and look like it is working. That is, of course, if your connection from the router to the CSU/DSU is working properly. If not, you have a local problem.

Summary

I know getting through this chapter probably wasn't the most fun you've had recently. But understanding all those types of wires and cabling, along with their unique capacities, their associated standards, and the right connectors to use with them plus where to place them, is integral to having a solid, foundational understanding of the things that make a great network run quickly and reliably.

It's critical for you to grasp the basics of networking. Having the facts about how a good network is designed and implemented and what goes into that process will make you an effective and efficient technician—and maybe, some day, a highly paid system administrator.

Exam Essentials

Understand the various types of cables used in today's networks. Coaxial (other than for cable modems) is rarely used, but twisted-pair and fiber-optic cable are very common in today's networks.

Understand the various types of ends that are used on each type of cable. Coax uses BNC; twisted-pair uses RJ-11 for voice and RJ-45 for data; and fiber uses various ends, depending on its use.

Describe the various types of media converters that are available. These include single-mode fiber to Ethernet, multimode fiber to Ethernet, fiber to coaxial, and single-mode to multimode fiber.

Understand what a T568A to T568A cable is. A T568A to T568A cable is also known as an Ethernet straight-through cable and is used to connect hosts to switches, for example.

Understand what a T568A to T568B cable is. A T568A to T568B cable is also known as an Ethernet crossover cable and is used to connect switches to switches, for example.

Define the function of a T1 crossover cable. In rare instances, you may have the need to run a cable between two CSU/DSUs. In that case, you will need a T1 crossover cable. A T1 cable uses pairs 1 and 2, so to connect two T1 CSU/DSU devices back-to-back requires a crossover cable that swaps these pairs. Specifically, pins 1, 2, 4, and 5 are connected to 4, 5, 1, and 2, respectively.

Written Lab

You can find the answers to the written labs in Appendix A.

1. Which UTP wiring uses four twisted wire pairs (eight wires) and is rated for 250 MHz?
2. The point at which the operational control or ownership changes from your company to a service provider is referred to as ______________________ .
3. Which type of cable will you use to connect two switches to each other?
4. Which RG rating of coax is used for cable modems?

5. Which UTP uses four twisted wire pairs (eight wires), is rated for 100 MHz, and is capable of handling the disturbance on each pair caused by transmitting on all four pairs at the same time?

6. You want to connect a host to a switch port. What type of Ethernet cable will you use?

7. In what instance would you use T1 crossover cable?

8. T568A uses which pins to make a connection?

9. A crossover uses which pins to make a connection?

10. What are two advantages of fiber-optic cabling?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Why would a network administrator use plenum-rated cable during an installation? (Choose two.)
   A. Low combustion temperature
   B. High combustion temperature
   C. Reduces toxic gas released during a fire
   D. Is not susceptible to any interference

2. Which of the following Ethernet unshielded twisted-pair cabling types is/are commonly used?
   A. 10BaseT
   B. 100BaseTX
   C. 1000BaseTX
   D. All of the above

3. In which of the following categories is UTP cable not rated?
   A. Category 2
   B. Category 3
   C. Category 5e
   D. Category 9

4. What type of connector does UTP cable typically use?
   A. BNC
   B. ST
   C. RJ-45
   D. SC

5. Which of the following provides the longest cable run distance?
   A. Single-mode fiber
   B. Multimode fiber
   C. Category 3 UTP
   D. Coax

6. You need to crimp on a connector using an RJ-45 connector. Which pin-out configuration would you use to connect a host into a switch?
   A. UTP
   B. Straight-through
   C. Crossover
   D. Rolled

7. Why is fiber-optic cable immune to electromagnetic interference (EMI) and radio frequency interference (RFI)?

   A. Because it transmits analog signals using electricity

   B. Because it transmits analog signals using light impulses

   C. Because it transmits digital signals using light impulses

   D. Because it transmits digital signals using electricity

8. What type of cable transmits lights from end to end?

   A. Coax

   B. Fiber-optic

   C. UTP

   D. Category 2

9. What is the main difference between single-mode fiber (SMF) and multimode fiber (MMF)?

   A. Electrical signals

   B. Number of light rays

   C. Number of digital signals

   D. That signal-mode can be run a shorter distance

10. What type of cable should be used if you need to make a cable run longer than 100 meters?

    A. Category 5e

    B. Category 6

    C. Fiber-optic

    D. Coaxial

11. Which of the following are fiber-optic connectors? (Select three.)

    A. BNC

    B. ST

    C. RJ-11

    D. SC

    E. LC

    F. RJ-45

12. You need to connect two devices on a network and they need to send voice traffic. Which of the following cables will you use?

    A. Cat 3

    B. Cat 5

C. Cat 8

D. Rolled

13. How many hosts on a half-duplex segment can talk at one time?

A. Zero

B. One

C. Two

D. Unlimited

14. On which type of cable does EMI have the least effect?

A. Coax

B. Fiber-optic

C. UTP

D. STP

15. How many devices can be connected to a full-duplex segment?

A. Zero

B. One

C. Two

D. Four

16. How many wires are used in a 100BaseTX UTP transmission?

A. Two

B. Four

C. Six

D. Eight

17. A crossover cable is used to connect all of the following except ______________ .

A. Switch to switch

B. Host to host

C. Hub to switch

D. Host to switch

18. How is a T1 crossover cable wired?

A. Pins 1, 2, 4, and 5 are connected to 4, 5, 1, and 2.

B. Pins 2, 3, 4, and 5 are connected to 4, 5, 1, and 2.

C. Pins 1, 2, 4, and 5 are connected to 3, 4, 5, and 6.

D. Pins 4, 5, 6, and 7 are connected to 4, 5, 1, and 2.

19. The purpose of the demarcation point is to separate the customer from whom?

A. The branch office

B. Headquarters

C. The data center

D. The service provider

20. You need to make a T568B cable for a Fast Ethernet link. How many pairs will you use?

A. One

B. Two

C. Three

D. Four

Chapter 4

The Current Ethernet Specifications

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Properties of network traffic
  - Broadcast domains
  - CSMA/CD
  - Collision domains
  - MTU
  - ARP Table

✓ **2.1 Given a scenario, deploy the appropriate cabling solution**

- Ethernet deployment standards
  - 100BaseT
  - 1000BaseT
  - 1000BaseLX
  - 1000BaseSX
  - 10GBaseT

Before we dive into the complex worlds of networking devices, the TCP/IP and DoD models, IP addressing, subnetting, and routing in the upcoming chapters, you have to understand the big picture of LANs and learn the answer to these key questions: How is Ethernet used in today's networks? What are Media Access Control (MAC) addresses, and how are these identifiers utilized in networking?

This chapter will answer those questions and more. I'll not only discuss the basics of Ethernet and the way MAC addresses are used on an Ethernet LAN, I'll also cover the protocols used with Ethernet at the Data Link layer. You'll also learn about the various Ethernet specifications.

So now, let's get started with the fundamentals of connecting two hosts together.

NOTE

To find Todd Lammle CompTIA videos and questions, please see `www.lammle.com/network+`.

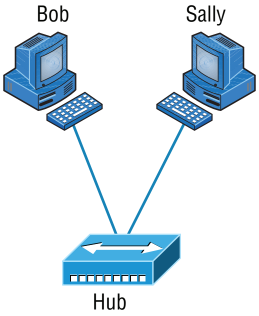
Network Basics

Networks and networking have grown exponentially over the last 20 years—understandably so. They've had to evolve at light speed just to keep up with huge increases in basic mission-critical user needs ranging from sharing data and printers to more advanced demands like videoconferencing. Unless everyone who needs to share network resources is located in the same office area (an increasingly uncommon situation), the challenge is to connect the sometimes large number of relevant networks together so all users can share the networks' wealth.

Let's take a look at how communication happens on a basic local area network (LAN), which I started to discuss in Chapter 1, "Introduction to Networks." Starting with Figure 4.1, you get a picture of a basic LAN network that's connected together using an Ethernet connection to a hub. This network is actually one collision domain and one broadcast domain, but don't stress if you have no idea what this means—I'm going to talk about both collision and broadcast domains in depth in Chapter 5, "Networking Devices."

Okay, about Figure 4.1; how would you say the PC named Bob communicates with the PC named Sally? Well, they're both on the same LAN connected with a multiport repeater (a hub). So does Bob just send out a data message, "Hey Sally, you there?" or does Bob use Sally's IP address and put things more like, "Hey 192.168.0.3, are you there?" I hope you picked the IP address option, but even if you did, the news is still bad—both answers are wrong! Why? Because Bob is actually going to use Sally's MAC address (known as a *hardware address*), which is burned right into the network card of Sally's PC, to get hold of her.

FIGURE 4.1 The basic network



This is all good, but how does Bob get Sally's MAC address when Bob knows only Sally's name and doesn't even have her IP address? Bob is going to start by using name resolution (hostname-to-IP-address resolution), something that's usually accomplished using Domain Name Service (DNS). And note that if these two hosts are on the same LAN, Bob can just broadcast to Sally asking her for the information (no DNS needed)—welcome to Microsoft Windows!

Here's the output from a network analyzer depicting a simple name-resolution process from Bob to Sally:

```
Time        Source       Destination    Protocol    Info
53.892794   192.168.0.2  192.168.0.255  NBNS        Name query NB SALLY<00>
```

As I already mentioned, because the two hosts are on a local LAN, Windows (Bob) will broadcast to resolve the name Sally (the destination 192.168.0.255 is a broadcast address). Let's take a look at the rest of the information:

```
EthernetII,Src:192.168.0.2(00:14:22:be:18:3b),Dst:Broadcast(ff:ff:ff:ff:ff:ff)
```

This output shows that Bob knows his own MAC address and source IP address, but not Sally's IP address or MAC address. So, Bob sent a Data Link layer broadcast address of all *F*s and an IP LAN broadcast to 192.168.0.255. Again, no worries—you're going to learn all about broadcasts in Chapter 6, "Introduction to the Internet Protocol."

After the name is resolved, the next thing Bob has to do is broadcast on the LAN to get Sally's MAC address so he can communicate to her PC:

```
Time       Source       Destination Protocol Info
5.153054   192.168.0.2  Broadcast   ARP Who has 192.168.0.3? Tell 192.168.0.2
```

Next, check out Sally's response:

```
Time         Source      Destination  Protocol  Info
5.153403     192.168.0.3 192.168.0.2  ARP  192.168.0.3 is 00:0b:db:99:d3:5e
5.53.89317   192.168.0.3 192.168.0.2  NBNS Name query response NB 192.168.0.3
```

Okay, sweet—Bob now has both Sally's IP address and her MAC address (00:0b:db:99:de:5e). These are both listed as the source address at this point because this information was sent from Sally back to Bob. So, *finally*, Bob has all the goods he needs to communicate with Sally. And just so you know, I'm also going to tell you all about Address Resolution Protocol (ARP) and show you exactly how Sally's IP address was resolved to a MAC address a little later, in Chapter 6.

Importantly, I want you to understand that Sally still had to go through the same resolution processes to communicate back to Bob—sounds crazy, huh? Consider this welcome to IPv4 and basic networking with Windows—and we haven't even added a router yet!

Ethernet Basics

Ethernet is a contention media-access method that allows all hosts on a network to share the same bandwidth of a link. Ethernet is popular because it's readily scalable, meaning that it's comparatively easy to integrate new technologies, such as Fast Ethernet and Gigabit Ethernet, into an existing network infrastructure. It's also relatively simple to implement in the first place, and with it, troubleshooting is reasonably straightforward.

Ethernet uses both Data Link and Physical layer specifications, and this part of the chapter will give you both the Data Link layer and Physical layer information you need to effectively implement, troubleshoot, and maintain an Ethernet network.

In the following sections, I'll also cover some basic terms used in networking with Ethernet technologies. Let's start with collision domains.

Collision Domain

The term *collision domain* is an Ethernet term that refers to a particular network scenario wherein one device sends a packet out on a network segment and thereby forces every other device on that same physical network segment to pay attention to it. This is bad because if two devices on one physical segment transmit at the same time, a *collision event*—a situation where each device's digital signals interfere with another on the wire—occurs and forces the devices to retransmit later. Collisions have a dramatically negative effect on network performance, so they're definitely something we want to avoid!

The situation I just described is typically found in a hub environment where each host segment connects to a hub that represents only one collision domain and one broadcast domain. This begs the question, What's a broadcast domain?

Broadcast Domain

Here's that answer: A *broadcast domain* refers to the set of all devices on a network segment that hear all the broadcasts sent on that segment.

Even though a broadcast domain is typically a boundary delimited by physical media like switches and repeaters, it can also reference a logical division of a network segment where all hosts can reach each other via a Data Link layer (hardware address) broadcast.

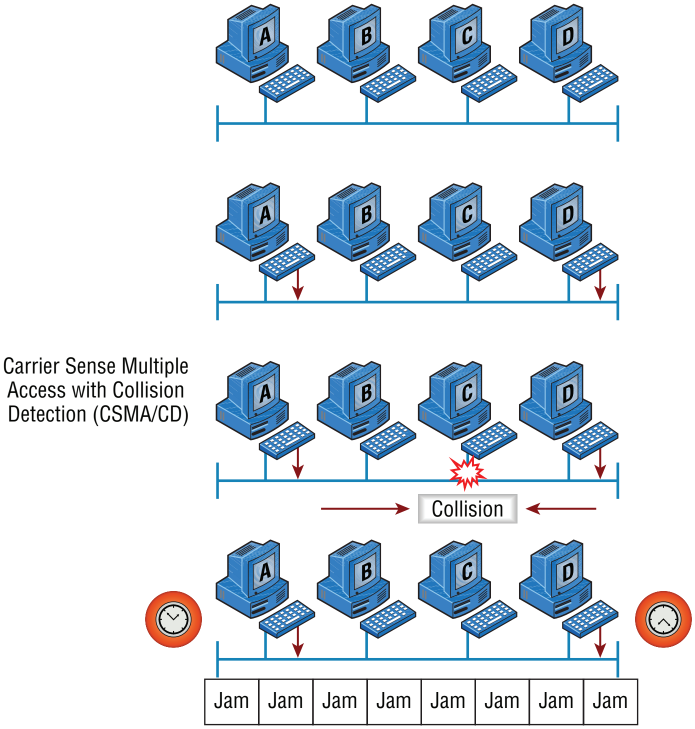
That's the basic story, but rest assured, I'll be delving deeper into the skinny on collision and broadcast domains a bit later, in Chapter 5.

CSMA/CD

Ethernet networking uses *Carrier Sense Multiple Access with Collision Detection (CSMA/CD)*, a media access control method that helps devices share the bandwidth evenly without having two devices transmit at the same time on the network medium. CSMA/CD was created to overcome the problem of those collisions that occur when packets are transmitted simultaneously from different hosts. And trust me—good collision management is crucial because when a host transmits in a CSMA/CD network, all the other hosts on the network receive and examine that transmission. Only bridges, switches, and routers, but not hubs, can effectively prevent a transmission from propagating throughout the entire network.

So, how does the CSMA/CD protocol work? Let's start by taking a look at Figure 4.2, where a collision has occurred in the network.

FIGURE 4.2 CSMA/CD


A
B
C
D
Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
Collision
Jam Jam Jam Jam Jam Jam Jam Jam

When a host wants to transmit over the network, it first checks for the presence of a digital signal on the wire. If all is clear, meaning that no other host is transmitting, the host will then proceed with its transmission. But it doesn't stop there. The transmitting host constantly monitors the wire to make sure no other hosts begin transmitting. If the host detects another signal on the wire, it sends out an extended jam signal that causes all hosts on the segment to stop sending data (think busy signal). The hosts respond to that jam signal by waiting a while before attempting to transmit again. Backoff algorithms, represented by the clocks counting down on either side of the jammed devices, determine when the colliding stations can retransmit. If collisions keep occurring after 15 tries, the hosts attempting to transmit will then time out. Pretty clean!

When a collision occurs on an Ethernet LAN, the following things happen:

- A jam signal informs all devices that a collision occurred.
- The collision invokes a random backoff algorithm.
- Each device on the Ethernet segment stops transmitting for a short time until the timers expire.
- All hosts have equal priority to transmit after the timers have expired.

And following are the effects of having a CSMA/CD network that has sustained heavy collisions:

- Delay
- Low throughput
- Congestion

NOTE

Backoff on an 802.3 network is the retransmission delay that's enforced when a collision occurs. When a collision occurs, a host will resume transmission after the forced time delay has expired. After this backoff delay period has expired, all stations have equal priority to transmit data.

Broadband/Baseband

We have two ways to send analog and digital signals down a wire: broadband and baseband.

We hear the term *broadband* a lot these days because that is pretty much what everyone uses at home. It allows us to have both our analog voice and digital data carried on the same network cable or physical medium. Broadband allows us to send multiple frequencies of different signals down the same wire at the same time (called frequency-division multiplexing) and to send both analog and digital signals.

Baseband is what all LANs use. This is where all the bandwidth of the physical media is used by only one signal. For example, Ethernet uses only one digital signal at a time, and it requires all the available bandwidth. If multiple signals are sent from different hosts at the same time, we get collisions; same with wireless, except that uses only analog signaling.

Bit Rates vs. Baud Rate

Bit rate is a measure of the number of data bits (0s and 1s) transmitted in one second in either a digital or analog signal. A figure of 56,000 bits per second (bps) means 56,000 0s or 1s can be transmitted in one second, which we simply refer to as bps.

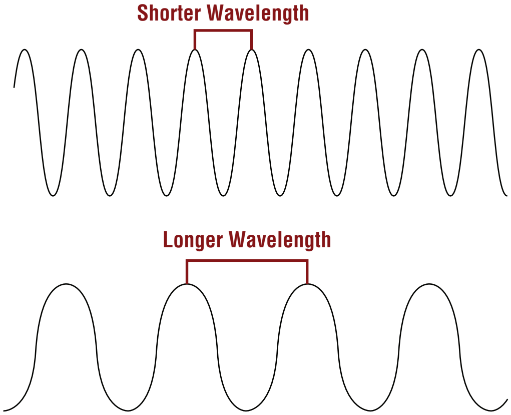
In the 1970s and 1980s, we used the term *baud rate* a lot, but that was replaced by *bps* because it was more accurate. *Baud* was a term of measurement named after a French engineer, Jean-Maurice-Émile Baudot, because he used it to measure the speed of telegraph transmissions.

One baud is one electronic state change per second—for example, from 0.2 volts to 3 volts or from binary 0 to 1. However, since a single state change can involve more than a single bit of data, the bps unit of measurement has replaced it as a more accurate definition of how much data you're transmitting or receiving.

Wavelength

Has anyone ever told you that they were on the same wavelength as you? That means they thought you were basically thinking the same way they were. The same is true of the inverse—if they say, "You're not on the same wavelength." With electromagnetic radiation, radio waves, light waves, or even infrared (heat) waves make characteristic patterns as they travel through space. Some patterns can be the same, and some can be different, as shown in Figure 4.3.

FIGURE 4.3 Shorter and longer wavelengths



Each wave pattern has a certain shape and length. The distance between peaks (high points) is called wavelength. If two wave patterns are different, we would say they're not on the same wavelength and that is the way we tell different kinds of electromagnetic energy apart. We can use this to our advantage in electronics by sending traffic on different wavelengths at the same time.

In the following sections, I'm going to cover Ethernet in detail at both the Data Link layer (Layer 2) and the Physical layer (Layer 1).

Half- and Full-Duplex Ethernet

Just so you know, half-duplex Ethernet is defined in the original 802.3 Ethernet specification. Basically, when you run half duplex, you're using only one wire pair with a digital signal either transmitting or receiving. This really isn't all that different from full duplex because you can both transmit and receive—you just don't get to do that at the same time running half duplex as you can if you're running full duplex.

Here's how it works: If a host hears a digital signal, it uses the CSMA/CD protocol to help prevent collisions and to permit retransmitting if a collision does occur. Half-duplex Ethernet—typically 10BaseT—is only about 30 to 40 percent efficient because a large 10BaseT network will usually provide only 3 Mbps to 4 Mbps at most. Although it's true that 100 Mbps Ethernet can and sometimes does run half duplex, it's just not very common to find that happening anymore.

In contrast, full-duplex Ethernet uses two pairs of wires at the same time instead of one measly wire pair like half duplex employs. Plus, full duplex uses a point-to-point connection between the transmitter of the sending device and the receiver of the receiving device (in most cases the switch). This means that with full-duplex data transfer, you not only get faster data-transfer speeds, but you also get collision prevention too—sweet!

You don't need to worry about collisions because now it's like a freeway with multiple lanes instead of the single-lane road provided by half duplex. Full-duplex Ethernet is supposed to offer 100 percent efficiency in both directions—for example, you can get 20 Mbps with a 10 Mbps Ethernet running full duplex or 200 Mbps for Fast Ethernet. But this rate is something known as an *aggregate rate*, which translates as "you're supposed to get" 100 percent efficiency. No guarantees, in networking as in life.

Full-duplex Ethernet can be used in many situations; here are some examples:

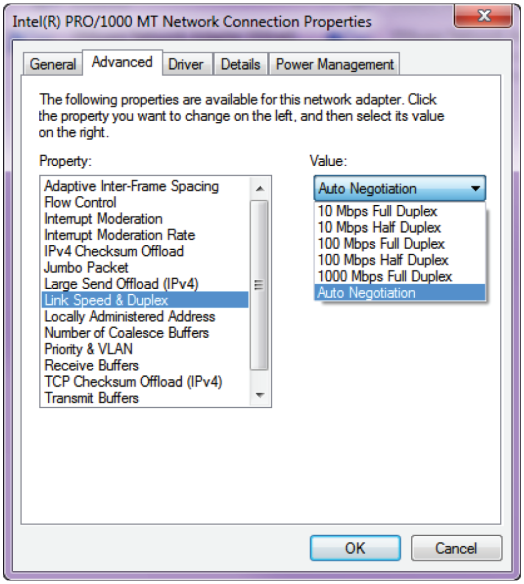
- With a connection from a switch to a host
- With a connection from a switch to a switch
- With a connection from a host to a host using a crossover cable

NOTE

You can run full duplex with just about any device except a hub.

You may be wondering: If it's capable of all that speed, why wouldn't it deliver? Well, when a full-duplex Ethernet port is powered on, it first connects to the remote end and then negotiates with the other end of the Fast Ethernet link. This is called an *auto-detect mechanism*. This mechanism first decides on the exchange capability, which means it checks to see if it can run at 10, 100, or even 1000 Mbps. It then checks to see if it can run full duplex, and if it can't, it will run half duplex instead.

Hosts usually auto-detect both the Mbps and the duplex type available (the default setting), but you can manually set both the speed and duplex type on the network interface card (NIC), as shown here.



Intel(R) PRO/1000 MT Network Connection Properties

The following properties are available for this network adapter. Click the property you want to change on the left, and then select its value on the right.

Property: Link Speed & Duplex

Value: Auto Negotiation

Today, it's pretty rare to go into a NIC configuration on a host and change these settings, but this example demonstrates that you can do that if you want.

Remember that half-duplex Ethernet shares a collision domain and provides a lower effective throughput than full-duplex Ethernet, which typically has a private collision domain and a higher effective throughput.

Lastly, remember these important points:

- There are no collisions in full-duplex mode.
- A dedicated switch port is required for each full-duplex host.
- The host network card and the switch port must be capable of operating in full-duplex mode.

Now let's take a look at how Ethernet works at the Data Link layer.

Ethernet at the Data Link Layer

Ethernet at the Data Link layer is responsible for Ethernet addressing, commonly referred to as *hardware addressing* or *MAC addressing*. Ethernet is also responsible for framing packets received from the Network layer and preparing them for transmission on the local network through the Ethernet contention media-access method known as CSMA/CD.

Ethernet MAC addresses are made up of hexadecimal addresses. So before I discuss MAC addresses, let's start by talking about binary, decimal, and hexadecimal addresses and how to convert one to another.

Binary to Decimal and Hexadecimal Conversion

Understanding the differences between binary, decimal, and hexadecimal numbers and how to convert one format into the other is very important before we move on to discussing the TCP/IP protocol stack and IP addressing in Chapters 6 and 7.

So let's get started with binary numbering. It's pretty simple, really. Each digit used is limited to being either a 1 (one) or a 0 (zero), and each digit is called 1 bit (short for *bi*nary digi*t*). Typically, you count either 4 or 8 bits together, with these being referred to as a *nibble* and a *byte*, respectively.

What's interesting about binary numbering is the value represented in a decimal format—the typical decimal format being the base-10 number scheme that we've all used since kindergarten. The binary numbers are placed in a value spot, starting at the right and moving left, with each spot having double the value of the previous spot.

Table 4.1 shows the decimal values of each bit location in a nibble and a byte. Remember, a nibble is four bits and a byte is eight bits. In network addressing, we often refer to a byte as an *octet*. Mathematically, octal addressing actually refers to base 8, which is completely different from the base 10 we are familiar with. So, technically speaking we are using the term incorrectly, but it's the common usage anyway. When we get to the subnetting chapter, you'll see that I'll use *byte* and *octet* interchangeably when discussing IP addressing.

TABLE 4.1 Binary values

Nibble Values	Byte Values
8 4 2 1	128 64 32 16 8 4 2 1

What all this means is that if a one digit (1) is placed in a value spot, then the nibble or byte takes on that decimal value and adds it to any other value spots that have a 1. And if a zero (0) is placed in a bit spot, you don't count that value.

Let me clarify things for you—if we have a 1 placed in each spot of our nibble, we then add up 8 + 4 + 2 + 1 to give us a maximum value of 15. Another example for our nibble values is 1010, which means that the 8 bit and the 2 bit are turned on and equal a decimal value of 10. If we have a nibble binary value of 0110, then our decimal value is 6 because the 4 and 2 bits are turned on.

But the byte values can add up to a value that's significantly higher than 15. This is how—if we count every bit as a one (1), then the byte binary value looks like this (remember, 8 bits equal a byte):

11111111

We then count up every bit spot because each is turned on. It looks like this, which demonstrates the maximum value of a byte:

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255

A binary number can equal plenty of other decimal values. Let's work through a few examples:

10010110

Which bits are on? The 128, 16, 4, and 2 bits are on, so we'll just add them up: 128 + 16 + 4 + 2 = 150.

01101100

Which bits are on? The 64, 32, 8, and 4 bits are on, so we add them up: 64 + 32 + 8 + 4 = 108.

11101000

Which bits are on? The 128, 64, 32, and 8 bits are on, so we add the values: 128 + 64 + 32 + 8 = 232.

You should memorize Table 4.2 before braving the IP sections in Chapter 6 and Chapter 7 since this lists all available subnet masks.

TABLE 4.2 Binary-to-decimal memorization chart

Binary Value	Decimal Value
10000000	128
11000000	192
11100000	224
11110000	240
11111000	248
11111100	252
11111110	254
11111111	255

Hexadecimal addressing is completely different than binary or decimal—it's converted by reading nibbles, not bytes. By using a nibble, we can convert these bits to hex pretty simply. First, understand that the hexadecimal addressing scheme uses only the numbers 0 through 9. And because the numbers 10, 11, 12, and so on can't be used (because they are two-digit numbers), the letters *A*, *B*, *C*, *D*, *E*, and *F* are used to represent 10, 11, 12, 13, 14, and 15, respectively.

Table 4.3 shows both the binary value and the decimal value for each hexadecimal digit.

TABLE 4.3 Hex-to-binary-to-decimal chart

Hexadecimal Value	Binary Value	Decimal Value
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

Did you notice that the first 10 hexadecimal digits (0–9) are the same values as the decimal values? If not, look again. This handy fact makes those values super easy to convert.

So suppose you have something like this: 0x6A. (Some manufacturers put *0x* in front of characters so you know that they're a hex value, while others just give you an *h*. It doesn't have any other special meaning.) What are the binary and decimal values? To correctly answer that question, all you have to remember is that each hex character is one nibble and two hex characters together make a byte. To figure out the binary value, first put the hex characters into two nibbles and then put them together into a byte. 6 = 0110 and A (which is 10 in decimal) = 1010, so the complete byte is 01101010.

To convert from binary to hex, just take the byte and break it into nibbles.

Here's how you do that: Say you have the binary number 01010101. First, break it into nibbles—0101 and 0101—with the value of each nibble being 5 because the 1 and 4 bits are on. This makes the hex answer 0x55. And in decimal format, the binary number is 01010101, which converts to 64 + 16 + 4 + 1 = 85.

Okay, now try another binary number:

11001100

Our answer is 1100 = 12 and 1100 = 12 (therefore, it's converted to CC in hex). The decimal conversion answer is 128 + 64 + 8 + 4 = 204.

One more example, and then we need to get working on the Physical layer. Suppose we're given the following binary number:

10110101

The hex answer is 0xB5 because 1011 converts to B and 0101 converts to 5 in hex value. The decimal equivalent is 128 + 32 + 16 + 4 + 1 = 181.

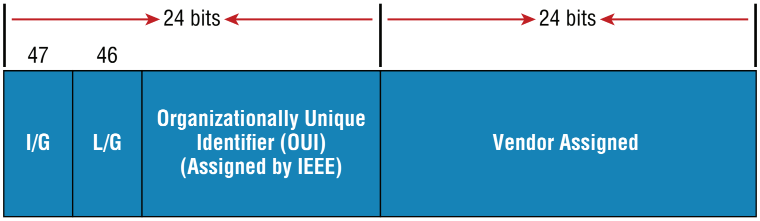
NOTE See the written lab at the end of this chapter for more practice with binary/hex/decimal conversion.

Ethernet Addressing

Now that you've got binary-to-decimal and hexadecimal address conversion down, we can get into how Ethernet addressing works. It uses the *Media Access Control (MAC) address* burned into each and every Ethernet NIC. The MAC, or hardware, address is a 48-bit (6-byte) address written in a hexadecimal format.

Figure 4.4 shows the 48-bit MAC addresses and how the bits are divided.

FIGURE 4.4 Ethernet addressing using MAC addresses



The *organizationally unique identifier (OUI)* is assigned by the Institute of Electrical and Electronics Engineers (IEEE) to an organization. It's composed of 24 bits, or 3 bytes. The organization, in turn, assigns a globally administered address (24 bits, or 3 bytes) that is unique to each and every adapter it manufactures. Look closely at the figure. The Individual/Group (I/G) address bit is used to signify if the destination MAC address is a unicast or a multicast/broadcast Layer 2 address. If the bit is set to 0, then it is an Individual MAC address and is a unicast address. If the bit is set to 1, it is a Group address and is a multicast/broadcast address.

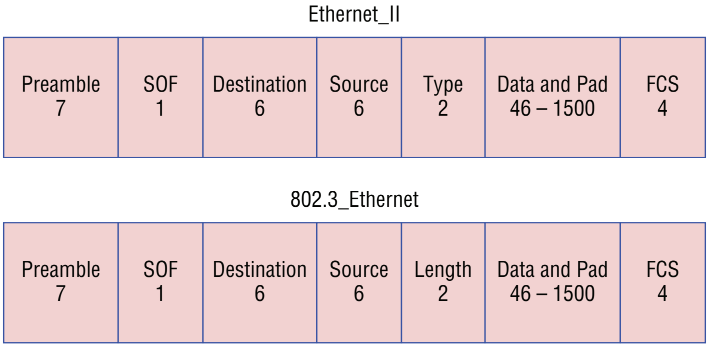
The next bit is the Local/Global bit (L/G). This bit is used to tell if the MAC address is the burned-in-address (BIA) or a MAC address that has been changed locally. You'll see this happen when we get to IPv6 addressing. The low-order 24 bits of an Ethernet address represent a locally administered or manufacturer-assigned code. This portion commonly starts with 24 0s for the first card made and continues in order until there are 24 1s for the last (16,777,216th) card made. You'll find that many manufacturers use these same six hex digits as the last six characters of their serial number on the same card.

Ethernet Frames

The Data Link layer is responsible for combining bits into bytes and bytes into frames. Frames are used at the Data Link layer to encapsulate packets handed down from the Network layer for transmission on a type of physical media access.

The function of Ethernet stations is to pass data frames between each other using a group of bits known as a MAC frame format. This provides error detection from a cyclic redundancy check (CRC). But remember—this is error detection, not error correction. The 802.3 frames and Ethernet frame are shown in Figure 4.5.

FIGURE 4.5 802.3 and Ethernet frame formats in bytes



Ethernet_II

Preamble	SOF	Destination	Source	Type	Data and Pad	FCS
7	1	6	6	2	46 – 1500	4

802.3_Ethernet

Preamble	SOF	Destination	Source	Length	Data and Pad	FCS
7	1	6	6	2	46 – 1500	4

NOTE Encapsulating a frame within a different type of frame is called *tunneling*.

NOTE The following information regarding frame headings and the various types of Ethernet frames are beyond the scope of the CompTIA Network+ objectives. Throughout the rest of this book, I'll show you screen shots from a network analyzer. It's always good to understand what you are looking at, so I put this information in to help you understand a frame structure.

Following are the details of the different fields in the 802.3 and Ethernet frame types:

Preamble An alternating 1,0 pattern provides a clock at the start of each packet, which allows the receiving devices to lock the incoming bit stream.

Start of Frame Delimiter (SOF)/Synch The preamble is seven octets, and the start of a frame (SOF) is one octet (synch). The SOF is 10101011, where the last pair of 1s allows the receiver to come into the alternating 1,0 pattern somewhere in the middle and still synch up and detect the beginning of the data.

Destination Address (DA) This transmits a 48-bit value using the least significant bit (LSB) first. The DA is used by receiving stations to determine whether an incoming packet is addressed to a particular host and can be an individual address or a broadcast or multicast MAC address. Remember that a broadcast is all 1s (or *F*s in hex) and is sent to all devices, but a multicast is sent only to a similar subset of hosts on a network.

Source Address (SA) The SA is a 48-bit MAC address used to identify the transmitting device, and it uses the LSB first. Broadcast and multicast address formats are illegal within the SA field.

Length or Type 802.3 uses a Length field, but the Ethernet frame uses a Type field to identify the Network layer protocol. 802.3 by itself cannot identify the upper-layer routed protocol and must be used with a proprietary LAN protocol—Internetwork Packet Exchange (IPX), for example.

Data This is a packet sent down to the Data Link layer from the Network layer. The size can vary from 64 to 1,500 bytes.

Frame Check Sequence (FCS) FCS is a field that is at the end of the frame and is used to store the CRC.

Okay—let's take a minute to look at some frames caught on our trusty network analyzer. You can see that the following frame has only three fields: Destination, Source, and Type, displayed as Protocol Type on this analyzer:

```
Destination:   00:60:f5:00:1f:27
Source:        00:60:f5:00:1f:2c
Protocol Type: 08-00 IP
```

This is an Ethernet_II frame. Notice that the Type field is IP, or 08-00 (mostly just referred to as 0x800) in hexadecimal.

The next frame has the same fields, so it must be an Ethernet_II frame too:

```
Destination:   ff:ff:ff:ff:ff:ff Ethernet Broadcast
Source:        02:07:01:22:de:a4
Protocol Type: 08-00 IP
```

Did you notice that this frame was a broadcast? You can tell because the destination hardware address is all 1s in binary, or all *F*s in hexadecimal.

Let's take a look at one more Ethernet_II frame. You can see that the Ethernet frame is the same Ethernet_II frame we use with the IPv4 routed protocol. The difference is that the Type field has 0x86dd when we are carrying IPv6 data, and when we have IPv4 data, we use 0x0800 in the Protocol field:

```
Destination: IPv6-Neighbor-Discovery_00:01:00:03 (33:33:00:01:00:03)
Source: Aopen_3e:7f:dd (00:01:80:3e:7f:dd)
Type: IPv6 (0x86dd)
```

This is the beauty of the Ethernet_II frame. Because of the Protocol field, we can run any Network layer routed protocol and it will carry the data because it can identify that particular Network layer protocol!

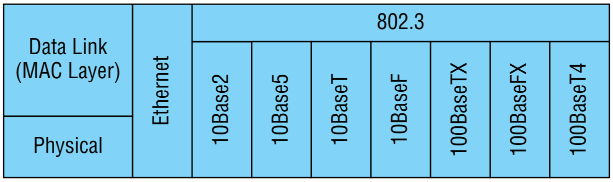
Ethernet at the Physical Layer

Ethernet was first implemented by a group called DIX (Digital, Intel, and Xerox). They created and implemented the first Ethernet LAN specification, which the IEEE used to create the IEEE 802.3 Committee. This was a 10 Mbps network that ran on coax, then on twisted-pair, and finally on fiber physical media.

The IEEE extended the 802.3 Committee to two new committees known as 802.3u (Fast Ethernet), 802.3ab (Gigabit Ethernet on Category 5+), and then finally to 802.3ae (10 Gbps over fiber and coax).

Figure 4.6 shows the IEEE 802.3 and original Ethernet Physical layer specifications.

FIGURE 4.6 Ethernet Physical layer specifications



When designing your LAN, it's really important to understand the different types of Ethernet media available to you. Sure, it would be great to run Gigabit Ethernet to each desktop and 10 Gbps between switches, as well as to servers. Although this is just starting to happen, justifying the cost of that network today for most companies would be a pretty hard sell. But if you mix and match the different types of Ethernet media methods currently available instead, you can come up with a cost-effective network solution that works great!

The Electronic Industries Association and the newer Telecommunications Industry Alliance (EIA/TIA) together form the standards body that creates the Physical layer specifications for Ethernet. The EIA/TIA specifies that Ethernet use a *registered jack (RJ) connector* on *unshielded twisted-pair (UTP)* cabling (RJ-45). However, the industry is calling this just an 8-pin modular connector.

Each Ethernet cable type that is specified by the EIA/TIA has something known as *inherent attenuation*, which is defined as the loss of signal strength as it travels the length of a cable and is measured in decibels (dB). The cabling used in corporate and home markets is measured in categories. A higher-quality cable will have a higher-rated category and lower attenuation. For example, Category 5 is better than Category 3 because Category 5 cables have more wire twists per foot and therefore less crosstalk. *Crosstalk* is the unwanted signal interference from adjacent pairs in the cable.

Here are the original IEEE 802.3 standards:

10Base2 This is also known as *Thinnet* and can support up to 30 workstations on a single segment. It uses 10 Mbps of baseband technology, coax up to 185 meters in length, and a physical and logical bus with Attachment Unit Interface (AUI) connectors. The 10 means 10 Mbps, and *Base* means baseband technology—a signaling method for communication on the network—and the 2 means almost 200 meters. 10Base2 Ethernet cards use BNC (British Naval Connector, Bayonet Neill-Concelman, or Bayonet Nut Connector) and T-connectors to connect to a network.

10Base5 Also known as *Thicknet*, 10Base5 uses a physical and logical bus with AUI connectors, 10 Mbps baseband technology, and coax up to 500 meters in length. You can go up to 2,500 meters with repeaters and 1,024 users for all segments.

10BaseT This is 10 Mbps using Category 3 UTP wiring. Unlike on 10Base2 and 10Base5 networks, each device must connect into a hub or switch, and you can have only one host per segment or wire. It uses an RJ-45 connector (8-pin modular connector) with a physical star topology and a logical bus.

Each of the 802.3 standards defines an AUI, which allows a one-bit-at-a-time transfer to the Physical layer from the Data Link media-access method. This allows the MAC address to remain constant but means the Physical layer can support both existing and new technologies. The original AUI interface was a 15-pin connector, which allowed a transceiver (transmitter/receiver) that provided a 15-pin-to-twisted-pair conversion.

There's an issue, though—the AUI interface can't support 100 Mbps Ethernet because of the high frequencies involved. So basically, 100BaseT needed a new interface, and the 802.3u specifications created one called the Media Independent Interface (MII) that provides 100 Mbps throughput. The MII uses a nibble, which you of course remember is defined as 4 bits. Gigabit Ethernet uses a Gigabit Media Independent Interface (GMII) and transmits 8 bits at a time.

802.3u (Fast Ethernet) is compatible with 802.3 Ethernet because they share the same physical characteristics. Fast Ethernet and Ethernet use the same maximum transmission unit (MTU) and the same MAC mechanisms, and they both preserve the frame format that is used by 10BaseT Ethernet. Basically, Fast Ethernet is just based on an extension to the IEEE 802.3 specification, and because of that, it offers us a speed increase of 10 times 10BaseT.

Here are the expanded IEEE Ethernet 802.3 standards, starting with Fast Ethernet:

100BaseTX (IEEE 802.3u) 100BaseTX, most commonly known as Fast Ethernet, uses EIA/TIA Category 5 or 5e or 6 and UTP two-pair wiring. It allows for one user per segment up to 100 meters long (328 feet) and uses an RJ-45 connector with a physical star topology and a logical bus.

NOTE 100BaseT and 100BaseTX: What's the difference? 100BaseT is the name of a group of standards for Fast Ethernet that includes 100BaseTX. Also included are 100BaseT4 and 100BaseT2. The same can be said about 1000BaseT and 1000BaseX.

100BaseFX (IEEE 802.3u) Uses 62.5/125-micron multimode fiber cabling up to 412 meters long and point-to-point topology. It uses ST and SC connectors, which are media-interface connectors.

NOTE Ethernet's implementation over fiber can sometimes be referred to as 100BaseTF even though this isn't an actual standard. It just means that Ethernet technologies are being run over fiber cable.

1000BaseCX (IEEE 802.3z) Copper twisted-pair called twinax (a balanced coaxial pair) that can run only up to 25 meters and uses a special 9-pin connector known as the High-Speed Serial Data Connector (HSSDC).

1000BaseT (IEEE 802.3ab) Category 5, four-pair UTP wiring, and up to 100 meters long (328 feet).

1000BaseTX Category 5, two-pair UTP wiring up to 100 meters long (328 feet). Not used, and has been replaced by Category 6 cabling.

1000BaseSX (IEEE 802.3z) The implementation of Gigabit Ethernet runs over multimode fiber-optic cable instead of copper twisted-pair cable and uses short wavelength laser. Multimode fiber (MMF), using 62.5- and 50-micron core, utilizes an 850 nanometer (nm) laser and can go up to 220 meters with 62.5-micron; 550 meters with 50-micron.

1000BaseLX (IEEE 802.3z) Single-mode fiber that uses a 9-micron core, 1,300 nm laser, and can go from 3 km up to 10 km.

10GBaseT 10GBaseT is a standard created by the IEEE 802.3an committee to provide 10 Gbps connections over conventional UTP cables (Category 5e, 6, 6A, or 7 cables). 10GBaseT allows the conventional RJ-45 used for Ethernet LANs. It can support signal transmission at the full 100-meter distance specified for LAN wiring. If you need to implement a 10 Gbps link, this is the most economical way to go!

10GBaseSR An implementation of 10 Gigabit Ethernet that uses short-wavelength lasers at 850 nm over multimode fiber. It has a maximum transmission distance of between 2 and 300 meters (990 feet), depending on the size and quality of the fiber.

10GBaseLR An implementation of 10 Gigabit Ethernet that uses long-wavelength lasers at 1310 nm over single-mode fiber. It also has a maximum transmission distance between 2 meters and 10 km, or 6 miles, depending on the size and quality of the fiber.

10GBaseER An implementation of 10 Gigabit Ethernet running over single-mode fiber that uses extra-long-wavelength lasers at 1,550 nm. It has the longest transmission distances possible of all the 10 Gigabit technologies: anywhere from 2 meters up to 40 km, again depending on the size and quality of the fiber used.

10GBaseSW 10GBaseSW, as defined by IEEE 802.3ae, is a mode of 10GBaseS for MMF with an 850 nm laser transceiver and a bandwidth of 10 Gbps. It can support up to 300 meters of cable length. This media type is designed to connect to SONET equipment.

10GBaseLW 10GBaseLW is a mode of 10GBaseL supporting a link length of 10 km on standard single-mode fiber (SMF) (G.652). This media type is also designed to connect to SONET equipment.

10GBaseEW 10GBaseEW is a mode of 10GBaseE supporting a link length of up to 40 km on SMF based on G.652 using optical-wavelength 1,550 nm. This is another media type designed to connect to SONET equipment.

NOTE

If you want to implement a network medium that is not susceptible to electromagnetic interference (EMI), fiber-optic cable provides a more secure, long-distance cable that is not susceptible to EMI at high speeds like UTP is.

Table 4.4 summarizes the cable types.

TABLE 4.4 Common Ethernet cable types

Ethernet Name	Cable Type	Maximum Speed	Maximum Transmission Distance	Notes
10Base5	Coax	10 Mbps	500 meters per segment	Also called thicknet, this cable type uses vampire taps to connect devices to cable.
10Base2	Coax	10 Mbps	185 meters per segment	Also called thinnet, a very popular implementation of Ethernet over coax.
10BaseT	UTP	10 Mbps	100 meters per segment	One of the most popular network cabling schemes.
100BaseTX	UTP, STP	100 Mbps	100 meters per segment	Two pairs of Category 5 UTP.
10BaseFL	Fiber	10 Mbps	Varies (ranges from 500 meters to 2,000 meters)	Ethernet over fiber optics to the desktop.
100BaseFX	MMF	100 Mbps	2,000 meters	100 Mbps Ethernet over fiber optics.

TABLE 4.4 Common Ethernet cable types *(continued)*

Ethernet Name	Cable Type	Maximum Speed	Maximum Transmission Distance	Notes
1000BaseT	UTP	1000 Mbps	100 meters	Four pairs of Category 5 or higher.
1000BaseTX	UTP	1000 Mbps	100 meters	Two pairs of Category 6 or higher.
1000BaseSX	MMF	1000 Mbps	550 meters	Uses SC fiber connectors. Max length depends on fiber size.
1000BaseCX	Balanced, shielded copper	1000 Mbps	25 meters	Uses a special connector, the HSSDC.
1000BaseLX	MMF and SMF	1000 Mbps	550 meters multimode/2,000 meters single mode	Uses longer wavelength laser than 1000BaseSX. Uses SC and LC connectors.
10GBaseT	UTP	10 Gbps	100 meters	Connects to the network like a Fast Ethernet link using UTP.
10GBaseSR	MMF	10 Gbps	400 meters	850 nm laser. Max length depends on fiber size and quality.
10GBaseLR	SMF	10 Gbps	10 kilometers	1,310 nm laser. Max length depends on fiber size and quality.
10GBaseER	SMF	10 Gbps	40 kilometers	1,550 nm laser. Max length depends on fiber size and quality.
10GBaseSW	MMF	10 Gbps	400 meters	850 nm laser transceiver.
10GBaseLW	SMF	10 Gbps	10 kilometers	Typically used with SONET.
10GBaseEW	SMF	10 Gbps	40 kilometers	1,550 nm optical wavelength.

NOTE An advantage of 100BaseFX over 100BaseTX is longer cable runs, but 100BaseTX is easier to install.

I know there's a lot of information to remember about the various Ethernet and fiber types used in today's networks, but for the CompTIA Network+ exam, you really need to know them. Trust me, I haven't inundated you with unnecessary information!

Real World Scenario

Deploy the Appropriate Wired Connectivity Standard

You have been tasked with installing wiring to handle the new networking technologies of 1000 Mbps to the desktop and Voice over IP (VoIP), with 10 Gbps between the access switches and the core switches. What cabling do you consider installing in order to accomplish this in a cost-effective manner?

First, you need to verify your distances. Since this will not include any wireless stations, you need to double-check the distances to each station and make sure the phone is within 100 meters (or closer) for connectivity to your access switches.

Once you have your distances verified at 100 meters or less, you can use UTP wiring to the stations and phones and possibly even connect the stations into the back of the phones. Most phones have switches included, so this means you only need to run one Category 5 or better 1000BaseT four-pair cable to each cubicle or office.

For your connections from your access switches to your core switches, you can use 10GbaseT if your runs are 100 meters or less, or you can use 10GbaseSR, which allows runs up to 400 meters using multimode fiber.

Ethernet over Other Standards (IEEE 1905.1-2013)

IEEE 1905.1-2013 is an IEEE standard that defines a convergent digital home network for both wireless and wireline technologies. The technologies include IEEE 802.11 (Wi-Fi), IEEE 1901 (HomePlug, HD-PLC) powerline networking, IEEE 802.3 Ethernet, and Multimedia over Coax (MoCA). The 1905.1-2013 was published in April 2013. The IEEE 1905.1 Standard Working Group is sponsored by the IEEE Power Line Communication Standards Committee (PLCSC). The idea behind the 1905.1 technology standards is simple setup, configuration, and operation of home networking devices using both wired and wireless technologies. This will take advantage of the performance, coverage, and mobility benefits of multiple interfaces (Ethernet, Wi-Fi, Powerline, and MoCA), which enables better coverage and throughput in every room for both wireless and fixed devices.

We'll discuss the following:

- Ethernet over Power Line
- Ethernet over HDMI

Ethernet over Power Line

In February 2011, the IEEE finally published a standard for Broadband over Power Line (BPL) called IEEE 1901, also referred to as Power Line Communication (PLC) or even Power Line Digital Subscriber Line (PDSL). Although this technology has been available for decades in theory, without an IEEE standard it was just not adopted as an alternative to other high-speed media.

However, it is highly likely that this technology will really start to see some traction, especially from the power companies who will be able to gather data from every device in your house and specifically tell you how much power is being used by your refrigerator, washers and dryers, and especially your computer and televisions, among all the other devices plugged into a wall power outlet.

In the future, BPL will allow you to just plug a computer into a wall power socket and have more than 500 Mbps for up to 1,500 meters.

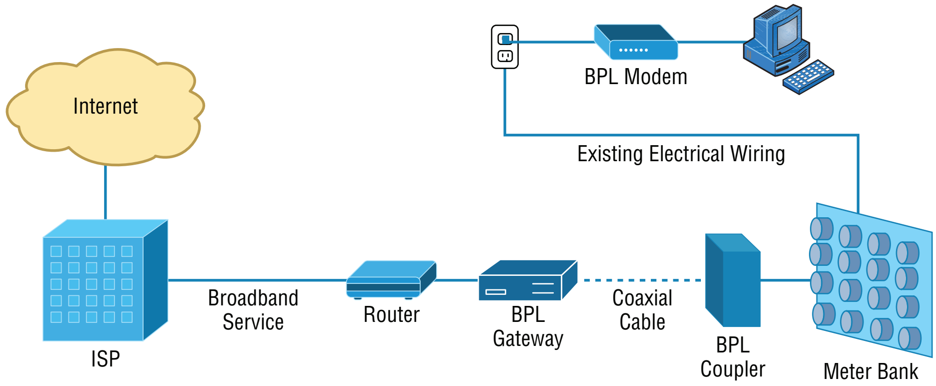
Near my home in Boulder, Colorado, Xcel Energy is using BPL in combination with radio links for its SmartGridCity pilot project, which will send data from power meters, hot water heaters, thermostats, and more.

An example of an adapter is shown in Figure 4.7.

FIGURE 4.7 Powerline adapter sets

This technology can be used to deliver Internet access to the home as well. For a computer (or any other device), you would simply need to plug a BPL modem into any outlet in an equipped building to have high-speed Internet access. The basic BPL installation is shown in Figure 4.8.

FIGURE 4.8 Basic BPL installation



After the gateway is connected through the coupler to the meter bank for the building, any electrical outlet can be used with the BPL modem to receive the ISP connection to the Internet. The following challenges still exist:

- The fact that power lines are typically noisy.
- The frequency at which the information is transmitted is used by shortwave, and the unshielded power lines can act as antennas, thereby interfering with shortwave communications.

Ethernet over HDMI

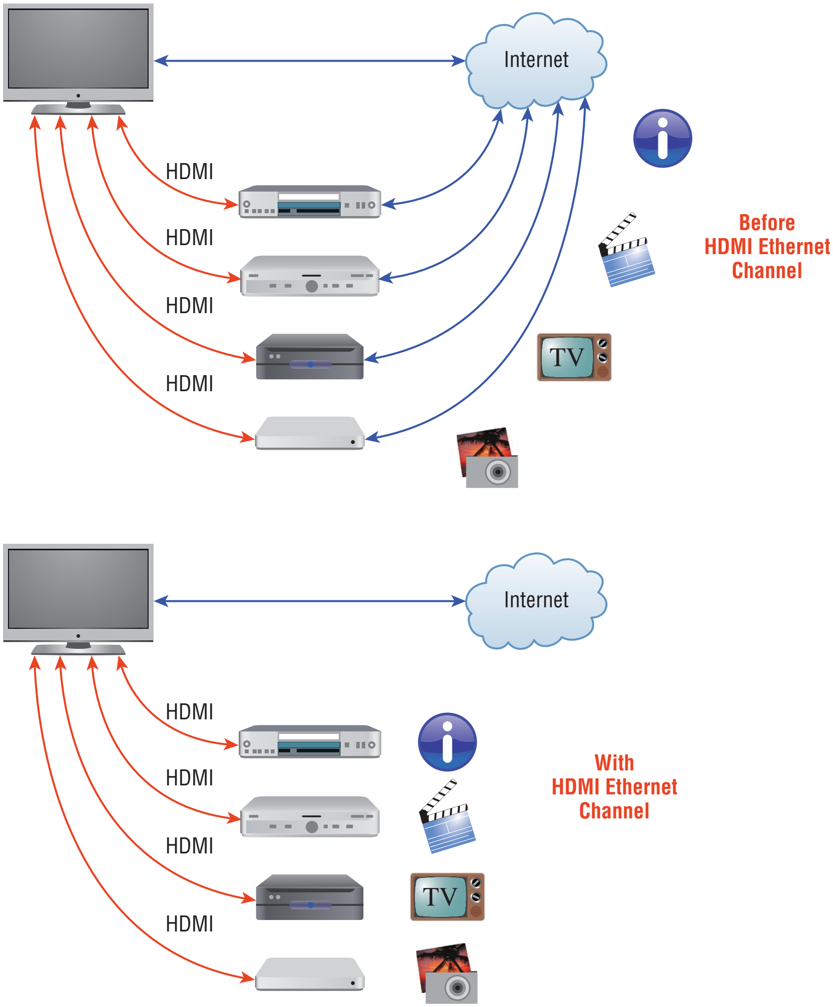
HDMI Ethernet Channel technology consolidates video, audio, and data streams into a single HDMI cable, combining the signal quality of HDMI connectivity with the power and flexibility of home entertainment networking.

Figure 4.9 shows how a possible home entertainment network will look before and after Ethernet over HDMI is implemented.

It incorporates a dedicated data channel into the HDMI link, enabling high-speed, bidirectional networking at up to 100 Mbps.

Armed with the basics covered in the chapter, you're equipped to go to the next level and put Ethernet to work using various network devices. But to ensure that you're really ready, read the summary, go over the exam essentials, and do the written lab and review questions for this chapter!

FIGURE 4.9 Ethernet over HDMI



Summary

In this chapter, you learned the fundamentals of Ethernet networking, how hosts communicate on a network, and how CSMA/CD works in an Ethernet half-duplex network.

I also showed you the differences between half- and full-duplex modes.

I finished the chapter with a description of the common Ethernet cable types used in today's networks. And by the way, you'd be wise to study that section really well!

Exam Essentials

Understand basic Ethernet communication. Know how hosts use hardware addresses to communicate on an Ethernet LAN.

Understand Ethernet addressing. Know the hexadecimal addressing scheme used to create an Ethernet address.

Understand binary, decimal, and hexadecimal addressing. Know the different addressing types, and also use the written lab to practice your conversions.

Written Lab

In this section, you will write in the answers to the following conversion tables. You can find the answers in Appendix A.

1. Convert from decimal IP address to binary format.

   Complete the following table to express 192.168.10.15 in binary format.

128	64	32	16	8	4	2	1	Binary

2. Complete the following table to express 172.16.20.55 in binary format.

128	64	32	16	8	4	2	1	Binary

3. Complete the following table to express 10.11.12.99 in binary format.

128	64	32	16	8	4	2	1	Binary

4. Convert the following from binary format to decimal IP address.

   Complete the following table to express 11001100.00110011.10101010.01010101 in decimal IP address format.

128	64	32	16	8	4	2	1	Binary

5. Complete the following table to express 11000110.11010011.00111001.11010001 in decimal IP address format.

128	64	32	16	8	4	2	1	Binary

6. Complete the following table to express 10000100.11010010.10111000.10100110 in decimal IP address format.

128	64	32	16	8	4	2	1	Binary

7. Convert the following from binary format to hexadecimal.

Complete the following table to express 11011000.00011011.00111101.01110110 in hexadecimal.

128	64	32	16	8	4	2	1	Hexadecimal

8. Complete the following table to express 11001010.11110101.10000011.11101011 in hexadecimal.

128	64	32	16	8	4	2	1	Hexadecimal

9. Complete the following table to express 10000100.11010010.01000011.10110011 in hexadecimal.

128	64	32	16	8	4	2	1	Hexadecimal

Review Questions

You can find the answers to the review questions in Appendix B.

1. On an Ethernet switched network, what address does one host computer use to communicate with another?

   A. IP address

   B. MAC address

   C. Street address

   D. HUB address

2. Which of the following can run full duplex and achieve 200 Mbps with Cat 5e cable?

   A. 100BaseF

   B. 100BaseTX

   C. 1000BaseF

   D. 1000BaseT

3. How many devices in a collision domain have to listen when a single host talks?

   A. 2

   B. 3

   C. 1

   D. All

4. If you are using a cable medium called 10Base2, what does this mean?

   A. That you are running Ethernet over HDMI

   B. That you are running Ethernet over fiber

   C. That you are running Ethernet over thicknet

   D. That you are bundling multiple connections

   E. That you are really old and using thinnet coax for your LAN medium

5. What network access control method helps devices share the bandwidth evenly without having two devices transmit at the same time on the network medium?

   A. TCP/IP

   B. CSMA/CD

   C. HTTPS

   D. TFTP

6. What is the maximum distance of 10GBaseSR?

   A. 100 meters (328 feet)

   B. 302 meters (990 feet)

C. 305 meters (1,000 feet)

D. 1,593 km (6 miles)

7. How many wire pairs are used with half duplex?

A. Two

B. One

C. Four

D. None of the above

8. How many wire pairs are used with 100BaseTX full duplex?

A. Two

B. One

C. Four

D. A or C

9. What is the maximum distance of 10GBaseLR?

A. 1 mile

B. 3 miles

C. 6 miles

D. 25 miles

10. What is the effective total throughput increase with a full-duplex connection?

A. None

B. Twice as much

C. Four times as much

D. Ten times as much

11. What device can you not use full-duplex communication with?

A. Host

B. Hub

C. Switch

D. Router

12. What is the decimal equivalent of this binary number: 11000000.10101000.00110000.11110000?

A. 192.168.48.192

B. 192.168.48.240

C. 192.168.64.224

D. 192.168.32.248

13. Which IEEE standard is used for Ethernet over Power Lines?
    - A. 802.3p
    - B. 1901
    - C. 802.16
    - D. 1918

14. How is the decimal value 10 represented in binary?
    - A. 1000
    - B. 1001
    - C. 1010
    - D. 1011

15. What is the decimal value for the binary number 11101000?
    - A. 128
    - B. 194
    - C. 224
    - D. 232

16. What is the decimal number 10 in hexadecimal?
    - A. 9
    - B. A
    - C. C
    - D. B

17. How many bits is a MAC address?
    - A. 16
    - B. 32
    - C. 48
    - D. 64

18. What is the maximum distance of 1000BaseT?
    - A. 100 meters (328 feet)
    - B. 128 meters (420 feet)
    - C. 1,000 meters (3280 feet)
    - D. 1,024 meters (3360 feet)

19. What is the purpose of the Frame Check Sequence (FCS) in an Ethernet frame?
    - **A.** Error correction
    - **B.** Error detection
    - **C.** Error recovery
    - **D.** Creating errors

20. What does the *Base* mean in 100BaseTX?
    - **A.** Broadband
    - **B.** 100 Mbps
    - **C.** Baseband
    - **D.** Twisted-pair at 100 Mbps

Chapter 5

Networking Devices

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.1 Explain the purposes and uses of ports and protocols**

- DHCP 67, 68
- DNS 53

✓ **1.2 Explain devices, applications, protocols, and services at their appropriate OSI layers**

- Layer 1—Physical
- Layer 2—Data link
- Layer 3—Network
- Layer 4—Transport
- Layer 5—Session
- Layer 6—Presentation
- Layer 7—Application

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Properties of network traffic
  - Broadcast domains
  - CSMA/CD
  - CSMA/CA
  - Collision domains
  - Broadcast
  - Multicast
  - Unicast
- Performance concepts
  - Traffic shaping

✓ **1.4 Given a scenario, configure the appropriate IP addressing components.**

- IP reservations

✓ **1.8 Explain the functions of network services**

- DNS service
  - Record types
    - A, AAA
    - TXT (SPF, DKIM)
    - SRV
    - MX
    - CNAME
    - NS
    - PTR
  - Internal vs. external DNS
  - Third-party/cloud-hosted DNS
  - Hierarchy
  - Forward vs. reverse zone
- DHCP service
  - MAC reservations
  - Pools
  - IP exclusions
  - Scope options
  - Lease time
  - TTL
  - DHCP relay/IP helper
  - IPAM

✓ **2.2 Given a scenario, determine the appropriate placement of networking devices on a network and install/configure them**

- Hub
- Modems
- Wireless range extender
- VoIP endpoint

✓ **2.3 Explain the purposes and use cases for advanced networking devices**

- Multilayer switch
- Load balancer
- IDS/IPS
- Proxy server
- VPN concentrator
- NGFW/Layer 7 Firewall
- VoIP PBX
- VoIP gateway
- Content filter

✓ **3.4 Given a scenario, use remote access methods.**

- Modem

In this chapter, I'll tell you all about the networking devices I've introduced so far. I'll go into much greater detail about each device, and yes—I'm going to present even more of them to you! Because all the components that you'll learn about shortly are typically found in today's networks and internetworks, it's very important that you be familiar with them.

We'll start by covering the more common network devices that you would be most likely to come across and then move on to discuss some of the more specialized devices that you may or may not always find running in a network.

I'll finish the chapter by using examples to discuss how routers, hubs, and switches work within internetworks today.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Common Network Connectivity Devices

By now, you should be fairly savvy regarding the various types of network media and connections, so it's time to learn about some of the devices they hook up to that are commonly found on today's networks.

First, I'll define the basic terms; then, later in this chapter, I'll show you how these devices actually work within a network. At that time, I'll give you more detailed descriptions of these devices and the terminology associated with them.

Because these devices connect network entities, they're known as *connectivity devices*. Here's a list of the devices I'll be and related concepts covering in this chapter:

- Network interface card (NIC)
- Hub
- Bridge
- Basic switch
- Basic router
- Basic firewall
- IDS/IPS/HIDS
- Access point

- Wireless Range extender
- Contention Methods
- Dynamic Host Configuration Protocol (DHCP) server

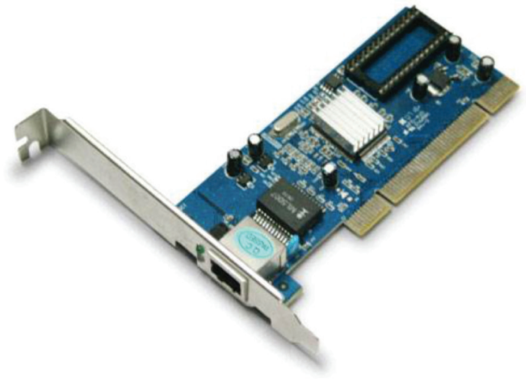
Network Interface Card

Those of you who aren't familiar with NICs probably want to be, at this point, so here goes: a *network interface card (NIC)* is installed in your computer to connect, or interface, your computer to the network. It provides the physical, electrical, and electronic connections to the network media. The NIC is called a Layer 2 device because the information it uses for communication, the MAC address, resides on the Data Link layer.

A NIC either is an expansion card or is built right into the computer's motherboard. Today, almost all NICs are built into the computer motherboard, providing 10, 100, and 1000 megabits per second (Mbps), but there was a time when all NICs were expansion cards that plugged into motherboard expansion slots. In some notebook computers, NIC adapters can be connected to the USB port or through a PC card slot.

Figure 5.1 shows a typical 100 Mbps Ethernet NIC.

FIGURE 5.1 Network interface card



Nowadays, most PCs and laptops of all types come with an Ethernet and wireless connector built into the motherboard, so you usually don't need a separate card. It's rare to find a laptop today without a built-in wireless network card, but you can buy external wireless cards for desktops and laptops if you've got legacy equipment that needs them.

NICs today usually have one, two, or more LEDs; one, usually green, is called a link light, indicating that an Ethernet connection has been established with the device on the other end of the cable, and it flickers when traffic is being passed back or forth. The other, or others, usually indicates the speed of the connection: 10, 100, or 1000 Mbps. There's no universal standard for NIC LEDs, so check the manual to familiarize yourself with the ones you are working with. But it's not always that cut-and-dried that blinking LED can mean the NIC is receiving a proper signal from the hub or switch, but it can also indicate connectivity to and detection of a carrier on a segment. Another possibility is that it's found connectivity with a router or other end device using a crossover cable.

The other LED is aptly named the activity LED, and it tends to flicker constantly. That activity indicates the intermittent transmission and reception of frames arriving at the network or leaving it.

NOTE The first LED you should verify is the link LED because if it's not illuminated, the activity LED simply cannot illuminate.

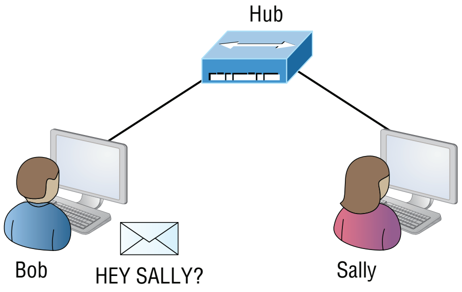
Hub

As you learned earlier, a *hub* is the device that connects all the segments of the network together in a star topology Ethernet network. As a hub has no intelligence, it is a Layer 1 device. Each device in the network connects directly to the hub through a single cable and is used to connect multiple devices without segmenting a network. Any transmission received on one port will be sent out to all the other ports in the hub, including the receiving pair for the transmitting device, so that Carrier Sense Multiple Access with Collision Detection (CSMA/CD) on the transmitter can monitor for collisions.

So, basically, this means that if one station sends a broadcast, all the others will receive it; yet based on the addressing found in the frame, only the intended recipient will actually listen and process it. This arrangement simulates the physical bus that the CSMA/CD standard was based on, and it's why we call the use of a hub in an Ethernet environment a physical star/logical bus topology.

Figure 5.2 depicts a typical hub as you might find it employed within a small network. Since there are only two users, there isn't a problem in using a hub here. However, if there were 20 users, everyone would see Bob's request to send a packet to Sally. Most of the time, hubs really aren't recommended for corporate networks because of their limitations.

FIGURE 5.2 A typical hub

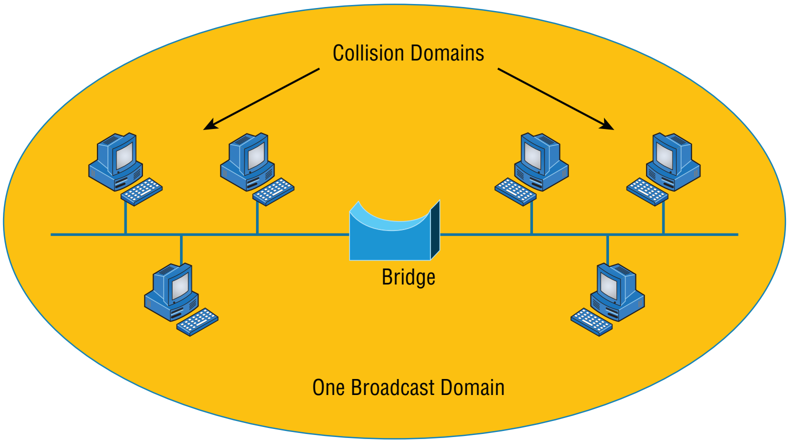


It's important to note that hubs are nothing more than glorified repeaters that are incapable of recognizing frames and data structures—the reason they act with such a lack of intelligence. A broadcast sent out by any device on the hub will be propagated to all devices connected to it. And just as in a physical bus topology configuration, any two or more of those connected devices have the potential of causing a collision with each other, which means that this hardware device will create a LAN with the most network traffic collisions. Hubs are not suggested for use in today's corporate network for this reason.

Bridge

A *bridge*—specifically, a transparent bridge—is a network device that connects two similar network segments together. Its primary function is to keep traffic separated on either side of the bridge, breaking up collision domains, as pictured in Figure 5.3.

FIGURE 5.3 Bridges break up collision domains.



What we can see here is that traffic is allowed to pass through the bridge only if the transmission is intended for a station on the opposite side. The main reasons you would place a bridge in your network would be to connect two segments together or to divide a busy network into two segments. As bridges use MAC addresses to make forwarding decisions, they are considered Layer 2 devices.

Bridges are software based, so, interestingly, you can think of a switch as a hardware-based, multiport bridge. In fact, the terms *bridge* and *switch* are often used interchangeably because the two devices used basically the same bridging technologies. The past tense is there for a reason—you'd be hard-pressed to buy a bridge today.

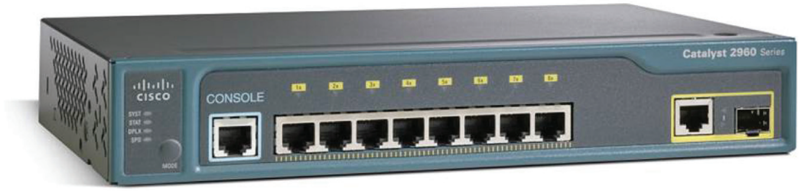
Switch

Switches connect multiple segments of a network together much like hubs do, but with three significant differences—a switch recognizes frames and pays attention to the source and destination MAC address of the incoming frame as well as the port on which it was received. A switch makes each of its ports a unique, singular collision domain. Hubs don't do those things. They simply send anything they receive on one port out to all the others. As switches use MAC addresses to make forwarding decisions, they are considered Layer 2 devices.

So, if a switch determines that a frame's final destination happens to be on a segment that's connected via a different port than the one on which the frame was received, the switch will only forward the frame out from the specific port on which its destination is located. If the switch can't figure out the location of the frame's destination, it will flood the frame out every port except the one on which the frame port was received.

Figure 5.4 shows a typical low-cost Ethernet switch. It looks a lot like a hub. However, switches can come in very large, expensive sizes. Switches that can perform the basic switching process and do not allow you to configure more advanced features—like adding an IP address for telnetting to the device or adding VLANs—are called unmanaged switches. Others, like Cisco switches that do allow an IP address to be configured for management with such applications as SNMP and do allow special ports to be configured (as in VoIP), are called managed switches.

FIGURE 5.4 Typical Ethernet switch



That's as far as we're going with switches right now. I'll bring them up later on in this chapter and cover them in much greater detail in Chapter 11, "Switching and Virtual LANs." For now, you can think of a switch as a faster, smarter bridge that has more ports.

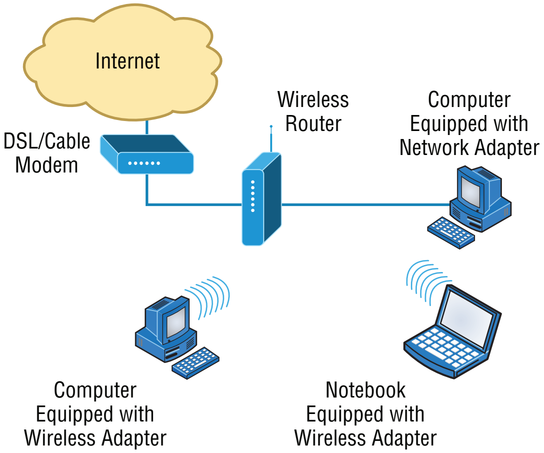
Switches are Layer 2 devices, which means they segment the network with MAC addresses. If you see the term *Layer 3 switch*, that means you are talking about a router, not a Layer 2 switch. The terms *router* and *Layer 3 switch* are interchangeable.

Router

A *router* is a network device used to connect many, sometimes disparate, network segments together, combining them into what we call an *internetwork*. A well-configured router can make intelligent decisions about the best way to get network data to its destination. It gathers the information it needs to make these decisions based on a network's particular performance data. As routers use IP addresses to make forwarding decisions, they are considered Layer 3 devices.

Figure 5.5 shows a small office, home office (SOHO) router that provides wired and wireless access for hosts and connects them to the Internet without any necessary configuration. But know that I certainly don't recommend leaving a router with the default configuration! No worries, though—I'll go over the configuration process with you in Chapter 10, "Routing Protocols."

FIGURE 5.5 Router connected to the Internet, providing access for hosts


Internet
DSL/Cable Modem
Wireless Router
Computer Equipped with Network Adapter
Computer Equipped with Wireless Adapter
Notebook Equipped with Wireless Adapter

Routers can be multifaceted devices that behave like computers unto themselves with their own complex operating systems—for example, Cisco's IOS. You can even think of them as CPUs that are totally dedicated to the process of routing packets. And due to their complexity and flexibility, you can configure them to actually perform the functions of other types of network devices (like firewalls, for example) by simply implementing a specific feature within the router's software.

NOTE

Routers can have many different names: *Layer 3 switch* and *multilayer switch* are the most common, besides the name *router*, of course. Remember, if you hear just the word *switch*, that means a Layer 2 device. Routers, Layer 3 switches, and multilayer switches are all Layer 3 devices.

Interface Configurations

When configuring interfaces on a router or switch, unless you're doing complex configurations such as connecting up a Voice over IP (VoIP) network, the interface configurations are pretty straightforward.

There is a major difference between a router interface and a switch interface configuration, however. On a switch, you do not add an IP address since they only read to Layer 2, and most of the time, you never even need to configure a switch interface. First, they are enabled by default, and second, they are very good at auto-detecting the speed, duplex, and, in newer switches, even the Ethernet cable type (crossover or straight-through). A router is much different and an IP address is expected on each interface; they are not enabled by default, and a good Layer 3 network design must be considered before installing a router.

Let's start by taking a look at a basic Cisco switch configuration. First, notice by the output shown that there is no configuration on the interfaces, yet you can plug this switch into your network and it would work. This is because all ports are enabled and there are some very basic configurations that allow the switch to run without any configuration—they can be considered plug-and-play in a small or home network:

```
Switch#sh running-config
[output cut]
!
interface FastEthernet0/1
!
interface FastEthernet0/2
!
interface FastEthernet0/3
!
interface FastEthernet0/4
!
interface FastEthernet0/5
!
interface FastEthernet0/6
!
interface FastEthernet0/7
!
interface FastEthernet0/8
!
```

Let's take a look at a configuration of a simple switch interface. First, we'll notice the duplex options:

```
Switch(config-if)#duplex ?
  auto  Enable AUTO duplex configuration
  full  Force full duplex operation
  half  Force half-duplex operation
```

All switch ports are set to duplex auto by default, and usually you can just leave this configuration alone. However, be aware that if your network interface card is set to half duplex and the switch port is configured for full duplex, the port will receive errors and you'll eventually get a call from the user. This is why it is advised to just leave the defaults on your hosts and switch ports, but it is a troubleshooting spot to check when a problem is reported from a single user.

The next configuration and/or troubleshooting spot you may need to consider is the speed of the port:

```
Switch(config-if)#speed ?
  10    Force 10Mbps operation
  100   Force 100Mbps operation
  auto  Enable AUTO speed configuration
```

Again, this is set to auto, but you may want to force the port to be 100 and full duplex. Typically, the NIC will run this without a problem and you'll be sure you're getting the most bang for your buck on your switch port.

Let's take a look at a router interface. We're pretty much going to configure (or not configure) the same parameters. However, you should be very aware that a router interface and a switch interface perform different functions. A router interface will break up collision domains just as a switch interface does, but the purpose of a router interface is to create and maintain broadcast domains and connectivity of WAN services. Basic Layer 2 switches cannot provide these services. As I mentioned, you must have a Layer 3 design before you can implement a router, meaning you must have your subnet design laid out on your network diagram, and your IP addressing scheme must be completely understood. You cannot start configuring router interfaces randomly; there must be a design and it needs to be correct.

Unlike switches, router interfaces do not just work when you plug them into the network—they must be configured and enabled. All ports are shut down by default, and why shouldn't they be? Unless you have a network design and understand IP addressing, what good is a router to your network?

Let's take a look:

```
Router(config-if)#duplex ?
  auto  Enable AUTO duplex configuration
  full  Force full duplex operation
  half  Force half-duplex operation


Router(config-if)#speed ?
  10    Force 10Mbps operation
  100   Force 100Mbps operation
  auto  Enable AUTO speed configuration
```

```
Router(config-if)#ip address ?
  A.B.C.D  IP address
  dhcp     IP Address negotiated via DHCP
  pool     IP Address autoconfigured from a local DHCP pool
```

First, we can see that the basics are there, duplex and speed, but also, to make a router interface useful at all we must add an IP address. Notice that the options allow you to configure a specific IP address or allow the interface to receive the address from a DHCP server. You would only use this option if you had an IP address reservation for the router interface on your DHCP server since having your router get a random IP address from a DHCP server would be hard to manage. Let's finish the basics:

```
Router(config-if)#ip address 1.1.1.1 255.0.0.0
Router(config-if)#no shutdown
Router(config-if)#
*Oct  5 17:26:46.522: %LINK-3-UPDOWN: Interface FastEthernet0/0,
changed state to up
*Oct  5 17:26:47.522: %LINEPROTO-5-UPDOWN: Line protocol on
Interface FastEthernet0/0, changed state to up
```

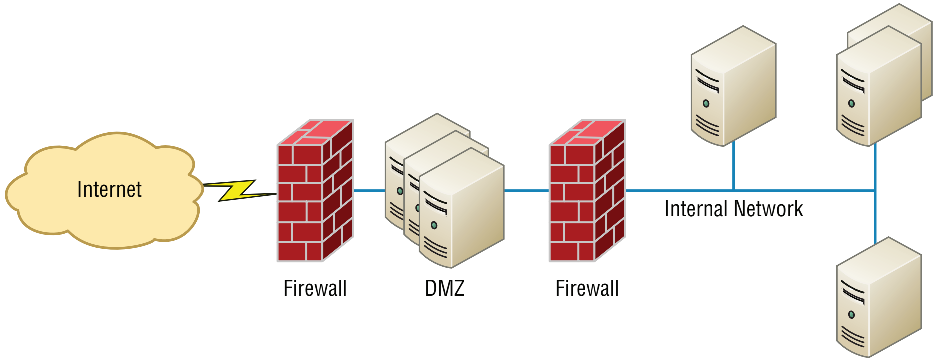
The interface can now be connected to a Layer 2 switch and the hosts connected to the same broadcast domain must set their default gateway address to 1.1.1.1, and voilà, they can now send packets to the router.

Firewall

So what, exactly, is a *firewall*? Basically, firewalls are your network's security guards, and to be real, they're probably the most important thing to implement on your network. That's because today's networks are almost always connected to the Internet—a situation that makes security crucial! A firewall protects your LAN resources from invaders that prowl the Internet for unprotected networks while simultaneously preventing all or some of your LAN's computers from accessing certain services on the Internet. You can employ them to filter packets based on rules that you or the network administrator create and configure to strictly delimit the type of information allowed to flow in and out of the network's Internet connection. Firewalls operate at multiple layers of the OSI model. Some firewalls can operate up to the Application layer.

A firewall can be either a stand-alone "black box" or a software implementation placed on a server or router. Either way, the firewall will have at least two network connections: one to the Internet (known as the *public* side) and one to the network (known as the *private* side). Sometimes, there is a second firewall, as shown in Figure 5.6. This firewall is used to connect servers and equipment that can be considered both public and private (like web and email servers). This intermediary network is known as a *demilitarized zone (DMZ)*.

FIGURE 5.6 Example of firewalls with a DMZ



Firewalls are the first line of defense for an Internet-connected network. Without them in place, any network that's connected to the Internet is essentially wide open to anyone with a little technical savvy who seeks to exploit LAN resources and/or access your network's sensitive information.

IDS/IPS

Intrusion detection systems (IDSs) and *intrusion prevention systems (IPSs)* are very important in today's networks. They are network security appliances that monitor networks and packets for malicious activity. An IDS is considered monitor mode and just records and tells you about problems, whereas an IPS can work in real time to stop threats as they occur.

The main difference between them is that an IPS works inline to actively prevent and block intrusions that are detected based on the rules you set up. IPSs can send an alarm, create correlation rules and remediation, drop malicious packets, provide malware protection, and reset the connection of offending source hosts.

HIDS

In a *host-based IDS (HIDS)*, software runs on one computer to detect abnormalities on that system alone by monitoring applications, system logs, and event logs—not by directly monitoring network traffic.

Systems like these are typically implemented on servers because they're a bear to manage if spread across several client computers on a network. Plus, if the IDS database is on the local computer and its data becomes compromised by an attack, the IDS data could be corrupted, too.

NOTE Other types of IDSs are protocol based (PIDS), which monitor traffic for one protocol on one server, and application protocol based (APIDS), which monitor traffic for a group of servers running the same application (such as SQL).

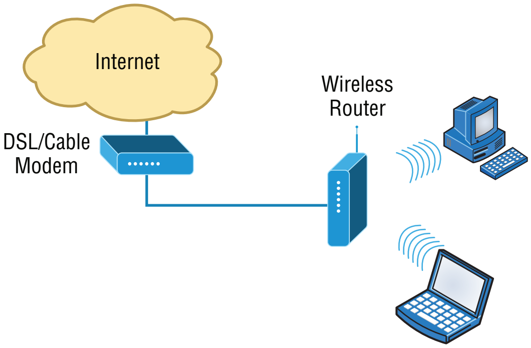
Access Point

I'll be covering access points (APs) in depth in Chapter 12, but I'll introduce them here. Understand that an AP is just a hub that accepts wireless clients via an analog wireless signal. APs operate at Layer 2.

It's no secret that wireless is the key to all networks in the world today, and wireless networks will be even more prevalent in the future when all our home appliances have IP addresses and communicate wirelessly to our networks, for example. The ease of communicating on a network using an AP instead of having to use an Ethernet cable has changed our world forever.

Figure 5.7 shows how an AP would look in a small network, such as a home.

FIGURE 5.7 Example of an AP in a network



The wireless client modulates a digital signal to an analog signal, which the AP can read and demodulate back to a digital signal. The AP creates one collision domain and can only run half duplex, which is why you can describe an AP as being like a hub. However, even though there are some standards that provide some full-duplex-type connectivity, a wireless host will never achieve the same type of throughput, security, and consistency that a wired Ethernet network would, but does that matter? Like rock 'n' roll, wireless is here to stay.

Wireless Range Extender

In some cases you need the WLAN to extend further than the technology in use is designed to deliver. In that case, you can deploy what is called an extender. These are radios and antennas that operate in the same frequency or channel and receive the signal as a station would and then transmit it in the direction you desire to clients that are out of reach of the original AP.

These devices should be placed so there is at least 15 percent overlap of the coverage areas of the AP and the extender.

Contention Methods

In both wireless and wired environments that are shared mediums, meaning devices share a collision domain, such as when connected to a hub or when connected to a wireless access point, there is potential for frames from multiple devices colliding, destroying both packets. Both wired and wireless environments use a *contention method* to arbitrate access to the medium to help prevent collisions or at the least to recover from them when they occur. In the following sections, we'll look at the method used in each environment.

CSMA/CA

When the device sending the frame is transmitting onto a wireless network, the CSMA/CA contention method is used. The method starts with a check of the medium (in this case, a check of the radio frequency) for activity called *physical carrier sense*. If the medium is not clear, the station will implement an internal countdown mechanism called the *random back-off algorithm*. This counter will have started counting down after the last time this station was allowed to transmit. All stations will be counting down their own individual timers. When a station's timer expires, it is allowed to send. If the physical carrier is clear and the countdown timer is at zero, the station will send.

The frame will go to the AP. The AP will acknowledge reception of the frame. If the frame is destined for another wireless station located on this wireless LAN, the frame will be forwarded to it by the AP. When this occurs, the AP will follow the same CSMA/CA contention method to get the frame onto the wireless medium.

If the frame is destined for a station on the wired LAN, the AP will drop the 802.11 MAC header (which is structured differently from an Ethernet MAC header) and build a new Ethernet MAC header by using its MAC address as the source address and the MAC address of the default gateway as the destination. The LAN router will receive the frame and normal LAN routing to the destination will continue from there, using the CSMA/CD contention mechanism (covered a bit later) to place the frame in the wire at each step. If frames are returned to the station, the AP will receive them, drop the Ethernet MAC header, build an 802.11 MAC header, and return the frame to the wireless station. When this occurs, the AP will follow the same CSMA/CA contention method to get the frame onto the wireless medium.

Describing CSMA/CA Operation

Because it is impossible for wireless stations to detect collisions, another contention method is required to arbitrate access to the network. The method is called *Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)*. It requires a more involved process of checking for existing wireless traffic before a frame can be transmitted wirelessly. The stations (including the AP) must also acknowledge all frames. The steps in the process are as follows:

1. Laptop A has a frame to send to laptop B. Before sending, laptop A must check for traffic in two ways. First, it performs carrier sense, which means it listens to see whether any radio waves are being received on its transmitter.

2. If the channel is *not* clear (traffic is being transmitted), laptop A will decrement an internal countdown mechanism called the *random back-off algorithm*. This counter will have started counting down after the last time this station was allowed to transmit. All stations will be counting down their own individual timers. When a station's timer expires, it is allowed to send.
3. If laptop A checks for carrier sense and there is no traffic and its timer hits zero, it will send the frame.
4. The frame goes to the AP.
5. The AP sends an acknowledgment back to laptop A. Until that acknowledgment is received by laptop A, all other stations must remain silent. The AP will cache the frame, where it already may have other cached frames that need to be relayed to other stations. Each frame that the AP needs to relay must wait its turn to send the frame using the same mechanism as the stations.
6. When the frame's turn comes up in the cache queue, the frame from laptop A will be relayed to laptop B.
7. Laptop B sends an acknowledgment back to the AP. Until that acknowledgment is received by the AP, all other stations must remain silent.

When you consider that this process has to occur for every single frame and that there are many other frame types used by the AP to manage other functions of the network that also create competition for air time, it is no wonder that actual throughput on a wireless LAN is at best about half the advertised rate.

For example, if two wireless stations were the only wireless clients and they were using 802.11g, which is capable of 56 Mbps, the *very best* throughput experienced would be about 25 to 28 Mbps. Moreover, as soon as a third station arrives, throughput will go down again because the stations are dividing the air time by 3 instead of 2. Add a fourth, and it gets even worse! Such is the challenge of achieving throughput on a wireless LAN.

CSMA/CD

When the device sending the frame is transmitting onto a wired network, the CSMA/CD contention method is used. This method is somewhat more efficient because it is possible for wired computers to detect collisions while wireless stations cannot. When a host's or router's interface needs to send a frame, it checks the wire, and if no traffic is detected, it sends without checking a random back-off timer.

However, it continues to listen, and if it detects that a collision has occurred, it sends out a jam signal that requires all stations to stop transmitting. Then the two computers that were involved in the collision will both wait a random amount of time (that each arrives at independently) and will resend. So instead of using a random break-off algorithm every time a transmission occurs, Ethernet uses its ability to detect collisions and uses this timer only when required, which makes the process more efficient.

Describing CSMA/CD Operation

The contention method used in Ethernet is called *Carrier Sense Multiple Access with Collision Detection (CSMA/CD)*. It has mechanisms that help minimize but not eliminate collisions. Its operation is as follows:

1. When a device needs to transmit, it checks the wire. If a transmission is already under way, the device can tell. This is called *carrier sense*.
2. If the wire is clear, the device will transmit. Even as it is transmitting, it is performing carrier sense.
3. If another host is sending simultaneously, there will be a collision. The collision is detected by both devices through carrier sense.
4. Both devices will issue a jam signal to all the other devices, which indicates to them to *not* transmit.
5. Then both devices will increment a retransmission counter. This is a cumulative total of the number of times this frame has been transmitted and a collision has occurred. There is a maximum number at which the device aborts the transmission of the frame.
6. Both devices will calculate a random amount of time and will wait that amount of time before transmitting again. This calculation is called a *random back-off*.
7. In most cases, because both devices choose random amounts of time to wait, another collision will not occur.

Dynamic Host Configuration Protocol Server

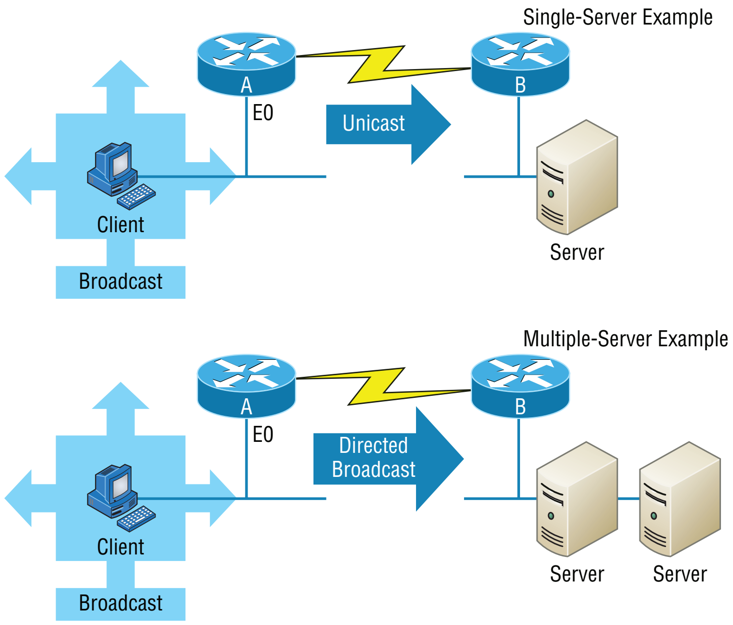
Even though I'm going to get into the finer points of DHCP soon, in Chapter 6, "Introduction to the Internet Protocol," I want to give you some basic insight into this server service here.

In essence, DHCP servers assign IP addresses to hosts. This protocol gives us a much easier way to administer—by automatically providing IP information—than the alternative and tedious method known as static IP addressing, where we have to address each host manually. It works well in any network environment, from tiny to huge, and allows all types of hardware to be employed as a DHCP server, including routers.

It works like this: A DHCP server receives a request for IP information from a DHCP client using a broadcast (as Chapter 6 will show you in detail). The DHCP server is configured by the administrator with what is called a pool of addresses that it uses for this purpose. When the administrator configures this pool, they can also set some addresses in the pool as "off limits." These are called IP exclusions. It means that these addresses cannot be assigned. An example might be the address of the router interface.

The only hitch is that if the DHCP server isn't on the same segment as the DHCP client, the broadcast won't be received by the server because by default, routers won't forward broadcasts, as shown in Figure 5.8.

FIGURE 5.8 DHCP client sends broadcasts looking for a DHCP server.



In Figure 5.8, Router A is configured with the IP helper address command on interface E0 of the router. Whenever interface E0 receives a broadcast request, Router A will forward that request as a unicast (meaning instead of a broadcast, the packet now has the destination IP address of the DHCP server).

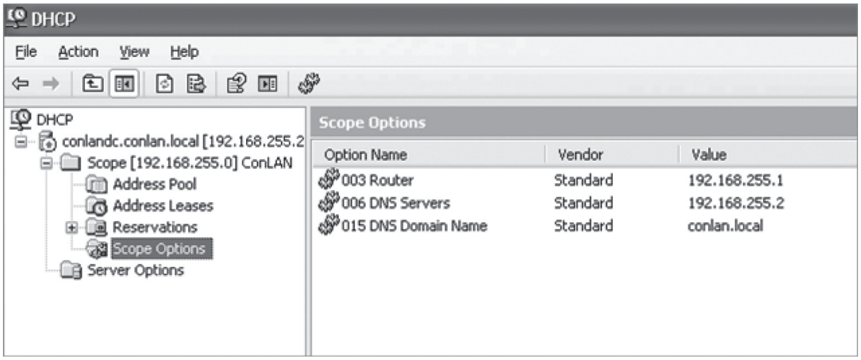
So, as shown in the figure, you can configure Router A to forward these requests and even use multiple DHCP servers for redundancy, if needed. This works because the router has been configured to forward the request to a single server using a unicast or by sending the request to multiple servers via a directed broadcast.

Personally, most of the time I use a Windows server to act as the DHCP server for my entire internetwork and have my routers forward client requests. It is possible to have a DHCP server on every network segment, but that is not necessary because of the routers' forwarding ability.

Figure 5.9 shows a Windows server with something called scope options.

Scope options provide IP configuration for hosts on a specific subnet. Below Scope Options, you'll find Server Options; these options provide IP information for all scopes configured on the server. If I had just one Domain Name Service (DNS) server for the entire network, I'd configure the server options with my DNS server information; that DNS server information would then show up automatically in all scopes configured on my server.

FIGURE 5.9 A Windows DHCP server's scope options



Scope Options

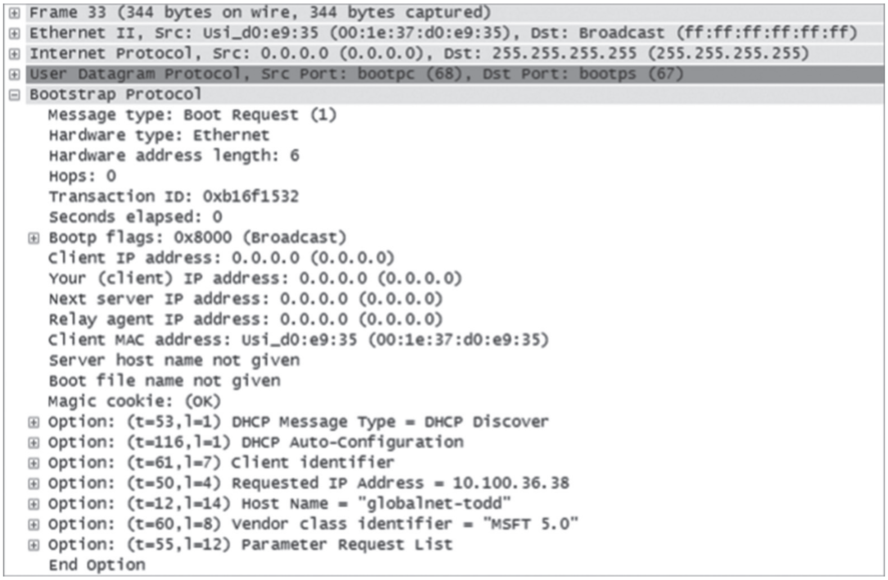
Option Name	Vendor	Value
003 Router	Standard	192.168.255.1
006 DNS Servers	Standard	192.168.255.2
015 DNS Domain Name	Standard	conlan.local

So, what exactly does a DHCP client ask for, and what does a DHCP server provide? Is it just an IP address, a mask, and a default gateway? No, it is much more than that. Scope options comprise the informational elements that the DHCP server can provide to the DHCP clients. Here are some examples of these options:

- TTL (provides the default TCP TTL value for TCP packets sent by the client)
- DNS server
- TFTP server (especially important for IP phones that need to get a configuration for a TFTP server)

Let's take a look at a DHCP client request on an analyzer. Figure 5.10 shows the options that the client is requesting from the DHCP server.

FIGURE 5.10 DHCP client request to a DHCP server

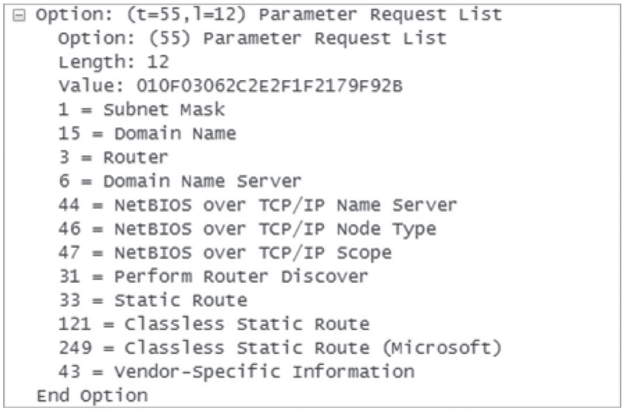


```
⊞ Frame 33 (344 bytes on wire, 344 bytes captured)
⊞ Ethernet II, Src: Usi_d0:e9:35 (00:1e:37:d0:e9:35), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
⊞ Internet Protocol, Src: 0.0.0.0 (0.0.0.0), Dst: 255.255.255.255 (255.255.255.255)
⊞ User Datagram Protocol, Src Port: bootpc (68), Dst Port: bootps (67)
⊟ Bootstrap Protocol
    Message type: Boot Request (1)
    Hardware type: Ethernet
    Hardware address length: 6
    Hops: 0
    Transaction ID: 0xb16f1532
    Seconds elapsed: 0
  ⊞ Bootp flags: 0x8000 (Broadcast)
    Client IP address: 0.0.0.0 (0.0.0.0)
    Your (client) IP address: 0.0.0.0 (0.0.0.0)
    Next server IP address: 0.0.0.0 (0.0.0.0)
    Relay agent IP address: 0.0.0.0 (0.0.0.0)
    Client MAC address: Usi_d0:e9:35 (00:1e:37:d0:e9:35)
    Server host name not given
    Boot file name not given
    Magic cookie: (OK)
  ⊞ Option: (t=53,l=1) DHCP Message Type = DHCP Discover
  ⊞ Option: (t=116,l=1) DHCP Auto-Configuration
  ⊞ Option: (t=61,l=7) Client identifier
  ⊞ Option: (t=50,l=4) Requested IP Address = 10.100.36.38
  ⊞ Option: (t=12,l=14) Host Name = "globalnet-todd"
  ⊞ Option: (t=60,l=8) Vendor class identifier = "MSFT 5.0"
  ⊞ Option: (t=55,l=12) Parameter Request List
    End Option
```

First, you can see that the DHCP service runs on top of the BootP protocol (port 68) and that the DHCP client is looking for a BootP server (port 67). The client IP address is 0.0.0.0, and the client doesn't know the DHCP server address either because this is a broadcast to 255.255.255.255 (the Data Link layer broadcast shows ff:ff:ff:ff:ff:ff). Basically, all the DHCP client knows for sure is its own MAC address. The client is "requesting" a certain IP address because this is the IP address it received from the server the last time it requested an IP address.

The DHCP client Parameter Request List option shown at the bottom of Figure 5.10 has been expanded and is shown in Figure 5.11. Notice all the parameter information that can be sent to a DHCP client from the server.

FIGURE 5.11 DHCP client parameter request list



```
⊟ Option: (t=55,l=12) Parameter Request List
    Option: (55) Parameter Request List
    Length: 12
    Value: 010F03062C2E2F1F2179F92B
    1 = Subnet Mask
    15 = Domain Name
    3 = Router
    6 = Domain Name Server
    44 = NetBIOS over TCP/IP Name Server
    46 = NetBIOS over TCP/IP Node Type
    47 = NetBIOS over TCP/IP Scope
    31 = Perform Router Discover
    33 = Static Route
    121 = Classless Static Route
    249 = Classless Static Route (Microsoft)
    43 = Vendor-Specific Information
  End Option
```

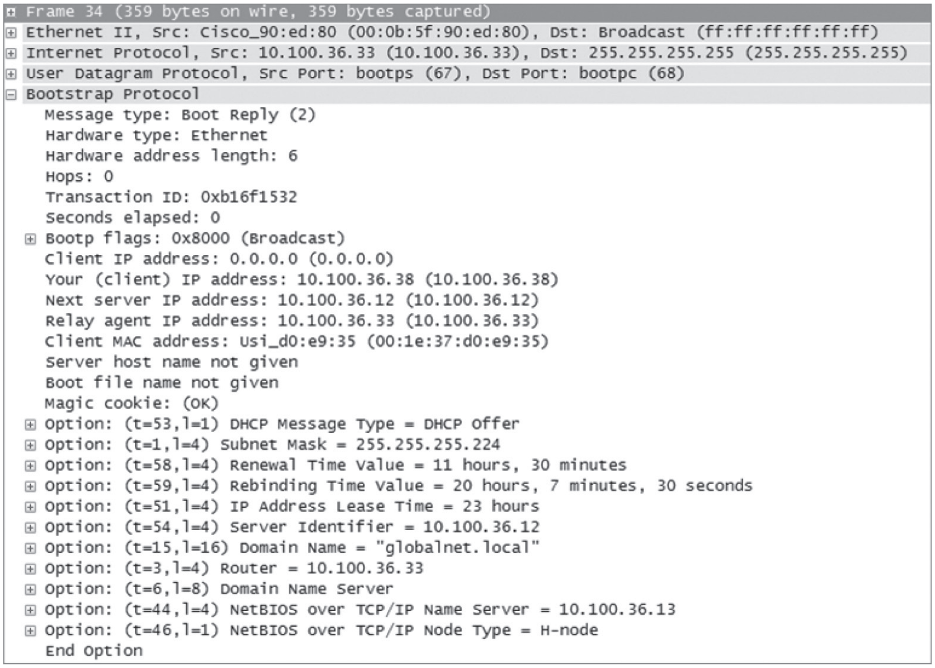
That is quite a request list! The DHCP server will respond with the options that it has configured and are available to provide to a DHCP client. Let's take a look and see what the server responds with. Figure 5.12 shows the DHCP server response.

The client is going to get the IP address that it asked for (10.100.36.38), a subnet mask of 255.255.255.224, a lease time of 23 hours (the amount of time before the IP address and other DHCP information expires on the client), the IP address of the DHCP server, the default gateway (router), the DNS server IP address (it gets two), the domain name used by DNS, and some NetBIOS information (used by Windows for name resolution).

The lease time is important and can even be used to tell you if you have a DHCP problem or, more specifically, that the DHCP server is no longer handing out IP addresses to hosts. If hosts start failing to get onto the network one at a time as they try to get a new IP address as their lease time expires, you need to check your server settings.

Here is another example of a possible DHCP problem: You arrive at work after a weekend and find that some hosts were left on and some were shut down. The hosts that were left running and not shut down are still working, but the hosts that were shut down and were restarted on Monday morning do not get a new IP address. This is a good indication that you need to head over to your DHCP server and take a look at what is going on.

FIGURE 5.12 DHCP server response



```
⊞ Frame 34 (359 bytes on wire, 359 bytes captured)
⊞ Ethernet II, Src: Cisco_90:ed:80 (00:0b:5f:90:ed:80), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
⊞ Internet Protocol, Src: 10.100.36.33 (10.100.36.33), Dst: 255.255.255.255 (255.255.255.255)
⊞ User Datagram Protocol, Src Port: bootps (67), Dst Port: bootpc (68)
⊟ Bootstrap Protocol
    Message type: Boot Reply (2)
    Hardware type: Ethernet
    Hardware address length: 6
    Hops: 0
    Transaction ID: 0xb16f1532
    Seconds elapsed: 0
  ⊞ Bootp flags: 0x8000 (Broadcast)
    Client IP address: 0.0.0.0 (0.0.0.0)
    Your (client) IP address: 10.100.36.38 (10.100.36.38)
    Next server IP address: 10.100.36.12 (10.100.36.12)
    Relay agent IP address: 10.100.36.33 (10.100.36.33)
    Client MAC address: Usi_d0:e9:35 (00:1e:37:d0:e9:35)
    Server host name not given
    Boot file name not given
    Magic cookie: (OK)
  ⊞ Option: (t=53,l=1) DHCP Message Type = DHCP Offer
  ⊞ Option: (t=1,l=4) Subnet Mask = 255.255.255.224
  ⊞ Option: (t=58,l=4) Renewal Time Value = 11 hours, 30 minutes
  ⊞ Option: (t=59,l=4) Rebinding Time Value = 20 hours, 7 minutes, 30 seconds
  ⊞ Option: (t=51,l=4) IP Address Lease Time = 23 hours
  ⊞ Option: (t=54,l=4) Server Identifier = 10.100.36.12
  ⊞ Option: (t=15,l=16) Domain Name = "globalnet.local"
  ⊞ Option: (t=3,l=4) Router = 10.100.36.33
  ⊞ Option: (t=6,l=8) Domain Name Server
  ⊞ Option: (t=44,l=4) NetBIOS over TCP/IP Name Server = 10.100.36.13
  ⊞ Option: (t=46,l=1) NetBIOS over TCP/IP Node Type = H-node
    End Option
```

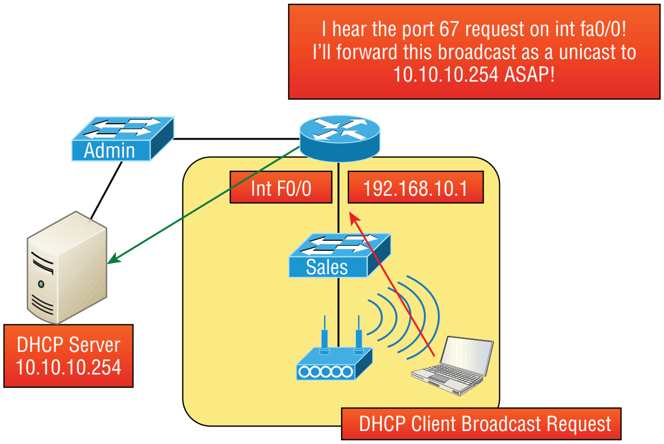
A DHCP server can also be configured with a reservation list so that a host always receives the same IP address. When this is done, the reservation is made on the basis of the router interface MAC address. Therefore, it is sometimes called a MAC reservation. You would use this reservation list for routers or servers if they were not statically assigned. However, you can use reservation lists for any host on your network as well.

DHCP is an Application layer protocol. While the DORA components operate at Layer 2, the protocol is managed and responds to the Application layer. DHCP uses UDP ports 67 and 68.

DHCP Relay

If you need to provide addresses from a DHCP server to hosts that aren’t on the same LAN as the DHCP server, you can configure your router interface to relay or forward the DHCP client requests, as shown in Figure 5.13. If we don’t provide this service, our router would receive the DHCP client broadcast, promptly discard it, and the remote host would never receive an address—unless we added a DHCP server on every broadcast domain! Let’s take a look at how we would typically configure DHCP service in today’s networks.

FIGURE 5.13 Configuring a DHCP relay


I hear the port 67 request on int fa0/0!
I'll forward this broadcast as a unicast to 10.10.10.254 ASAP!
Admin
Int F0/0
192.168.10.1
Sales
DHCP Server 10.10.10.254
DHCP Client Broadcast Request

So we know that because the hosts off the router don't have access to a DHCP server, the router will simply drop their client request broadcast messages by default. To solve this problem, we can configure the F0/0 interface of the router to accept the DHCP client requests and forward them to the DHCP server like this:

```
Router#config t
Router(config)#interface fa0/0
Router(config-if)#ip helper-address 10.10.10.254
```

Now I know that was a pretty simple example, and there are definitely other ways to configure the relay, but rest assured that I've covered the objectives for you. Also, I want you to know that `ip helper-address` forwards more than just DHCP client requests, so be sure to research this command before you implement it!

IPAM

IP address management (IPAM) tools are software products that integrate the management of DHCP and DNS. It is used to plan, track, and manage the IP addresses. With the integration of DNS ad DHCP each process is kept abreast of changes made to the other service. Many products offer additional functionality as well such as tracking of information such as IP addresses in use, the devices an IP is assigned to at what time, as well as to which user an IP was assigned.

Other Specialized Devices

In addition to the network connectivity devices I've discussed with you, there are several devices that, while they may not be directly connected to a network, do actively participate in moving network data. Here's a list of them:

- Multilayer switch
- Load balancer

- DNS server
- Proxy server
- Encryption devices
- Content filter
- Analog modem
- Packet shaper
- VPN concentrator
- Media converter
- VoIP endpoint
- VoIP PBX

Multilayer Switch

A *multilayer switch (MLS)* is a computer networking device that switches on Open Systems Interconnection (OSI) Layer 2 like an ordinary network switch but provides routing. A 24-port MLS gives you the best of both worlds. It operates at Layer 3 (routing) while still providing 24 collision domains, which a router could not do.

The major difference between the packet-switching operation of a router and that of a Layer 3 or multilayer switch lies in the physical implementation. In routers, packet switching takes place using a microprocessor, whereas a Layer 3 switch handles this by using application-specific integrated circuit (ASIC) hardware. I'd show you a picture of a Layer 3 switch, but they look just like regular Layer 2 switches and you already know what those look like. The differences are the hardware inside and the operating system.

Load Balancer

Your average router just sends incoming packets to their specified, correlative IP address on the network, but a *load balancer* can actually send incoming packets to multiple machines hidden behind one IP address—cool, right?

Today's load-balancing routers follow various rules to determine specifically how they will route network traffic. Depending on your needs, you can set rules based on the least load, fault tolerance, the fastest response times, or just dividing up (balancing) outbound requests for smooth network operations.

In fact, the fault tolerance, or redundancy, as well as the scalability so vital to large networking environments and e-commerce are some of the great benefits we gain using load balancers.

Think about this scenario: Say you have a website where people are placing orders for the stuff you've got for sale. Obviously, the orders placed vary in size, and the rate at which they come in varies; you definitely wouldn't want your servers becoming so overloaded that they hose up and crash your site, causing you to lose lots of money, now would you? That's where balancing the load of traffic between a group of servers comes to the rescue, because even if one of them freezes, your customers will still be able to access your site and place orders.

Domain Name Service Server

A *Domain Name Service (DNS) server* is one of the most important servers in your network and on the Internet as well. Why? Because without a DNS server, you would have to type `http://206.123.114.186` instead of simply entering `www.lammle.com`. So it follows that you can pretty much think of the DNS system as the phone book of the Internet.

A hostname is typically the name of a device that has a specific IP address; on the Internet, it is part of what is known as a fully qualified domain name (FQDN). An FQDN consists of a hostname and a domain name.

The process of finding the IP address for any given hostname is known as *name resolution*, and it can be performed in several ways: a HOSTS file (meaning you statically type in all names and IP addresses on each and every host), a request broadcast on the local network (Microsoft's favorite—why ask a server when you can just broadcast, right?), DNS, and Microsoft's Windows Internet Naming Service (WINS). DNS is the most popular today and is the resolution method you really need to know.

On the Internet, domains are arranged in a hierarchical tree structure. The following list includes some of the top-level domains currently in use:

`.com` A commercial organization. Most companies end up as part of this domain.

`.edu` An educational establishment, such as a university.

`.gov` A branch of the U.S. government.

`.int` An international organization, such as NATO or the United Nations.

`.mil` A branch of the U.S. military.

`.net` A network organization.

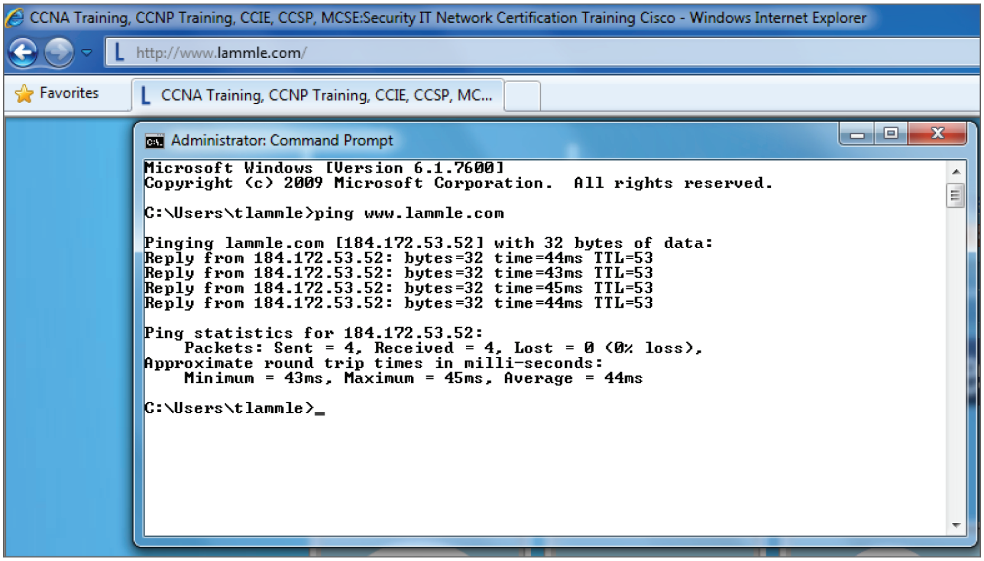
`.org` A nonprofit organization.

Your local ISP is probably a member of the `.net` domain, and your company is probably part of the `.com` domain. The `.gov` and `.mil` domains are reserved strictly for use by the government and the military within the United States. In other parts of the world, the final part of a domain name represents the country in which the server is located (`.ca` for Canada, `.jp` for Japan, `.uk` for Great Britain, and `.ru` for Russia, for example). Well over 130 countries are represented on the Internet.

The `.com` domain is by far the largest, followed by the `.edu` domain. Some new domain names are becoming popular, however, because of the increasing number of domain-name requests. These include `.firm` for businesses and companies, `.store` for businesses selling goods rather than services, `.arts` for cultural and entertainment organizations, and `.info` for informational services. The domains `.cc`, `.biz`, `.travel`, and `.post` are also in use on the Internet.

Figure 5.14 shows how, when you type in a domain name, the DNS server resolves it, allowing the host to send the HTTP packets to the server.

FIGURE 5.14 DNS resolution example


CCNA Training, CCNP Training, CCIE, CCSP, MCSE:Security IT Network Certification Training Cisco - Windows Internet Explorer
http://www.lammle.com/
Favorites
CCNA Training, CCNP Training, CCIE, CCSP, MC...
Administrator: Command Prompt

```
Microsoft Windows [Version 6.1.7600]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\tlammle>ping www.lammle.com

Pinging lammle.com [184.172.53.52] with 32 bytes of data:
Reply from 184.172.53.52: bytes=32 time=44ms TTL=53
Reply from 184.172.53.52: bytes=32 time=43ms TTL=53
Reply from 184.172.53.52: bytes=32 time=45ms TTL=53
Reply from 184.172.53.52: bytes=32 time=44ms TTL=53

Ping statistics for 184.172.53.52:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 43ms, Maximum = 45ms, Average = 44ms

C:\Users\tlammle>_
```

This DOS screen shows how the DNS server can resolve the human name to the IP address of the Lammle.com server when I ping the server by the name instead of the IP address.

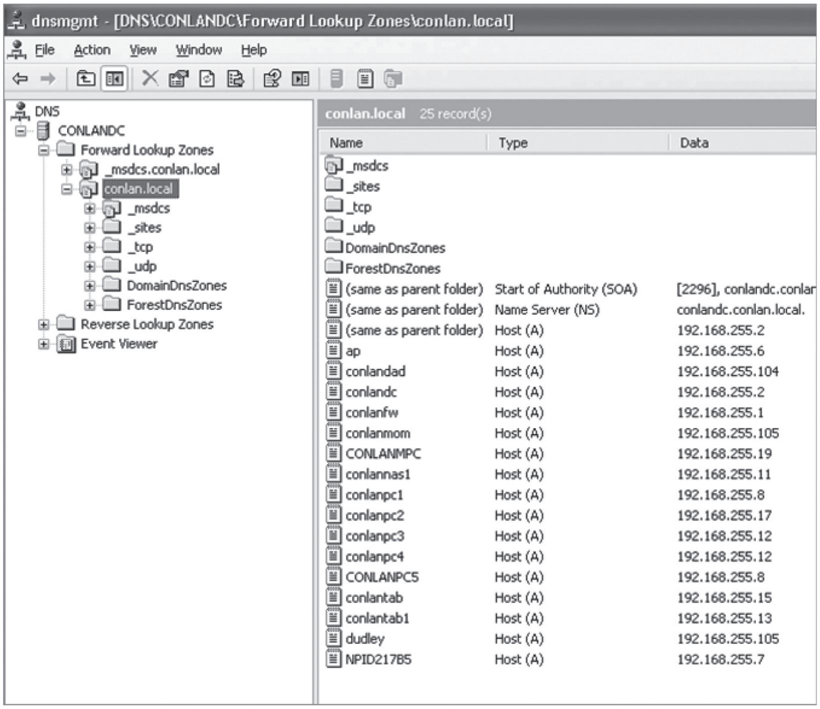
It should be easy to imagine how hard life would be without DNS translating human names to IP addresses, routing your packet through the Internet or internetwork to get to your servers. Figure 5.15 gives you an example of a Windows server configured as a DNS server.

To complete unqualified Domain Name Service (DNS) names that will be used to search and submit DNS queries at the client for resolution, you must have a list of DNS suffixes that can be appended to these DNS names. For DHCP clients, this can be set by assigning the DNS domain name option (option 15) and providing a single DNS suffix for the client to append and use in searches. For example, if you just wanted to ping todd instead of pinging todd.lammle.com, you can configure the DHCP server option 15 to provide the suffix for you.

Now the hosts can receive the IP address of this DNS server, and then this server will resolve hostnames to correct IP addresses. This is a mission-critical service in today's networks, don't you think? As shown in Figure 5.15, if I ping from a host to conlanpc1, the host will send the name-resolution request to the DNS server and translate this name to IP address 192.168.255.8.

Host (A) is called an A record and is what gives you the IP address of a domain or host. In IPv6, it's called a quad-A or AAAA record. In Figure 5.15, you can see that each name has an A record, which is associated to an IP address. So, A records resolve hostnames to IP addresses, but what happens if you know the IP address and want to know the hostname? There is a record for this, too! It's called the pointer record (PTR).

FIGURE 5.15 A Windows DNS server



Name	Type	Data
_msdcs		
_sites		
_tcp		
_udp		
DomainDnsZones		
ForestDnsZones		
(same as parent folder)	Start of Authority (SOA)	[2296], conlandc.conlar
(same as parent folder)	Name Server (NS)	conlandc.conlan.local.
(same as parent folder)	Host (A)	192.168.255.2
ap	Host (A)	192.168.255.6
conlandad	Host (A)	192.168.255.104
conlandc	Host (A)	192.168.255.2
conlanfw	Host (A)	192.168.255.1
conlanmom	Host (A)	192.168.255.105
CONLANMPC	Host (A)	192.168.255.19
conlannas1	Host (A)	192.168.255.11
conlanpc1	Host (A)	192.168.255.8
conlanpc2	Host (A)	192.168.255.17
conlanpc3	Host (A)	192.168.255.12
conlanpc4	Host (A)	192.168.255.12
CONLANPC5	Host (A)	192.168.255.8
conlantab	Host (A)	192.168.255.15
conlantab1	Host (A)	192.168.255.13
dudley	Host (A)	192.168.255.105
NPID217B5	Host (A)	192.168.255.7

Other typical records found on DNS servers are *mail exchanger (MX) records*, which are used to translate mail records. The MX record points to the mail exchanger for a particular host. DNS is structured so that you can actually specify several mail exchangers for one host. This feature provides a higher probability that email will arrive at its intended destination. The mail exchangers are listed in order in the record, with a priority code that indicates the order in which they should be accessed by other mail-delivery systems. There are many other types of records the DNS server keeps as well, shown in Table 5.1.

TABLE 5.1 Additional DNS record types

Record Type	Explanation
AAAA	Used to map hostnames to an IPv6 address of the host.
TXT (SPF)	Used to provide authentication of mail sent and received by the same email system
TXT (DKIM)	Used to provide authentication of mail sent and received by the same email system

Record Type	Explanation
SRV	Generalized service location record, used for newer protocols instead of creating protocol-specific records such as MX
NS	Represents DNS server

If the first-priority mail exchanger doesn't respond in a given amount of time, the mail-delivery system tries the second one, and so on. Here are some sample mail-exchange records:

```
hostname.company.com.  IN    MX    10 mail.company.com.
hostname.company.com.  IN    MX    20 mail2.company.com.
hostname.company.com.  IN    MX    30 mail3.company.com.
```

In this example, if the first mail exchanger, `mail.company.com`, does not respond, the second one, `mail2.company.com`, is tried, and so on.

Another important record type on a DNS server is the *canonical name (CNAME) record*. This is also commonly known as the *alias record*, and it allows hosts to have more than one name. For example, suppose your web server has the hostname www and you want that machine to also have the name `ftp` so that users can use FTP to access a different portion of the file system as an FTP root. You can accomplish this with a CNAME record. Given that you already have an address record established for the hostname www, a CNAME record that adds `ftp` as a hostname would look something like this:

```
www.company.com.       IN    A      204.176.47.2
ftp.company.com.       IN    CNAME  www.company.com.
```

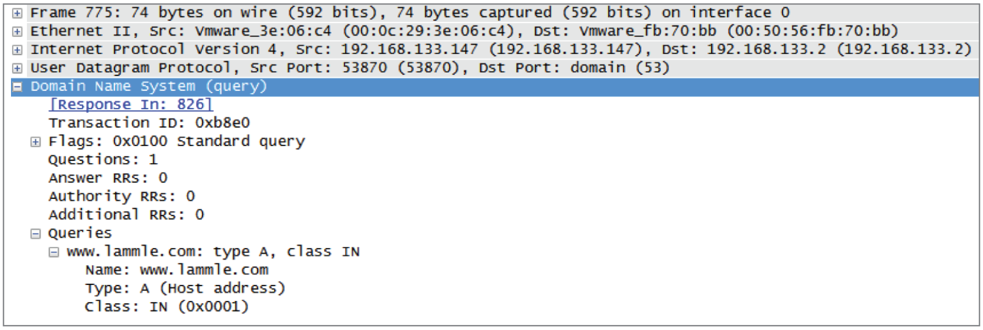
When you put all these record types together in a zone file, or DNS table, it might look like this:

```
mail.company.com.      IN    A      204.176.47.9
mail2.company.com.     IN    A      204.176.47.21
mail3.company.com.     IN    A      204.176.47.89
yourhost.company.com.  IN    MX     10 mail.company.com.
yourhost.company.com.  IN    MX     20 mail2.company.com.
yourhost.company.com.  IN    MX     30 mail3.company.com.
www.company.com.       IN    A      204.176.47.2
ftp.company.com.       IN    CNAME  www.company.com.
```

Finally, two other record types you should know about are AAA (for authentication servers such as RADIUS or TACACS+) and PTR, or pointer, records. PTR records are IP address to name mapping records rather than name to IP address mapping records. They reside in what is called a *reverse lookup zone* (or table) in the server and are used when an IP address is known but not a name.

Let's take a look a tad deeper for a minute into how resolution takes place between a host and a DNS server. Figure 5.16 shows a DNS query from my host to `www.lammle.com` from a browser.

FIGURE 5.16 A DNS query to `www.lammle.com`

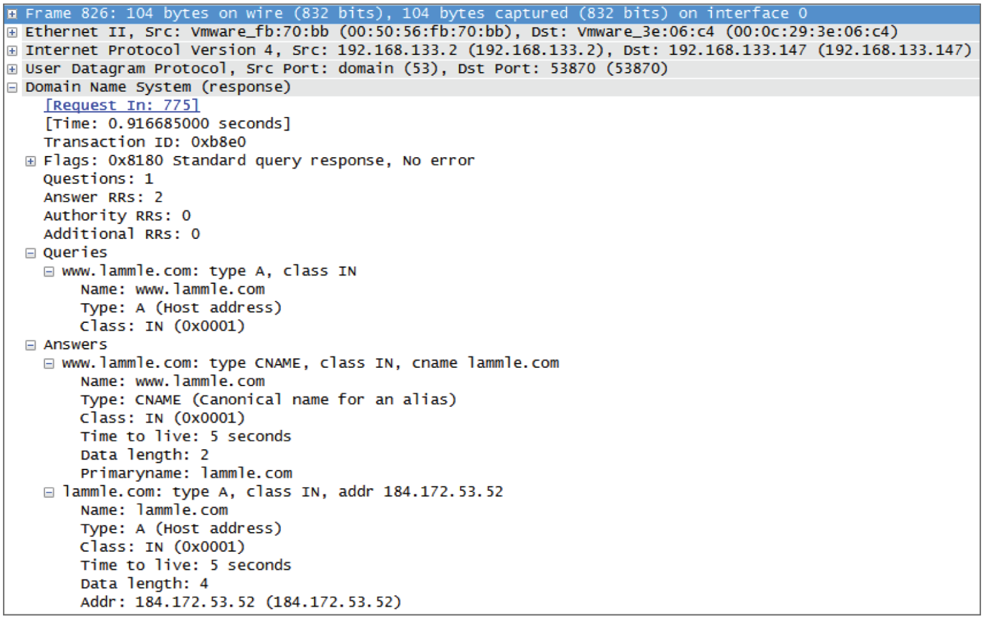


```
⊞ Frame 775: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
⊞ Ethernet II, Src: Vmware_3e:06:c4 (00:0c:29:3e:06:c4), Dst: Vmware_fb:70:bb (00:50:56:fb:70:bb)
⊞ Internet Protocol Version 4, Src: 192.168.133.147 (192.168.133.147), Dst: 192.168.133.2 (192.168.133.2)
⊞ User Datagram Protocol, Src Port: 53870 (53870), Dst Port: domain (53)
⊟ Domain Name System (query)
    [Response In: 826]
    Transaction ID: 0xb8e0
  ⊞ Flags: 0x0100 Standard query
    Questions: 1
    Answer RRs: 0
    Authority RRs: 0
    Additional RRs: 0
  ⊟ Queries
    ⊟ www.lammle.com: type A, class IN
        Name: www.lammle.com
        Type: A (Host address)
        Class: IN (0x0001)
```

This figure shows that DNS uses User Datagram Protocol (UDP) at the Transport layer (it uses Transport Control Protocol [TCP] if it is updating its phone book pages—we call these *zone updates*), and this query is asking destination port 53 (the DNS service) on host 192.168.133.2 who the heck `www.lammle.com` is.

Let's take a look at the server's response. Figure 5.17 shows the DNS answer to our query for `www.lammle.com`.

FIGURE 5.17 The DNS answer to our query



```
⊞ Frame 826: 104 bytes on wire (832 bits), 104 bytes captured (832 bits) on interface 0
⊞ Ethernet II, Src: Vmware_fb:70:bb (00:50:56:fb:70:bb), Dst: Vmware_3e:06:c4 (00:0c:29:3e:06:c4)
⊞ Internet Protocol Version 4, Src: 192.168.133.2 (192.168.133.2), Dst: 192.168.133.147 (192.168.133.147)
⊞ User Datagram Protocol, Src Port: domain (53), Dst Port: 53870 (53870)
⊟ Domain Name System (response)
    [Request In: 775]
    [Time: 0.916685000 seconds]
    Transaction ID: 0xb8e0
  ⊞ Flags: 0x8180 Standard query response, No error
    Questions: 1
    Answer RRs: 2
    Authority RRs: 0
    Additional RRs: 0
  ⊟ Queries
    ⊟ www.lammle.com: type A, class IN
        Name: www.lammle.com
        Type: A (Host address)
        Class: IN (0x0001)
  ⊟ Answers
    ⊟ www.lammle.com: type CNAME, class IN, cname lammle.com
        Name: www.lammle.com
        Type: CNAME (Canonical name for an alias)
        Class: IN (0x0001)
        Time to live: 5 seconds
        Data length: 2
        Primaryname: lammle.com
    ⊟ lammle.com: type A, class IN, addr 184.172.53.52
        Name: lammle.com
        Type: A (Host address)
        Class: IN (0x0001)
        Time to live: 5 seconds
        Data length: 4
        Addr: 184.172.53.52 (184.172.53.52)
```

Port 53 answered from server 192.168.133.147 with a CNAME and an A record with the IP address of 184.172.53.52. My host can now go to that server requesting HTTP pages using the IP address.

DNS is an Application layer protocol. DNS queries are made on UDP port 53.

Dynamic DNS

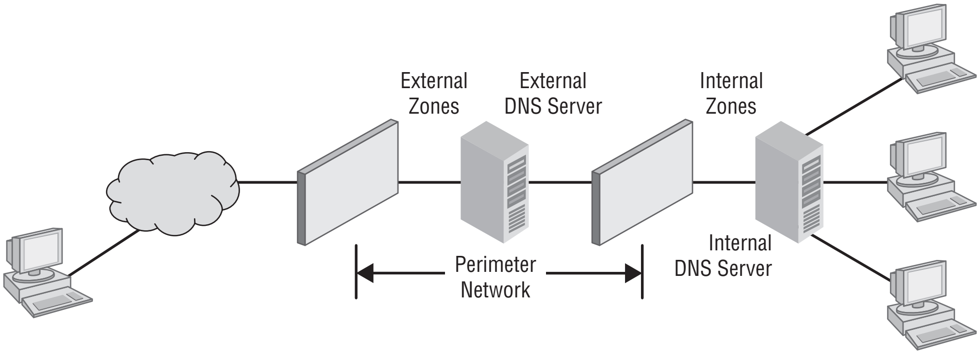
At one time all DNS records had to be manually entered into the DNS server and edited manually when changes occurred. Today, DNS is dynamic and works in concert with the DHCP function. Hosts register their names with the DNS server as they receive their IP address configuration from the DHCP server. Some older operating systems are not capable of self-registration (such as Windows NT), but the DHCP server can even be configured to perform registration on behalf of these clients with the DNS server.

This doesn't mean that manual records cannot be created if desired. In fact, some of the record types we have discussed can only be created manually. These include MX and CNAME records.

Internal and External DNS

DNS servers can be located in the DMZ or inside the intranet, as shown in Figure 5.18.

FIGURE 5.18 Internal and external DNS



When located in the DMZ, the DNS server should only contain the records of the devices that are placed in the DMZ. Implementing separate internal and external DNS servers might require you to include external resource records in the internal DNS zone. You need to do this when the Active Directory forest root uses the same DNS domain name as the external network or when you want to reference the externally accessible resources by their true IP addresses in the perimeter network rather than using the addresses published to the Internet by the firewall protecting the perimeter network.

Third-Party/Cloud-Hosted DNS

Some smaller organizations find that it makes more sense to outsource the DNS function. Rather than hire and train staff to set up, configure, and maintain the infrastructure required to keep name resolution up and secure, they might find it more cost effective to utilize a third party who make it their business to provide this service. There is no shortage of cloud providers falling all over themselves to provide you with cloud-based storage, and these same vendors stand ready to provide you with DNS as a service, and they'll probably do a better job at it than you will.

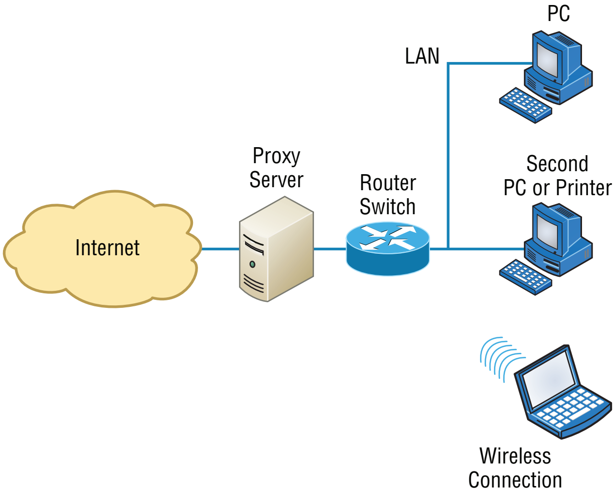
Proxy Server

A *proxy server* is basically a type of server that handles its client-machine requests by forwarding them on to other servers while allowing granular control over the traffic between the local LAN and the Internet. When it receives a request, the proxy will then connect to the specific server that can fulfill the request for the client that wants it. A proxy server operates at the Application layer.

Sometimes the proxy modifies the client's request or a server's response to it—or even handles the client's request itself. It will actually cache, or "remember," the specific server that would have normally been contacted for the request in case it's needed another time. This behavior really speeds up the network's function, thereby optimizing its performance. However, proxy servers can also limit the availability of the types of sites that users on a LAN have access to, which is a benefit for an administrator of the network if users are constantly connected to non-work sites and using all the WAN bandwidth.

Figure 5.19 shows where a proxy server would be typically found in a small-to-medium network.

FIGURE 5.19 A proxy server



There are two main types of proxy servers you'll typically find working in present-day networks:

Web Proxy Server A web proxy server is usually used to create a web cache. You experience this when you Google a site you've visited before. The web proxy "remembers" you, and the site not only loads faster, it sometimes even recalls your personal information by automatically filling in your username—or even your billing/shipping information when you place another order.

Caching Proxy Server A caching proxy server speeds up the network's service requests by recovering information from a client's earlier request. Caching proxies keep local copies of the resources requested often, which really helps minimize the upstream use of bandwidth. These servers can greatly enhance network performance.

I want to mention one more thing before we move on from proxies, and this is reverse proxies. Unlike a forward proxy, a reverse proxy takes requests from the Internet and forwards them to servers in an internal network, whereas the forward proxy we discussed in this section takes client requests and sends them to the Internet.

Encryption Devices

Although a number of the devices we have discussed earlier can perform encryption services, there are dedicated appliances that can perform encryption as well. The advantage of using these devices is that they normally provide more choice of encryption methods and stronger encryption options. They also offload the process from other devices like routers and servers, which is a good thing since the encryption/decryption process is very processor intensive and interferes with other functions that those routers and servers might be performing.

Sometimes these devices are called encryption gateways. They can either sit in line with a server or a local network, encrypting and decrypting all traffic, or function as an application server, encrypting any file sent to them within a network. Examples of encryption appliances are shown in Figure 5.20.

FIGURE 5.20 Encryption appliances

While an encryption appliance is dedicated to encryption, a content filtering appliance scans the content of what goes through it and filters out specific content or content types. Dedicating a device to this process offloads the work from servers or routers that could do this but at a cost of greatly slowing the devices. Also, there is usually more functionality and granular control available with a dedicated appliance.

Email is a good example of what you might run through one of these devices to filter out spam and objectionable content before the email is delivered. Another example of the use of a content filter might be to block websites based on the content of the web pages rather than on the basis of the URL or IP address. An example of a dedicated content/URL filtering appliance from SecPoint is shown in Figure 5.21.

FIGURE 5.21 Content filtering appliance

Analog Modem

A modem (modulator-demodulator) is a device that modulates an analog carrier signal to encode digital information and demodulates the signal to decode the transmitted information. I gave you an example of this when I explained APs earlier in the chapter because an AP modulates and demodulates a signal just like a modem. Figure 5.22 shows a current analog modem that can be used in today's networks, albeit with slow throughput.

FIGURE 5.22 Analog modem

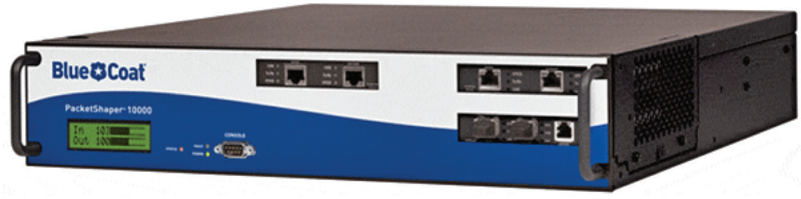
The goal is to produce a signal that can be transmitted easily and decoded to reproduce the original digital data. These signals are transmitted over telephone lines and demodulated by another modem at the receiver side in order to read the digital data.

Because modems connect to phone lines, the location and installation of these devices is fairly cut-and-dried. It will have to be near a phone line, with one end connected to the phone line and another to a computer or modem bank. The analog modem operates at Layer 1, like a repeater.

Packet Shaper

Packet shaping (also known as traffic shaping, it's a form of rate limiting) is an Internetworking traffic management technique that delays some or all packets to bring them into compliance with your or your company's traffic profile. Figure 5.23 shows a dedicated packet shaper appliance from Blue Coat.

FIGURE 5.23 Packet shaper

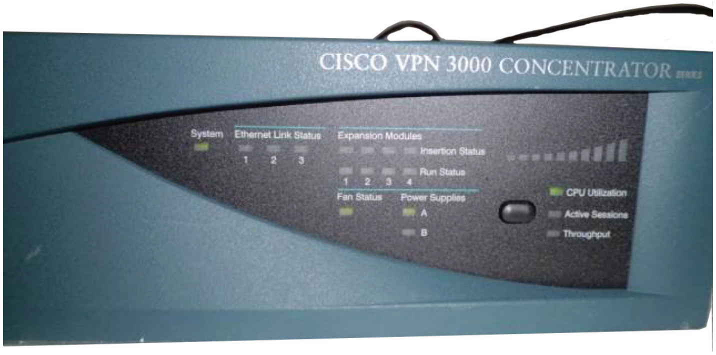


This process is used to optimize or guarantee performance, improve latency, and/or increase usable bandwidth for some kinds of packets by delaying other kinds, decided on by you.

VPN Concentrator

A VPN concentrator is a device that accepts multiple VPN connections from remote locations. Although this function can be performed by a router or server, as with the encryption gateways and content filtering devices discussed earlier, the same performance benefits can be derived from dedicating a device to this. Moreover, additional functionality usually comes with these devices, one of which is shown in Figure 5.24.

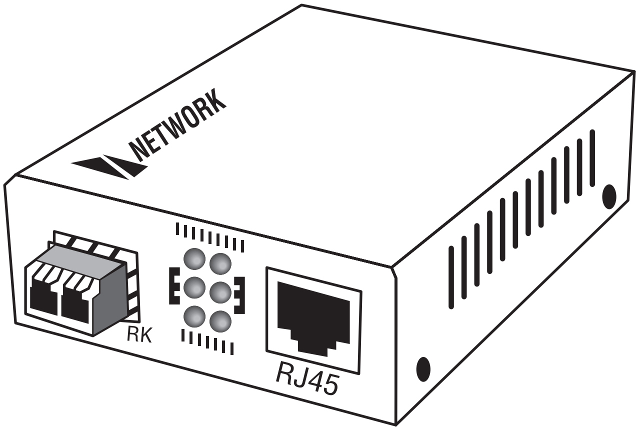
FIGURE 5.24 VPN concentrator



Media Converter

Media converters are used when you need to convert from one type of cabling to another type. This might be required to convert from one type of fiber to another or from Ethernet to fiber, for example. Figure 5.25 shows an Ethernet-to-fiber conversion box. Obviously, the location of these devices depends on where the conversion needs to take place. Media converters operate at Layer 1.

FIGURE 5.25 Media converter



VoIP PBX

A private branch exchange (PBX) is a private telephone switch that resides on the customer premises. It has a direct connection to the telecommunication provider's switch. It performs call routing within the internal phone system. This is how a company can have two "outside" lines but 50 internal phones. The call comes in on one of the two outside lines, and the PBX routes it to the proper extension. Sometimes the system converts analog to digital but not always.

A VoIP PBX is one that switches calls between VoIP (voice over Internet Protocol or IP) users on local lines while allowing all users to share a certain number of external phone lines. The typical IP PBX can also switch calls between a VoIP user and a traditional telephone user, or between two traditional telephone users in the same way that a conventional PBX does.

VoIP Endpoint

VoIP endpoints are desktop phone systems or wireless phone systems that are part of the converged networks where data and voice traffic are now combined in today's networks. These endpoints may also be implemented as conferencing systems in meeting rooms. There is more flexibility and freedom in the location and installation of these systems as more wireless modes of connectivity are introduced for these devices.

NGFW/Layer 7 Firewall

Next-generation firewalls (NGFWs) are a category of devices that attempt to address traffic inspection and application awareness shortcomings of a traditional stateful firewall, without hampering the performance. Although UTM devices also attempt to address these issues, they tend to use separate internal engines to perform individual security functions. This means a packet may be examined several times by different engines to determine whether it should be allowed into the network.

NGFWs are application aware, which means they can distinguish between specific applications instead of allowing all traffic coming in via typical web ports. Moreover, they examine packets only once during the deep packet inspection phase (which is required to detect malware and anomalies).

VoIP Gateway

A VoIP Gateway (Voice over IP Gateway) is a network device that helps to convert voice and fax calls between an IP network and Public Switched Telephone Network (PSTN) in real time. A VoIP gateway can typically support at least two T1/E1 digital channels. Most VoIP gateways feature at least one Ethernet and telephone port. Various protocols, such as MGCP, SIP, or LTP can help to control a gateway.

Planning and Implementing a Basic SOHO Network Using Network Segmentation

It's likely that at some point you'll have to break up one large network into a bunch of smaller ones because user response will have dwindled to a slow crawl as the network grew and grew. With all that growth, your LAN's traffic congestion will have reached epic proportions.

Determining Requirements

When implementing a SOHO network, the first thing to be done is to identify the requirements of the network and the constraints around which you must operate. This should drive your design and device choices. An example set of requirements and constraints might be as follows:

- A small number of computers are needed.
- There is a high need for Internet access.
- Resources need to be shared.
- Wired hosts and wireless hosts will need to communicate with each other.
- Security is very important.

With these constraints in mind, you might find that you'll need more than just a switch and some Cat 5e cabling for this project. There is a need for a router, an AP, and a firewall in this case. In addition, you need to think about compatibility between equipment and the types and brands of equipment to buy as well as environmental issues or limitations.

NOTE

Wireless and security constraints are covered in Chapter 12 and Chapter 15, respectively. Chapter 12 is "Wireless Networking," and Chapter 15 is "Physical Security and Risk."

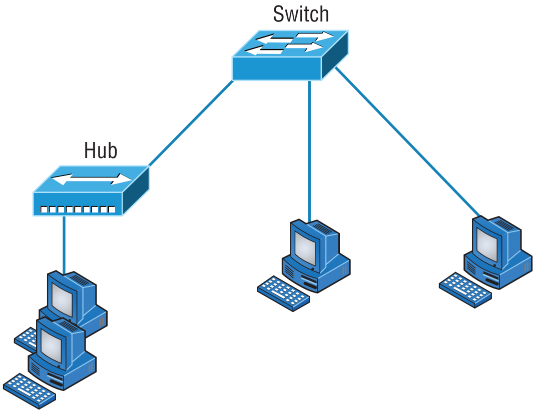
One of the most important considerations you must take very seriously when building a basic network is LAN traffic congestion, which can be lessened with network segmentation and is directly related to device types and compatibility requirements as well as equipment limitations. Let's look at how to use the segmentation devices I have defined so far in this chapter.

Here's a list of some of the nasty things that commonly cause LAN traffic congestion:

- Too many hosts in a broadcast domain
- Broadcast storms
- Multicasting
- Low bandwidth
- Adding hubs for connectivity to the network

The answer to fixing a huge but slow network is to break it up into a number of smaller networks—something called *network segmentation*. You do this by using devices like routers and switches, which are sometimes still referred to as bridges because switches still use bridging technologies. Figure 5.26 displays a network that's been segmented with a switch so each network segment connected to the switch is now a separate collision domain. But make note of the fact that this network is actually still one *broadcast domain*—the set of all devices on a network segment that hear all the broadcasts sent on that segment.

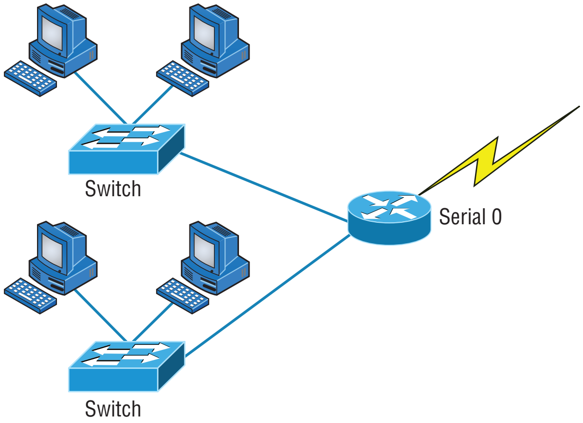
FIGURE 5.26 A switch can replace the hub, breaking up collision domains.



And keep in mind that the hub used in Figure 5.26 just extended the one collision domain from the switch port.

Routers are used to connect networks together and route packets of data from one network to another. (Cisco has become the de facto standard for routers because of its high-quality router products, great selection, and fantastic service.) Routers, by default, break up a broadcast domain. Figure 5.27 shows a router in our little network that creates an internetwork and breaks up broadcast domains.

FIGURE 5.27 Routers create an internetwork.



The network in Figure 5.27 is pretty cool. Each host is connected to its own collision domain, and the router has created two broadcast domains. And don't forget that the router provides connections to WAN services as well. The router uses something called a serial interface for WAN connections: specifically, a V.35 physical interface.

Breaking up a broadcast domain is important because when a host or server sends a network broadcast, every device on the network must read and process that broadcast—unless you've got a router. When the router's interface receives this broadcast, it can respond by basically saying, "Thanks, but no thanks," and discard the broadcast without forwarding it on to other networks. Even though routers are known for breaking up broadcast domains by default, it's important to remember that they break up collision domains as well.

There are two advantages of using routers in your network:

- They don't forward broadcasts by default.
- They can filter the network based on Layer 3 (network layer) information (such as an IP address).

Four router functions in your network can be listed as follows:

- Packet switching
- Packet filtering
- Internetwork communication
- Path selection

Remember that routers are really switches; they're actually what we call Layer 3 switches. Unlike Layer 2 switches, which forward or filter frames, routers (Layer 3 switches) use logical addressing and provide what is called *packet switching*. Routers can also provide packet filtering by using access lists, and when routers connect two or more networks together and use logical addressing (IP or IPv6), this is called an *internetwork*. Last, routers use a *routing table* (map of the internetwork) to make path selections and to forward packets to remote networks.

Conversely, switches aren't used to create internetworks (they do not break up broadcast domains by default); they're employed to add functionality to a network LAN. The main purpose of a switch is to make a LAN work better—to optimize its performance—providing more bandwidth for the LAN's users. And switches don't forward packets to other networks as routers do. Instead, they only "switch" frames from one port to another within the switched network.

By default, switches break up collision domains, as mentioned in Chapter 4, "The Current Ethernet Specifications." *Collision domain* is an Ethernet term used to describe a network scenario wherein one particular device sends a packet on a network segment, forcing every other device on that same segment to pay attention to it. At the same time, a different device tries to transmit, leading to a collision, after which both devices must retransmit, one at a time. Not very efficient! This situation is typically found in a hub environment where each host segment connects to a hub that represents only one collision domain and only one broadcast domain. By contrast, each and every port on a switch represents its own collision domain.

NOTE Switches create separate collision domains but a single broadcast domain. Routers provide a separate broadcast domain for each interface.

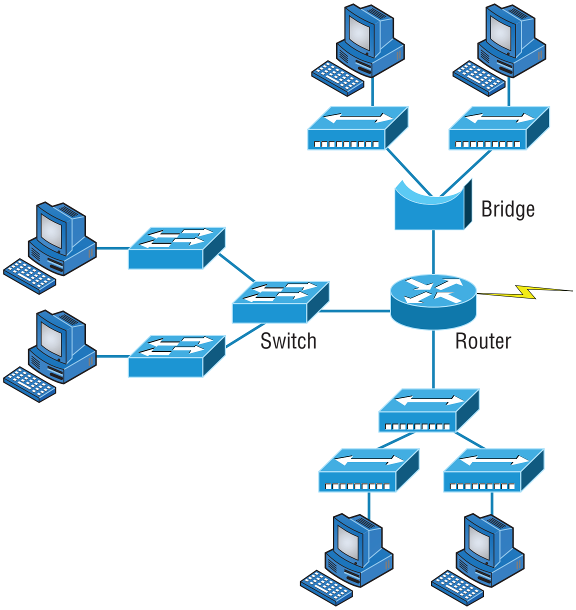
The term *bridging* was introduced before routers and hubs were implemented, so it's pretty common to hear people referring to bridges as switches. That's because bridges and switches basically do the same thing—break up collision domains on a LAN. (In reality, you cannot buy a physical bridge these days, only LAN switches, but these switches use bridging technologies.)

So this means a switch is basically just a multiple-port bridge with more brainpower, right? Well, pretty much, but there are differences. Switches do provide this function, but they do so with greatly enhanced management ability and features. Plus, most of the time, bridges only had two or four ports. Yes, you could get your hands on a bridge with up to 16 ports, but that's nothing compared to the hundreds available on some switches.

NOTE You would use a bridge in a network to reduce collisions within broadcast domains and to increase the number of collision domains in your network. Doing this provides more bandwidth for users. And keep in mind that using hubs in your network can contribute to congestion on your Ethernet network. As always, plan your network design carefully!

Figure 5.28 shows how a network would look with all these internetwork devices in place. Remember that the router will not only break up broadcast domains for every LAN interface but also break up collision domains.

FIGURE 5.28 Internetworking devices



When you look at Figure 5.28, do you see the router at center stage and see how it connects each physical network together? We have to use this layout because of the older technologies involved—bridges and hubs.

On the top internetwork in Figure 5.28, you'll notice that a bridge is used to connect the hubs to a router. The bridge breaks up collision domains, but all the hosts connected to both hubs are still crammed into the same broadcast domain. Also, the bridge creates only two collision domains, so each device connected to a hub is in the same collision domain as every other device connected to that same hub. This is actually pretty lame, but it's still better than having one collision domain for all hosts.

Notice something else: The three hubs at the bottom that are connected also connect to the router, creating one collision domain and one broadcast domain. This makes the bridged network look much better indeed.

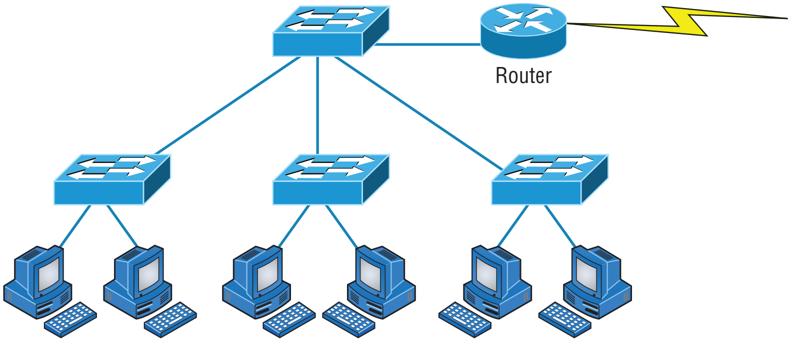
NOTE

Although bridges/switches are used to segment networks, they will not isolate broadcast or multicast packets.

The best network connected to the router is the LAN switch network on the left. Why? Because each port on that switch breaks up collision domains. But it's not all good—all devices are still in the same broadcast domain. Do you remember why this can be a really bad thing? Because all devices must listen to all broadcasts transmitted, that's why. And if your broadcast domains are too large, the users have less bandwidth and are required to process more broadcasts, and network response time will slow to a level that could cause office riots.

Once we have only switches in our network, things change a lot. Figure 5.29 shows the network that is typically found today.

FIGURE 5.29 Switched networks creating an internetwork



Here I've placed the LAN switches at the center of the network world so the router is connecting only logical networks together. If I implement this kind of setup, I've created virtual LANs (VLANs), something I'm going to tell you about in Chapter 11. So don't stress. But it is really important to understand that even though you have a switched network, you still need a router to provide your inter-VLAN communication, or internetworking. Don't forget that.

Obviously, the best network is one that's correctly configured to meet the business requirements of the company it serves. LAN switches with routers, correctly placed in the network, are the best network design. This book will help you understand the basics of routers and switches so you can make tight, informed decisions on a case-by-case basis.

Let's go back to Figure 5.28 again. Looking at the figure, how many collision domains and broadcast domains are in this internetwork? I hope you answered nine collision domains and three broadcast domains.

The broadcast domains are definitely the easiest to see because only routers break up broadcast domains by default. And because there are three connections, that gives you three broadcast domains. But do you see the nine collision domains? Just in case that's a no, I'll explain. The all-hub network is one collision domain; the bridge network equals three collision domains. Add in the switch network of five collision domains—one for each switch port—and you've got a total of nine.

Now, in Figure 5.29, each port on the switch is a separate collision domain and each VLAN is a separate broadcast domain. But you still need a router for routing between VLANs. How many collision domains do you see here? I'm counting 10—remember that connections between the switches are considered collision domains.

Real World Scenario

Should I Replace All My Hubs with Switches?

You're a network administrator at a large company in San Jose. The boss comes to you and says that he got your requisition to buy a switch and is not sure about approving the expense; do you really need it?

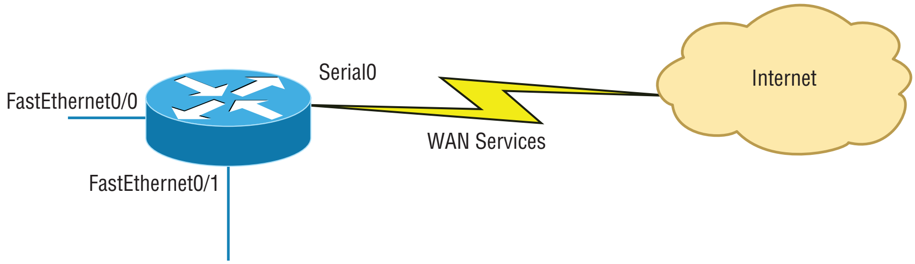
Well, if you can have it, sure—why not? Switches really add a lot of functionality to a network that hubs just don't have. But most of us don't have an unlimited budget. Hubs still can create a nice network—that is, of course, if you design and implement the network correctly.

Let's say that you have 40 users plugged into four hubs, 10 users each. At this point, the hubs are all connected together so that you have one large collision domain and one large broadcast domain. If you can afford to buy just one switch and plug each hub into a switch port, as well as plug the servers into the switch, then you now have four collision domains and one broadcast domain. Not great; but for the price of one switch, your network is a much better thing. So, go ahead! Put that requisition in to buy all new switches. What do you have to lose?

So now that you've gotten an introduction to internetworking and the various devices that live in an internetwork, it's time to head into internetworking models.

As I mentioned earlier, routers break up broadcast domains, which means that by default, broadcasts aren't forwarded through a router. Do you remember why this is a good thing? Routers break up collision domains, but you can also do that using Layer 2 (Data Link layer) switches. Because each interface in a router represents a separate network, it must be assigned unique network identification numbers, and each host on the network connected to that router must use the same network number. Figure 5.30 shows how a router works in an internetwork.

FIGURE 5.30 A router in an internetwork



Here are some points about routers that you should commit to memory:

- Routers, by default, will not forward any broadcast or multicast packets.
- Routers use the logical address in a Network layer header to determine the next hop router to forward the packet to.

- Routers can use access lists, created by an administrator, to control security on the types of packets that are allowed to enter or exit an interface.
- Routers can provide Layer 2 bridging functions if needed and can simultaneously route through the same interface.
- Layer 3 devices (routers, in this case) provide connections between virtual LANs (VLANs).
- Routers can provide quality of service (QoS) for specific types of network traffic.

Switching and VLANs are covered in Chapter 11.

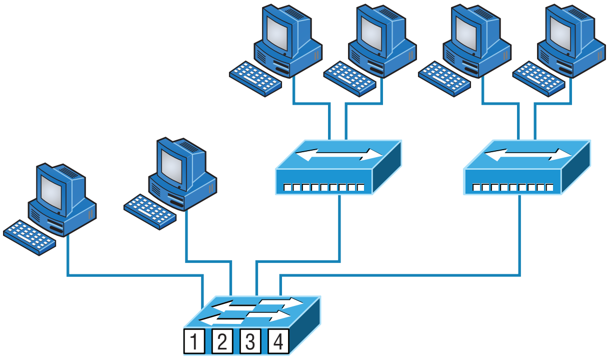
Switches and Bridges at the Data Link Layer

Layer 2 switching is considered hardware-based bridging because it uses specialized hardware called an *application-specific integrated circuit (ASIC)*. ASICs can run up to gigabit speeds with very low latency rates.

Latency is the time measured from when a frame enters a port to when it exits.

Bridges and switches read each frame as it passes through the network. The Layer 2 device then puts the source hardware address in a filter table and keeps track of which port the frame was received on. This information (logged in the bridge's or switch's filter table) is what helps the machine determine the location of the specific sending device. Figure 5.31 shows a switch in an internetwork.

FIGURE 5.31 A switch in an internetwork



Each segment has its own collision domain.
All segments are in the same broadcast domain.

The real estate business is all about location, location, location, and it's the same way for both Layer 2 and Layer 3 devices. Although both need to be able to negotiate the network, it's crucial to remember that they're concerned with very different parts of it. Primarily, Layer 3 machines (such as routers) need to locate specific networks, whereas Layer 2 machines (switches and bridges) need to eventually locate specific devices. So, networks are to routers as individual devices are to switches and bridges. And routing tables that "map" the internetwork are for routers as filter tables that "map" individual devices are for switches and bridges.

After a filter table is built on the Layer 2 device, it will forward frames only to the segment where the destination hardware address is located. If the destination device is on the same segment as the frame, the Layer 2 device will block the frame from going to any other segments. If the destination is on a different segment, the frame can be transmitted only to that segment. This is called *transparent bridging*.

When a switch interface receives a frame with a destination hardware address that isn't found in the device's filter table, it will forward the frame to all connected segments. If the unknown device that was sent the "mystery frame" replies to this forwarding action, the switch updates its filter table regarding that device's location. But in the event that the destination address of the transmitting frame is a broadcast address, the switch will forward all broadcasts to every connected segment by default.

All devices that the broadcast is forwarded to are considered to be in the same broadcast domain. This can be a problem; Layer 2 devices propagate Layer 2 broadcast storms that choke performance, and the only way to stop a broadcast storm from propagating through an internetwork is with a Layer 3 device—a router.

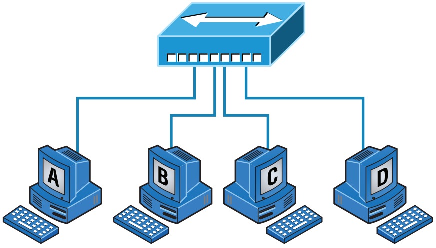
The biggest benefit of using switches instead of hubs in your internetwork is that each switch port is actually its own collision domain. (Conversely, a hub creates one large collision domain.) But even armed with a switch, you still can't break up broadcast domains. Neither switches nor bridges will do that. They'll typically simply forward all broadcasts instead.

Another benefit of LAN switching over hub-centered implementations is that each device on every segment plugged into a switch can transmit simultaneously—at least they can as long as there is only one host on each port and a hub isn't plugged into a switch port. As you might have guessed, hubs allow only one device per network segment to communicate at a time.

Hubs at the Physical Layer

As you know, a hub is really a multiple-port repeater. A repeater receives a digital signal, reamplifies or regenerates that signal, and then forwards the digital signal out all active ports without looking at any data. An active hub does the same thing. Any digital signal received from a segment on a hub port is regenerated or reamplified and transmitted out all ports on the hub. This means all devices plugged into a hub are in the same collision domain as well as in the same broadcast domain. Figure 5.32 shows a hub in a network.

FIGURE 5.32 A hub in a network



All devices are in the same collision domain.
All devices are in the same broadcast domain.
Devices share the same bandwidth.

Hubs, like repeaters, don't examine any of the traffic as it enters and is then transmitted out to the other parts of the physical media. Every device connected to the hub, or hubs, must listen if a device transmits. A physical star network—where the hub is a central device and cables extend in all directions out from it—is the type of topology a hub creates. Visually, the design really does resemble a star, whereas Ethernet networks run a logical bus topology, meaning that the signal has to run through the network from end to end.

NOTE Hubs and repeaters can be used to enlarge the area covered by a single LAN segment, although I do not recommend this. LAN switches and/or wireless APs are affordable for almost every situation.

Environmental Considerations

All of the equipment discussed in this chapter—switches, routers, hubs, and so on—require proper environmental conditions to operate correctly. These devices have the same needs as any computing device. The environmental concerns can be categorized thusly:

Temperature Like any device with a CPU, infrastructure devices such as routers, switches, and specialty appliances must have a cool area to operate. When temperatures rise, servers start rebooting and appliance CPUs start overworking as well. The room(s) where these devices are located should be provided with heavy-duty HVAC systems and ample ventilation. It may even be advisable to dedicate a suite for this purpose and put the entire system on a UPS with a backup generator in the case of a loss of power.

Humidity The air around these systems can be neither too damp nor too dry; it must be "just right." If it is too dry, static electricity will build up in the air, making the situation ripe for damaging a system. It takes very little static electricity to fry some electrical components. If it is too damp, connections start corroding and shorts begin to occur. A humidifying system should be used to maintain the level above 50 percent. The air conditioning should keep it within acceptable levels on the upper end.

Summary

Whew, this chapter covered quite a bit of information. You learned the difference between a router, a switch (bridge), and a hub and when to use each one. I also covered some devices that you might find in a network today, but not as often, such as VPN concentrators and content filters.

The information I discussed about DNS and DHCP is critical to your success on the Network+exam, and I highly suggest that you reread those sections. I covered how both the DNS and DHCP services work on a network.

In addition to the most common devices, I discussed the specialized network devices mentioned in the Network+objectives. I finished the chapter by discussing collision and broadcast domains in detail as well as how you would use a router, switch, and hub in your networks today.

All of the information in this chapter is fundamental, and you must understand it before moving on to the other chapters in this book.

Exam Essentials

Understand how DHCP works and its purpose. Dynamic Host Configuration Protocol (DHCP) provides IP configuration information to hosts. It is important to know how a DHCP client requests information from a server, how a server receives this information, and also how the server responds to the client and with what type of information.

Understand how DNS works and its purpose. Domain Name Service (DNS) is used to resolve human names to IP addresses. Understanding how DNS resolves these names is critical, as is understanding how a DNS query is sent and how a DNS server responds.

Understand the difference between a hub, a switch (bridge), and a router. A hub just connects network segments together. A switch/bridge segments the network using MAC addresses, and a router segments the network using logical addressing (IP and IPv6). Switches break up collision domains, and routers break up broadcast domains by default.

Remember the different names for a router. A router is a Layer 3 hardware device, but it can also be called a Layer 3 switch or a multilayer switch.

Remember the various devices used on networks today and when you would use each one and how. Understand the differences and how each device works: routers, switches, hubs, DNS servers, and DHCP servers.

Identify the purpose, benefits, and characteristics of using a proxy service. A proxy server keeps a LAN somewhat separated from the Internet. Doing so increases security and filtering control and has the tendency to speed up Internet access through caching of recently used web pages.

Describe the proper use of network segmentation when planning and implementing a basic SOHO network. Understand and apply the concepts of proper network segmentation when planning the use of various devices in the design of a SOHO network.

Describe the benefits of using dedicated appliances for certain services. Using appliances to offload functions such as encryption, content filtering, and VPN concentration can decrease the workload of other systems and add functionality that may be present in these dedicated devices.

Identify the environmental requirements of infrastructure devices. A cool temperature, ample ventilation, and the proper humidity level are all key to maintaining the operation of devices like routers, switches, and appliances.

Written Lab

Complete the table by filling in the appropriate layer of the OSI or hub, switch, or router device. You can find the answers in Appendix A.

Description	Device or OSI layer
This device sends and receives information about the Network layer.	
This layer creates a virtual circuit before transmitting between two end stations.	
A Layer 3 switch or multilayer switch.	
This device uses hardware addresses to filter a network.	
Ethernet is defined at these layers.	
This layer supports flow control and sequencing.	
This device can measure the distance to a remote network.	
Logical addressing is used at this layer.	
Hardware addresses are defined at this layer.	
This device creates one big collision domain and one large broadcast domain.	
This device creates many smaller collision domains, but the network is still one large broadcast domain.	
This device can never run full duplex.	
This device breaks up collision domains and broadcast domains.	

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following is not a term used when making SOHO Internet connections?
   - A. Hub
   - B. Router
   - C. NIC
   - D. Switch

2. What advantage does a switch have over a hub?
   - A. It discards frames.
   - B. Transmissions received on one port will be sent out all the other ports.
   - C. It recognizes frame boundaries and destination MAC addresses of incoming frames.
   - D. Any two or more devices the switch connects are capable of causing a collision with each other.

3. Which device is used to segment a network?
   - A. Hub
   - B. Switch
   - C. Repeater
   - D. All of the above

4. What is the primary function of a bridge?
   - A. Breaks up collision domains
   - B. Allows a NIC or other networking device to connect to a different type of media than it was designed for
   - C. Allows mobile users to connect to a wired network wirelessly
   - D. None of the above

5. A network device that is used to connect multiple devices together without segmenting a network is a ___________.
   - A. Hub
   - B. Wireless access point
   - C. Switch
   - D. Router

6. Which of the following is among the benefits of a switch?
   A. Protects LAN resources from attackers on the Internet
   B. Provides extra bandwidth
   C. Reduces throughput
   D. Allows access to all computers on a LAN

7. Which of the following devices can work at both Layers 2 and 3 of the OSI model?
   A. Hub
   B. Switch
   C. Multilayer switch
   D. Bridge

8. What is an advantage of using DHCP in a network environment?
   A. More difficult administration of the network
   B. Static IP addressing
   C. Can send an operating system for the PC to boot from
   D. Assigns IP address to hosts

9. What is a benefit of a multilayer switch (MLS) over a Layer 2 switch?
   A. Less bandwidth
   B. Routing functions
   C. Fewer features
   D. Fewer ports

10. Which device should be used if you need to send incoming packets to one or more machines that are hidden behind a single IP address?
    A. Switch
    B. Load balancer
    C. Hub
    D. Repeater

11. What role does the A record in a Domain Name Service (DNS) server have in your network?
    A. Translates human name to IP address
    B. Translates IP address to human name
    C. Enables printing, copying, and faxing from one device
    D. Controls network packets to optimize performance

12. Which device does not aid in network segmentation?

- **A.** Router
- **B.** Switch
- **C.** Hub
- **D.** Bridge

13. What is the most common use for a web proxy?

- **A.** Web cache
- **B.** Throughput increase
- **C.** DHCP services
- **D.** Support for user authentication

14. Which is not an advantage of network segmentation?

- **A.** Reducing congestion
- **B.** Improving security
- **C.** Containing network problems
- **D.** Preventing broadcast storms

15. Users arrive at the office after a weekend and the hosts that were shut down over the weekend are restarted but cannot access the LAN or Internet. Hosts that were not shut down are working fine. Where can the problem be?

- **A.** The DNS server
- **B.** The DHCP server
- **C.** The proxy server
- **D.** The firewall

16. You need a device that can prevent your users from accessing certain websites. Which device should you install?

- **A.** Firewall
- **B.** IDS
- **C.** IPS
- **D.** Proxy server

17. Which device creates separate collision domains and a single broadcast domain?

- **A.** Hub
- **B.** Router
- **C.** Switch
- **D.** Modem

18. Which of the following is *not* an advantage of using appliances to offload services like encryption and content filtering?

    A. Less expensive

    B. Reduced load on other devices

    C. Additional functionality

    D. Better performance

19. Which type of server in your network uses pointer and A records?

    A. NAT translation server

    B. IPS/IDS server

    C. DNS server

    D. Proxy server

20. Users on your network are saturating your bandwidth because they are using too many non-work-related sites. What device would limit the availability of the types of sites that users on a LAN have access to while providing granular control over the traffic between the local LAN and the Internet?

    A. Switch

    B. DHCP server

    C. DNS server

    D. Proxy server

Chapter

6

Introduction to the Internet Protocol

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.1 Explain the purposes and uses of ports and protocols**

- Protocols and ports
    - SSH 22
    - DNS 53
    - SMTP 25
    - SFTP 22
    - FTP 20, 21
    - TFTP 69
    - TELNET 23
    - DHCP 67, 68
    - HTTP 80
    - HTTPS 443
    - SNMP 161
    - RDP 3389
    - NTP 123
    - SIP 5060, 5061
    - SMB 445
    - POP 110
    - IMAP 143
- LDAP 389
- LDAPS 636
- H.323 1720
- Protocol types
    - ICMP
    - UDP

  - TCP
  - IP
- Connection-oriented vs. connectionless

✓ **1.2 Explain devices, applications, protocols and services at their appropriate OSI layers.**

- Layer 1 – Physical
- Layer 2 – Data link
- Layer 3 – Network
- Layer 4 – Transport
- Layer 5 – Session
- Layer 6 – Presentation
- Layer 7 – Application

✓ **1.3 Explain the concepts and characteristics of routing and switching.**

  - Properties of network traffic
  - Broadcast domains
  - Collision domains
  - Protocol data units
  - Broadcast
  - Multicast
  - Unicast

✓ **1.8 Explain the functions of network services.**

  - NTP

✓ **3.4 Given a scenario, use remote access methods.**

- Telnet
- HTTPS/management URL
- Remote file access
  - FTP/FTPS
  - SFTP
  - TFTP

✓ **4.5 Given a scenario, implement network device hardening.**

- Using secure protocols

The Transmission Control Protocol/Internet Protocol (TCP/IP) suite was created by the Department of Defense (DoD) to ensure and preserve data integrity as well as to maintain communications in the event of catastrophic war.

So it follows that if designed and implemented correctly, a TCP/IP network can truly be a solid, dependable, and resilient network solution. In this chapter, I'll cover the protocols of TCP/IP.

I'll begin by covering the DoD's version of TCP/IP and then compare this version and its protocols with the OSI reference model discussed in Chapter 2, "The Open Systems Interconnection Specifications."

After going over the various protocols found at each layer of the DoD model, I'll finish the chapter by adding more detail to the explanation of data encapsulation that I started in Chapter 2.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Introducing TCP/IP

Because TCP/IP is so central to working with the Internet and intranets, it's essential for you to understand it in detail. I'll begin by giving you some background on TCP/IP and how it came about and then move on to describe the important technical goals defined by the original designers. After that, you'll find out how TCP/IP compares to a theoretical model—the Open Systems Interconnection (OSI) model.

A Brief History of TCP/IP

The very first Request for Comments (RFC) was published in April 1969, which paved the way for today's Internet and its protocols. Each of these protocols is specified in the multitude of RFCs, which are observed, maintained, sanctioned, filed, and stored by the Internet Engineering Task Force (IETF).

TCP first came on the scene in 1974. In 1978, it was divided into two distinct protocols, TCP and IP, and finally documented into an RFC in 1980. Then, in 1983, TCP/IP replaced the Network Control Protocol (NCP) and was authorized as the official means of data transport for anything connecting to ARPAnet. ARPAnet was the Internet's ancestor, created by ARPA, the DoD's Advanced Research Projects Agency, again, way back in 1969 in reaction to the Soviets' launching of *Sputnik*. ARPA was soon redubbed DARPA, and it was divided into ARPAnet and MILNET (also in 1983); both were finally dissolved in 1990.

But contrary to what you might think, most of the development work on TCP/IP happened at UC Berkeley in Northern California, where a group of scientists were simultaneously working on the Berkeley version of Unix, which soon became known as the BSD, or the Berkeley Software Distribution series of Unix versions. Of course, because TCP/IP worked so well, it was packaged into subsequent releases of BSD Unix and offered to other universities and institutions if they bought the distribution tape. Basically, BSD Unix bundled with TCP/IP began as shareware in the world of academia and, as a result, became the basis of the huge success and exponential growth of today's Internet as well as smaller, private, and corporate intranets.

As usual, what may have started as a small group of TCP/IP aficionados evolved, and as it did, the U.S. government created a program to test any new published standards and make sure they passed certain criteria. This was to protect TCP/IP's integrity and to ensure that no developer changed anything too dramatically or added any proprietary features. It's this very quality—this open-systems approach to the TCP/IP family of protocols—that pretty much sealed its popularity because it guarantees a solid connection between myriad hardware and software platforms with no strings attached.

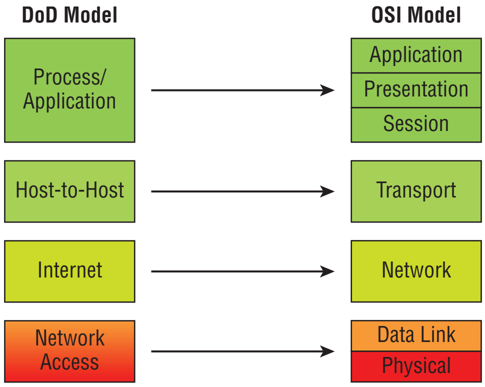
TCP/IP and the DoD Model

The DoD model is basically a condensed version of the OSI model; it's composed of four, instead of seven, layers:

- Process/Application layer
- Host-to-Host layer
- Internet layer
- Network Access layer

Figure 6.1 shows a comparison of the DoD model and the OSI reference model. As you can see, the two are similar in concept, but each has a different number of layers with different names.

FIGURE 6.1 The DoD and OSI models



When the different protocols in the IP stack are discussed, two layers of the OSI and DoD models are interchangeable. In other words, the Internet layer and the Network layer describe the same thing, as do the Host-to-Host layer and the Transport layer. The other two layers of the DoD model, Process/Application and Network Access, are composed of multiple layers of the OSI model.

A vast array of protocols operate at the DoD model's *Process/Application layer* to integrate the various activities and duties spanning the focus of the OSI's corresponding top three layers (Application, Presentation, and Session). We'll be looking closely at those protocols in the next part of this chapter. The Process/Application layer defines protocols for node-to-node application communication and also controls user-interface specifications.

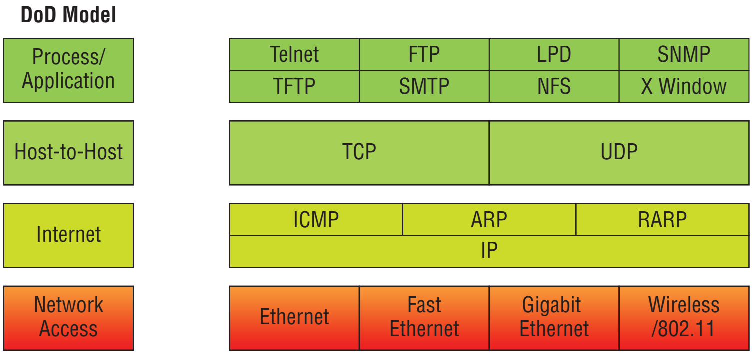
The *Host-to-Host layer* parallels the functions of the OSI's Transport layer, defining protocols for setting up the level of transmission service for applications. It tackles issues such as creating reliable end-to-end communication and ensuring the error-free delivery of data. It handles packet sequencing and maintains data integrity.

The *Internet layer* corresponds to the OSI's Network layer, designating the protocols relating to the logical transmission of packets over the entire network. It takes care of the logical addressing of hosts by giving them an IP address, and it handles the routing of packets among multiple networks.

At the bottom of the DoD model, the *Network Access layer* monitors the data exchange between the host and the network. The equivalent of the Data Link and Physical layers of the OSI model, the Network Access layer oversees hardware addressing and defines protocols for the physical transmission of data.

The DoD and OSI models are alike in design and concept and have similar functions in similar layers. Figure 6.2 shows the TCP/IP protocol suite and how its protocols relate to the DoD model layers.

FIGURE 6.2 The TCP/IP protocol suite



We'll now look at the different protocols in more detail, starting with the Process/Application layer protocols.

The Process/Application Layer Protocols

In the following sections, I'll describe the different applications and services typically used in IP networks and list their associated port numbers as well, which are discussed in detail in this chapter.

Telnet (TCP 23)

Telnet is the chameleon of protocols—its specialty is terminal emulation. It allows a user on a remote client machine, called the Telnet client, to access the resources of another machine, the Telnet server. Telnet achieves this by pulling a fast one on the Telnet server and making the client machine appear as though it were a terminal directly attached to the local network. This projection is actually a software shell—a virtual terminal that can interact with the chosen remote host.

These emulated terminals are of the text-mode type and can execute refined procedures such as displaying menus that give users the opportunity to choose options and access the applications on the duped server. Users begin a Telnet session by running the Telnet client software and then logging into the Telnet server.

Telnet offers no security or encryption and is replaced by Secure Shell (SSH) when security across the remote-configuration session is needed or desired.

File Transfer Protocol (TCP 20, 21)

File Transfer Protocol (FTP) is the protocol that actually lets you transfer files across an IP network, and it can accomplish this between any two machines that are using it. But FTP isn't just a protocol; it's also a program. Operating as a protocol, FTP is used by applications. As a program, it's employed by users to perform file tasks by hand. FTP also allows for access to both directories and files and can accomplish certain types of directory operations, such as relocating files into different directories.

Accessing a host through FTP is only the first step, though. Users must then be subjected to an authentication login that's probably secured with passwords and usernames implemented by system administrators to restrict access. You can get around this somewhat by adopting the username *anonymous*—although what you'll gain access to will be limited.

Even when employed by users manually as a program, FTP's functions are limited to listing and manipulating directories, typing file contents, and copying files between hosts. It can't execute remote files as programs. The problem with FTP is that all data is sent in clear text, just as with Telnet. If you need to make sure your FTP transfers are secure, then you'll use SFTP.

Secure File Transfer Protocol (TCP 22)

Secure File Transfer Protocol (SFTP) is used when you need to transfer files over an encrypted connection. It uses an SSH session (more on this later), which encrypts the connection, and SSH uses port 22, hence the port 22 for SFTP. Apart from the secure part, it's used just as FTP is—for transferring files between computers on an IP network, such as the Internet.

Trivial File Transfer Protocol (UDP 69)

Trivial File Transfer Protocol (TFTP) is the stripped-down, stock version of FTP, but it's the protocol of choice if you know exactly what you want and where to find it—plus it's easy to use, and it's fast, too! It doesn't give you the abundance of functions that FTP does, though. TFTP has no directory-browsing abilities; it can do nothing but send and receive files. This compact little protocol also skimps in the data department, sending much smaller blocks of data than FTP, and there's no authentication as with FTP, so it's insecure. Few sites support it because of the inherent security risks.

Real World Scenario

When Should You Use FTP?

The folks at your San Francisco office need a 50 MB file emailed to them right away. What do you do? Most email servers would reject the email because they have size limits. Even if there's no size limit on the server, it would still take a while to send this big file. FTP to the rescue! Most ISPs don't allow files larger than 10 MB to be emailed, so FTP is an option you should consider if you need to send and receive.

If you need to give someone a large file or you need to get a large file from someone, FTP is a nice choice. Smaller files (smaller than 10 MB) can be sent via email if you have the bandwidth (who doesn't these days?), even if they're compressed. To use FTP, you'll need to set up an FTP server on the Internet so that the files can be shared.

Besides, FTP is faster than email, which is another reason to use FTP for sending or receiving large files. In addition, because it uses TCP and is connection-oriented, if the session dies, FTP can sometimes start up where it left off. Try that with your email client!

Simple Mail Transfer Protocol (TCP 25)

Simple Mail Transfer Protocol (SMTP), answering our ubiquitous call to email, uses a spooled, or queued, method of mail delivery. Once a message has been sent to a destination, the message is spooled to a device—usually a disk. The server software at the destination posts a vigil, regularly checking the queue for messages. When it detects them, it proceeds to deliver them to their destination. SMTP is used to send mail; POP3 is used to receive mail.

Post Office Protocol (TCP 110)

Post Office Protocol (POP) gives us a storage facility for incoming mail, and the latest version is called POP3 (sound familiar?). Basically, how this protocol works is when a client device connects to a POP3 server, messages addressed to that client are released for downloading. It doesn't allow messages to be downloaded selectively, but once they are, the client-server interaction ends and you can delete and tweak your messages locally at will. A newer standard, IMAP, is being used more and more in place of POP3. Why?

Internet Message Access Protocol, Version 4 (TCP 143)

Because *Internet Message Access Protocol (IMAP)* makes it so you get control over how you download your mail, with it, you also gain some much-needed security. It lets you peek at the message header or download just a part of a message—you can now just nibble at the bait instead of swallowing it whole and then choking on the hook hidden inside!

With it, you can choose to store messages on the email server hierarchically and link to documents and user groups, too. IMAP even gives you search commands to use to hunt for messages based on their subject, header, or content. As you can imagine, it has some serious authentication features—it actually supports the Kerberos authentication scheme that MIT developed. And yes, IMAP4 is the current version.

Remote Desktop Protocol (TCP 3389)

Remote Desktop Protocol (RDP) is a proprietary protocol developed by Microsoft. It allows you to connect to another computer and run programs. RDP operates somewhat like Telnet, except instead of getting a command-line prompt as you do with Telnet, you get the actual graphical user interface (GUI) of the remote computer. Clients exist for most versions of Windows, and Macs now come with a preinstalled RDP client.

Microsoft currently calls its official RDP server software Remote Desktop Services; it was called Terminal Services for a while. Microsoft's official client software is currently referred to as Remote Desktop Connection, which was called Terminal Services Client in the past.

RDP is an excellent tool for remote clients, allowing them to connect to their work computer from home, for example, and get their email or perform work on other applications without running or installing any of the software on their home computer.

Transport Layer Security/Secure Sockets Layer (TCP 995/465)

Both *Transport Layer Security (TLS)* and its forerunner, Secure Sockets Layer (SSL), are cryptographic protocols that come in really handy for enabling secure online data-transfer activities like browsing the Web, instant messaging, Internet faxing, and so on. They're so similar that it's not within the scope of this book to detail the differences between them. They both use X.509 certificates and asymmetric cryptography to authenticate to the host they are communicating with and to exchange a key. This key is then used to encrypt data flowing between the hosts. This allows for data/message confidentiality, message integrity, and message authentication.

Even though I listed TLS/SSL as using ports 995 and 465, which is true if you're using Gmail, TLS/SSL isn't tied down to any certain ports and can use various different ones.

SIP (VoIP) (TCP or UDP 5060/TCP 5061)

Session Initiation Protocol (SIP) is a hugely popular signaling protocol used to construct and deconstruct multimedia communication sessions for many things like voice and video calls, videoconferencing, streaming multimedia distribution, instant messaging, presence information, and online games over the Internet.

RTP (VoIP) (UDP 5004/TCP 5005)

Real-time Transport Protocol (RTP) describes a packet-formatting standard for delivering audio and video over the Internet. Although initially designed as a multicast protocol, it's now used for unicast applications, too. It's commonly employed for streaming media, videoconferencing, and push-to-talk systems—all things that make it a de facto standard in Voice over IP (VoIP) industries.

MGCP (Multimedia) (TCP 2427/2727)

Media Gateway Control Protocol (MGCP) is a standard protocol for handling the signaling and session management needed during a multimedia conference.

The protocol defines a means of communication between a media gateway, which converts data from the format required for a circuit-switched network to that required for a packet-switched network, and the media gateway controller.

MGCP can be used to set up, maintain, and terminate calls between multiple endpoints.

H.323 (Video) (TCP 1720)

H.323 is a protocol that provides a standard for video on an IP network that defines how real-time audio, video, and data information is transmitted. This standard provides signaling, multimedia, and bandwidth control mechanisms. H.323 uses the RTP standard for communication.

Simple Network Management Protocol (UDP 161)

Simple Network Management Protocol (SNMP) collects and manipulates valuable network information. It gathers data by polling the devices on the network from a management station at fixed or random intervals, requiring them to disclose certain information. When all is well, SNMP receives something called a *baseline*—a report delimiting the operational traits of a healthy network. This protocol can also stand as a watchdog over the network, quickly notifying managers of any sudden turn of events. The network watchdogs are called *agents*, and when aberrations occur, agents send an alert called a *trap* to the management station. In addition, SNMP can help simplify the process of setting up a network as well as the administration of your entire internetwork.

SNMP Versions 1, v2, and 3

SNMP versions 1 and 2 are pretty much obsolete. This doesn't mean you won't see them in a network at some time, but v1 is super old and, well, outdated. SNMPv2 provided improvements, especially in performance. But one of the best additions was what was called GETBULK, which allowed a host to retrieve a large amount of data at once. However, v2 never really caught on in the networking world. SNMPv3 is now the standard and uses both TCP and UDP, unlike v1, which used only UDP. Version 3 added even more security and message integrity, authentication, and encryption. So, be careful when running SNMPv1 and v2 because they are susceptible to a packet sniffer reading the data.

Secure Shell (TCP 22)

Secure Shell (SSH) protocol sets up a secure Telnet session over a standard TCP/IP connection and is employed for doing things like logging into other systems, running programs on remote systems, and moving files from one system to another. And it does all of this while maintaining a nice, strong, encrypted connection. You can think of it as the new-generation protocol that's now used in place of `rsh` and `rlogin`—even Telnet.

Hypertext Transfer Protocol (TCP 80)

All those snappy websites comprising a mélange of graphics, text, links, and so on—the *Hypertext Transfer Protocol (HTTP)* is making it all possible. It's used to manage communications between web browsers and web servers, and it opens the right resource when you click a link, wherever that resource may actually reside.

Hypertext Transfer Protocol Secure (TCP 443)

Hypertext Transfer Protocol Secure (HTTPS) is a secure version of HTTP that arms you with a whole bunch of security tools for keeping transactions between a web browser and a server secure. It's what your browser needs to fill out forms, sign in, authenticate, and encrypt an HTTP message when you make a reservation or buy something online.

NOTE

Both SSH (port 22) and HTTPS (port 443) are used to encrypt packets over your intranet and the Internet.

Network Time Protocol (UDP 123)

Kudos to Professor David Mills of the University of Delaware for coming up with this handy protocol that's used to synchronize the clocks on our computers to one standard time source (typically, an atomic clock). *Network Time Protocol (NTP)* works in conjunction with other synchronization utilities to ensure that all computers on a given network agree on the time. This may sound pretty simple, but it's very important because so many of the transactions done today are time- and date-stamped. Think about your precious databases, for one. It can mess up a server pretty badly if it's out of sync with the machines connected to it, even by mere seconds (think crash!). You can't have a transaction entered by a machine at, say, 1:50 a.m. when the server records that transaction as having occurred at 1:45 a.m. So basically, NTP works to prevent "back to the future sans DeLorean" from bringing down the network—very important indeed!

Lightweight Directory Access Protocol (TCP 389)

If you're the system administrator of any decent-sized network, odds are you have a type of directory in place that keeps track of all your network resources, such as devices and users. But how do you access those directories? Through the *Lightweight Directory Access Protocol (LDAP)*, that's how. This protocol standardizes how you access directories, and its first and second inceptions are described in RFCs 1487 and 1777, respectively. There were a few glitches in those two earlier versions, so a third version—the one most commonly used today—was created to address those issues and is described in RFC 3377.

Internet Group Management Protocol

Internet Group Management Protocol (IGMP) is the TCP/IP protocol used for managing IP multicast sessions. It accomplishes this by sending out unique IGMP messages over the network to reveal the multicast-group landscape and to find out which hosts belong to which multicast group. The host machines in an IP network also use IGMP messages to become members of a group and to quit the group, too. IGMP messages come in seriously handy for tracking group memberships as well as active multicast streams. IGMP works at the Network layer and doesn't use port numbers.

NetBIOS (TCP and UDP 137–139)

Network Basic Input/Output System works only in the upper layers of the OSI model and allows for an interface on separate computers to communicate over a network.

It was first created in the early 1980s to work on an IBM LAN and was proprietary. Microsoft and Novell both created a NetBIOS implementation to allows their hosts to communicate to their servers, but Microsoft's version became the de facto version.

Server Message Block (TCP 445)

Server Message Block (SMB) is used for sharing access to files and printers and other communications between hosts on a Microsoft Windows network.

SMB can run on UDP port 137 and 138 and on TCP port 137 and 139 using NetBIOS.

Domain Name Service (TCP and UDP 53)

Domain Name Service (DNS) resolves hostnames—specifically, Internet names, such as `www.lammle.com–to` their corresponding IP addresses.

You don't have to use DNS; you can just type in the IP address of any device you want to communicate with. An IP address identifies hosts on a network and the Internet as well. However, DNS was designed to make our lives easier. Think about this: What would happen if you wanted to move your web page to a different service provider? The IP address would change, and no one would know what the new one was. DNS allows you to use a domain name to specify an IP address. You can change the IP address as often as you want and no one will know the difference.

DNS is used to resolve a *fully qualified domain name (FQDN)*—for example, `www.lammle.com` or `todd.lammle.com`—to an IP address. An FQDN, or DNS namespace, is a hierarchy that can logically locate a system based on its domain identifier.

If you want to resolve the name *todd*, you must either type in the FQDN of `todd.lammle.com` or have a device, such as a PC or router, add the suffix for you. For example, on a Cisco router, you can use the command `ip domain-name lammle.com` to append each request with the `lammle.com` domain. If you don't do that, you'll have to type in the FQDN to get DNS to resolve the name.

An important thing to remember about DNS is that if you can ping a device with an IP address but can't use its FQDN, you might have some type of DNS configuration failure.

Dynamic Host Configuration Protocol/Bootstrap Protocol (UDP 67/68)

Dynamic Host Configuration Protocol (DHCP) assigns IP addresses to hosts with information provided by a server. It allows easier administration and works well in small to even very large network environments. Many types of hardware can be used as a DHCP server, including routers.

DHCP differs from Bootstrap Protocol (BootP) in that BootP assigns an IP address to a host but the host's hardware address must be entered manually in a BootP table. You can think of DHCP as a dynamic BootP. But remember that BootP is also used to send an operating system that a host can boot from. DHCP can't do that.

Please also read the sections on DHCP and DNS in Chapter 5, "Networking Devices," if you have not done so; both figure largely in the exam objectives.

But there is a lot of information a DHCP server can provide to a host when the host is requesting an IP address from the DHCP server. Here's a partial list of the information a DHCP server can provide:

- IP address
- Subnet mask
- Domain name
- Default gateway (routers)
- DNS
- Windows Internet Naming Service (WINS) information

A DHCP server can give even more information than this, but the items in the list are the most common.

A client that sends out a DHCP Discover message in order to receive an IP address sends out a broadcast at both Layer 2 and Layer 3. The Layer 2 broadcast is all *F*s in hex, which looks like this: FF:FF:FF:FF:FF:FF. The Layer 3 broadcast is 255.255.255.255, which means all networks and all hosts. DHCP is connectionless, which means it uses User Datagram Protocol (UDP) at the Transport layer, also known as the Host-to-Host layer, which we'll talk about next.

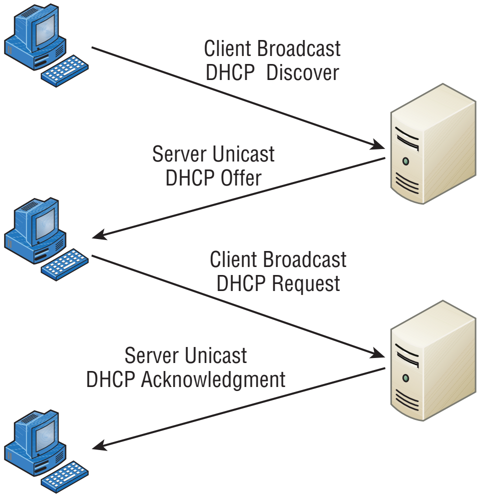
In case you don't believe me, here's an example of output from my trusty analyzer:

```
Ethernet II,Src:192.168.0.3(00:0b:db:99:d3:5e),Dst:Broadcast(ff:ff:ff:ff:ff:ff)
Internet Protocol,Src:0.0.0.0(0.0.0.0),Dst:255.255.255.255(255.255.255.255).
```

The Data Link and Network layers are both sending out "all hands" broadcasts saying, "Help—I don't know my IP address!"

Figure 6.3 shows the process of a client-server relationship using a DHCP connection.

FIGURE 6.3 DHCP client four-step process



The following is the four-step process (sometimes known as the DORA process) a client takes to receive an IP address from a DHCP server:

1. The DHCP client broadcasts a DHCP Discover message looking for a DHCP server (port 67).
2. The DHCP server that received the DHCP Discover message sends a unicast DHCP Offer message back to the host.
3. The client then broadcasts to the server a DHCP Request message asking for the offered IP address and possibly other information.
4. The server finalizes the exchange with a unicast DHCP Acknowledgment message.

What happens if you have a few hosts connected together with a switch or hub and you don't have a DHCP server? You can add IP information by hand (this is called *static IP addressing*), or Windows provides what is called Automatic Private IP Addressing (APIPA), a feature of later Windows operating systems. With APIPA, clients can automatically self-configure an IP address and subnet mask (basic IP information that hosts use to communicate, which is covered in detail in Chapter 7, "IP Addressing," and Chapter 8, "IP Subnetting, Troubleshooting IP, and Introduction to NAT") when a DHCP server isn't available. The IP address range for APIPA is 169.254.0.1 through 169.254.255.254. The client also configures itself with a default Class B subnet mask of 255.255.0.0. If you have a DHCP server and your host is using this IP address, this means your DHCP client on your host is not working or the server is down or can't be reached because of a network issue.

Now, let's take a look at the Transport layer, or what the DoD calls the Host-to-Host layer.

The Host-to-Host Layer Protocols

The main purpose of the Host-to-Host layer is to shield the upper-layer applications from the complexities of the network. This layer says to the upper layer, "Just give me your data stream, with any instructions, and I'll begin the process of getting your information ready to send."

The following sections describe the two protocols at this layer:

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)

In addition, we'll look at some of the key host-to-host protocol concepts as well as the port numbers.

Transmission Control Protocol

Transmission Control Protocol (TCP) takes large blocks of information from an application and breaks them into segments. It numbers and sequences each segment so that the destination's TCP process can put the segments back into the order the application intended. After these segments are sent, TCP (on the transmitting host) waits for an acknowledgment from the receiving end's TCP process, retransmitting those segments that aren't acknowledged.

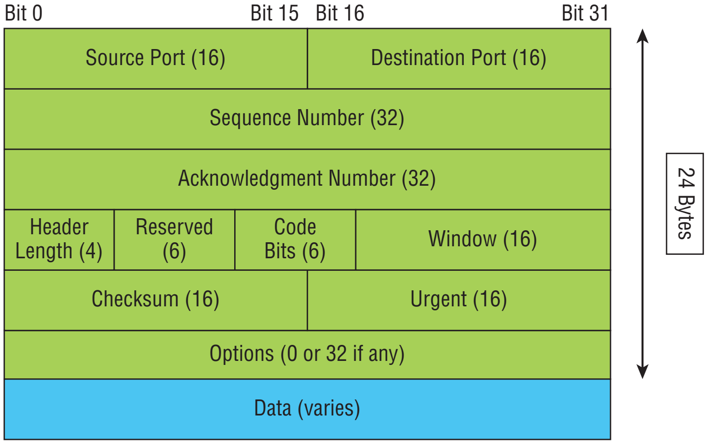
Remember that in a reliable transport operation, a device that wants to transmit sets up a connection-oriented communication with a remote device by creating a session. The transmitting device first establishes a connection-oriented session with its peer system; that session is called a *call setup* or a *three-way handshake*. Data is then transferred, and when the transfer is complete, a call termination takes place to tear down the virtual circuit.

TCP is a full-duplex, connection-oriented, reliable, and accurate protocol, but establishing all these terms and conditions, in addition to error checking, is no small task. TCP is very complicated and, not surprisingly, costly in terms of network overhead. And because today's networks are much more reliable than those of yore, this added reliability is often unnecessary.

Because the upper layers just send a data stream to the protocols in the Transport layers, I'll demonstrate how TCP segments a data stream and prepares it for the Internet layer. When the Internet layer receives the data stream, it routes the segments as packets through an internetwork. The segments are handed to the receiving host's Host-to-Host layer protocol, which rebuilds the data stream to hand to the upper-layer protocols.

Figure 6.4 shows the TCP segment format. The figure shows the different fields within the TCP header.

FIGURE 6.4 TCP segment format



The TCP header is 20 bytes long, or up to 60 bytes with options.

For more detailed information regarding the TCP header, which is beyond the scope of the CompTIA Network+ exam objectives, please see my book *CCNA: Cisco Certified Network Associate Study Guide* (Sybex, 2013).

User Datagram Protocol

If you were to compare *User Datagram Protocol (UDP)* with TCP, the former is basically the scaled-down economy model that's sometimes referred to as a *thin protocol*. Like a thin person on a park bench, a thin protocol doesn't take up a lot of room—or in this case, much bandwidth on a network.

UDP doesn't offer all the bells and whistles of TCP either, but it does do a fabulous job of transporting information that doesn't require reliable delivery—and it does so using far fewer network resources.

There are some situations in which it would definitely be wise for developers to opt for UDP rather than TCP. Remember the watchdog SNMP up there at the Process/Application layer? SNMP monitors the network, sending intermittent messages and a fairly steady flow of status updates and alerts, especially when running on a large network. The cost in overhead to establish, maintain, and close a TCP connection for each one of those little messages would reduce what would be an otherwise healthy, efficient network to a dammed-up bog in no time!

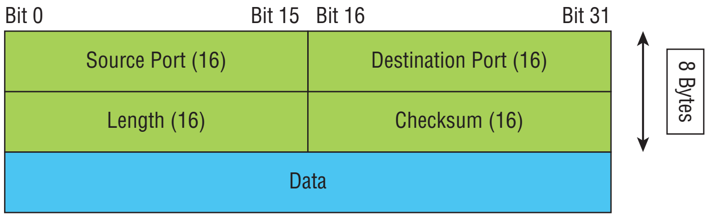
Another circumstance calling for UDP over TCP is when reliability is already handled at the Process/Application layer. DNS handles its own reliability issues, making the use of TCP both impractical and redundant. But ultimately, it's up to the application developer to decide whether to use UDP or TCP, not the user who wants to transfer data faster.

UDP does *not* sequence the segments and doesn't care in which order the segments arrive at the destination. But after that, UDP sends the segments off and forgets about them. It doesn't follow through, check up on them, or even allow for an acknowledgment of safe arrival—complete abandonment. Because of this, it's referred to as an *unreliable* protocol. This doesn't mean that UDP is ineffective, only that it doesn't handle issues of reliability. Because UDP assumes that the application will use its own reliability method, it doesn't use any. This gives an application developer a choice when running the IP stack: TCP for reliability or UDP for faster transfers.

Further, UDP doesn't create a virtual circuit, nor does it contact the destination before delivering information to it. Because of this, it's also considered a *connectionless* protocol.

Figure 6.5 clearly illustrates UDP's markedly low overhead as compared to TCP's hungry usage. Look at the figure carefully—can you see that UDP doesn't use windowing or provide for acknowledgments in the UDP header?

FIGURE 6.5 UDP segment



NOTE

For more detailed information regarding the UDP header, which is beyond the scope of the CompTIA Network+ exam objectives, please see my book *CCNA: Cisco Certified Network Associate Study Guide* (Sybex, 2013).

Key Concepts of Host-to-Host Protocols

Now that you've seen both a connection-oriented (TCP) and connectionless (UDP) protocol in action, it would be good to summarize the two here. Table 6.1 highlights some of the key concepts that you should keep in mind regarding these two protocols. You should memorize this table.

TABLE 6.1 Key features of TCP and UDP

TCP	UDP
Sequenced	Unsequenced
Reliable	Unreliable
Connection-oriented	Connectionless

TCP	UDP
Virtual circuit	No virtual circuit
High overhead	Low overhead
Acknowledgments	No acknowledgment
Windowing flow control	No windowing or flow control

A telephone analogy could really help you understand how TCP works. Most of us know that before you speak to someone on a phone, you must first establish a connection with that person—wherever they are. This is like a virtual circuit with TCP. If you were giving someone important information during your conversation, you might say, "You know?" or ask, "Did you get that?" Saying something like this is a lot like a TCP acknowledgment—it's designed to get your verification. From time to time (especially on cell phones), people also ask, "Are you still there?" They end their conversations with a "Good-bye" of some kind, putting closure on the phone call. TCP also performs these types of functions.

Alternatively, using UDP is like sending a postcard. To do that, you don't need to contact the other party first. You simply write your message, address the postcard, and mail it. This is analogous to UDP's connectionless orientation. Because the message on the postcard is probably not a matter of life or death, you don't need an acknowledgment of its receipt. Similarly, UDP doesn't involve acknowledgments.

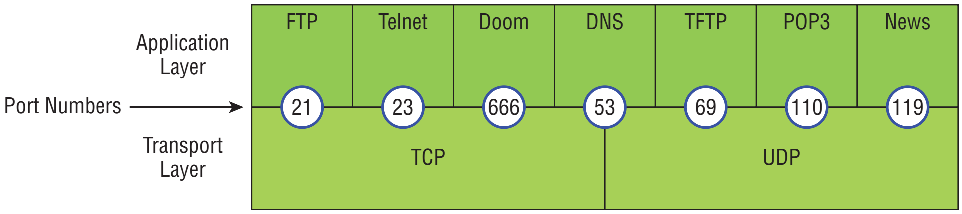
Port Numbers

TCP and UDP must use *port numbers* to communicate with the upper layers because they're what keep track of different simultaneous conversations originated by or accepted by the local host. Originating source port numbers are dynamically assigned by the source host and will usually have a value of 1024 or higher. Ports 1023 and below are defined in RFC 3232, which discusses what are called *well-known port numbers*.

Virtual circuits that don't use an application with a well-known port number are assigned port numbers randomly from a specific range instead. These port numbers identify the source and destination application or process in the TCP segment.

Figure 6.6 illustrates how both TCP and UDP use port numbers.

FIGURE 6.6 Port numbers for TCP and UDP



You just need to remember that numbers below 1024 are considered well-known port numbers and are defined in RFC 3232. Numbers 1024 and above are used by the upper layers to set up sessions with other hosts and by TCP as source and destination identifiers in the TCP segment.

Table 6.2 gives you a list of the typical applications used in the TCP/IP suite, their well-known port numbers, and the Transport layer protocols used by each application or process. It's important that you study and memorize this table for the CompTIA Network+ exam.

TABLE 6.2 Key protocols that use TCP and UDP

TCP	UDP
Telnet 23	SNMPv1/2 161
SMTP 25	TFTP 69
HTTP 80	DNS 53
FTP 20, 21	BOOTPS/DHCP 67,68
SFTP 22	NTP 123
DNS 53	
HTTPS 443	
SSH 22	
SMB 445	
POP3 110	
IMAP4 143	
RDP 3389	
SNMPv3 161	

Notice that DNS uses both TCP and UDP. Whether it opts for one or the other depends on what it's trying to do. Even though it's not the only application that can use both protocols, it's certainly one that you should remember in your studies.

The Internet Layer Protocols

In the DoD model, there are two main reasons for the Internet layer's existence: routing and providing a single network interface to the upper layers.

None of the other upper- or lower-layer protocols have any functions relating to routing—that complex and important task belongs entirely to the Internet layer. The Internet layer's second duty is to provide a single network interface to the upper-layer protocols. Without this layer, application programmers would need to write what are called *hooks* into every one of their applications for each different Network Access protocol. This would not only be a pain in the neck, it would also lead to different versions of each application—one for Ethernet, another one for Token Ring, and so on. To prevent this, IP provides one single network interface for the upper-layer protocols. That accomplished, it's then the job of IP and the various Network Access protocols to get along and work together.

All network roads don't lead to Rome—they lead to IP. And all the other protocols at this layer, as well as all those at the upper layers, use it. Never forget that. All paths through the DoD model go through IP. The following sections describe the protocols at the Internet layer:

- Internet Protocol (IP)
- Internet Control Message Protocol (ICMP)
- Address Resolution Protocol (ARP)
- Reverse Address Resolution Protocol (RARP)

Internet Protocol

Internet Protocol (IP) is essentially the Internet layer. The other protocols found here merely exist to support it. IP holds the big picture and could be said to "see all" in that it's aware of all the interconnected networks. It can do this because all the machines on the network have a software, or logical, address called an IP address, which I'll cover more thoroughly in the next chapter.

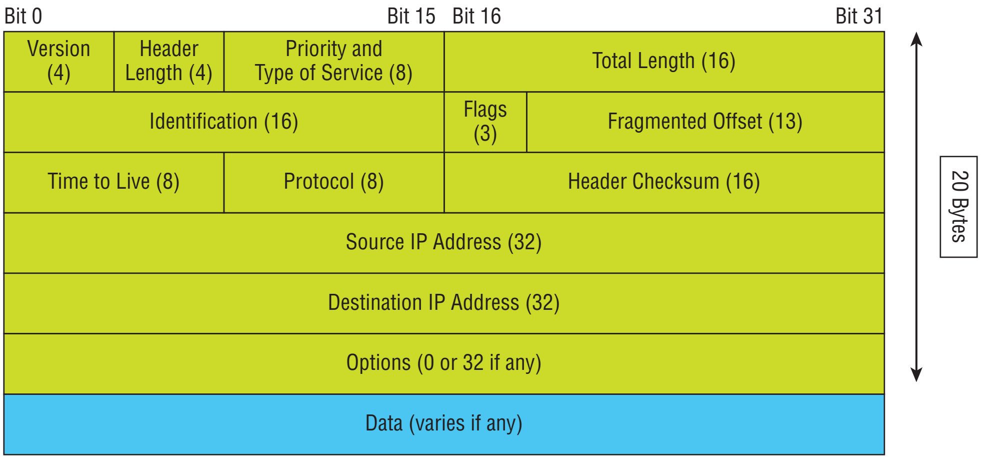
IP looks at each packet's destination address. Then, using a routing table, it decides where a packet is to be sent next, choosing the best path. The protocols of the Network Access layer at the bottom of the DoD model don't possess IP's enlightened scope of the entire network; they deal only with physical links (local networks).

Identifying devices on networks requires answering these two questions: Which network is it on? And what is its ID on that network? The answer to the first question is the *software address*, or *logical address* (the correct street). The answer to the second question is the *hardware address* (the correct mailbox). All hosts on a network have a logical ID called an IP address. This is the software, or logical, address and contains valuable encoded information, greatly simplifying the complex task of routing. (IP is discussed in RFC 791.)

IP receives segments from the Host-to-Host layer and fragments them into packets if necessary. IP then reassembles packets back into segments on the receiving side. Each packet is assigned the IP address of the sender and of the recipient. Each router (Layer 3 device) that receives a packet makes routing decisions based on the packet's destination IP address.

Figure 6.7 shows an IPv4 header. This will give you an idea of what IP has to go through every time user data is sent from the upper layers to a remote network.

FIGURE 6.7 IPv4 header



Bit 0 | Bit 15 | Bit 16 | Bit 31

Version (4) | Header Length (4) | Priority and Type of Service (8) | Total Length (16)

Identification (16) | Flags (3) | Fragmented Offset (13)

Time to Live (8) | Protocol (8) | Header Checksum (16)

Source IP Address (32)

Destination IP Address (32)

Options (0 or 32 if any)

Data (varies if any)

20 Bytes

NOTE

For more detailed information regarding the IP header, which is beyond the scope of the CompTIA Network+ exam objectives, please see my book *CCNA: Cisco Certified Network Associate Study Guide,* (Sybex, 2013).

Internet Control Message Protocol

Internet Control Message Protocol (ICMP) works at the Network layer and is used by IP for many different services. ICMP is a management protocol and messaging service provider for IP. Its messages are carried as IP packets.

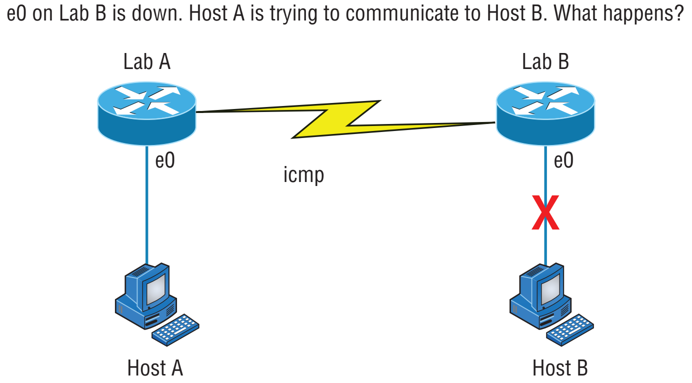
ICMP packets have the following characteristics:

- They can provide hosts with information about network problems.
- They are encapsulated within IP datagrams.

The following are some common events and messages that ICMP relates to, and the two most popular programs that use ICMP:

Destination Unreachable If a router can't send an IP datagram any further, it uses ICMP to send a message back to the sender, advising it of the situation. For example, take a look at Figure 6.8, which shows that the Ethernet interface of the Lab B router is down.

FIGURE 6.8 ICMP error message is sent to the sending host from the remote router.


e0 on Lab B is down. Host A is trying to communicate to Host B. What happens?
Lab A
Lab B
e0
icmp
e0
X
Host A
Host B

When Host A sends a packet destined for Host B, the Lab B router will send an ICMP Destination Unreachable message back to the sending device (directly to Host A, in this example).

Buffer Full If a router's memory buffer for receiving incoming datagrams is full, it will use ICMP to send out this message until the congestion abates.

Hops Each IP datagram is allotted a certain number of routers, called *hops*, to pass through. If a datagram reaches its limit of hops before arriving at its destination, the last router to receive it deletes it. The executioner router then uses ICMP to send an obituary message, informing the sending machine of the demise of its datagram.

Ping Ping uses ICMP echo request and reply messages to check the physical and logical connectivity of machines on an internetwork.

Traceroute Traceroute uses IP packet Time to Live time-outs to discover the path a packet takes as it traverses an internetwork.

NOTE

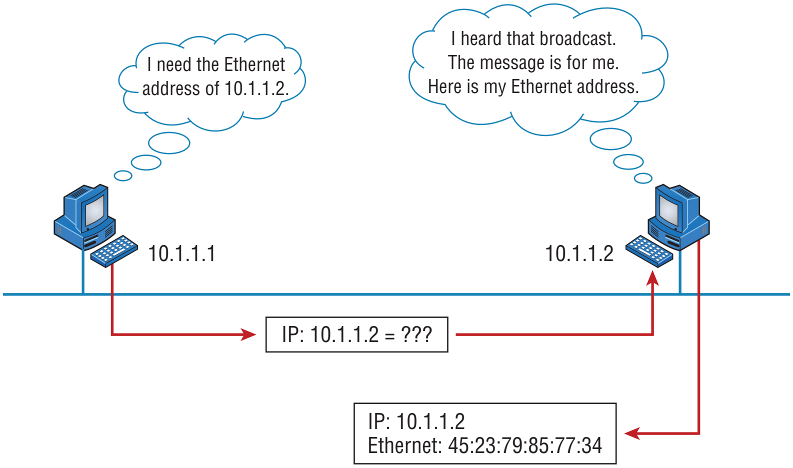
Both Ping and Traceroute (also just called Trace, and Microsoft Windows uses tracert) allow you to verify address configurations in your internetwork.

Address Resolution Protocol

Address Resolution Protocol (ARP) finds the hardware address of a host from a known IP address. Here's how it works: When IP has a datagram to send, it must inform a Network Access protocol, such as Ethernet or Token Ring, of the destination's hardware address on the local network. (It has already been informed by upper-layer protocols of the destination's IP address.) If IP doesn't find the destination host's hardware address in the ARP cache, it uses ARP to find this information.

As IP's detective, ARP interrogates the local network by sending out a broadcast asking the machine with the specified IP address to reply with its hardware address. So basically, ARP translates the software (IP) address into a hardware address—for example, the destination machine's Ethernet address. Figure 6.9 shows how an ARP broadcast looks to a local network.

FIGURE 6.9 Local ARP broadcast


I need the Ethernet address of 10.1.1.2.
I heard that broadcast. The message is for me. Here is my Ethernet address.
10.1.1.1
10.1.1.2
IP: 10.1.1.2 = ???
IP: 10.1.1.2
Ethernet: 45:23:79:85:77:34

ARP resolves IP addresses to Ethernet (MAC) addresses.

The following trace shows an ARP broadcast—notice that the destination hardware address is unknown and is all 0s in the ARP header. In the Ethernet header, a destination of all *F*s in hex (all 1s in binary), a hardware-address broadcast, is used to make sure all devices on the local link receive the ARP request:

```
 Flags:         0x00
 Status:        0x00
 Packet Length: 64
 Timestamp:     09:17:29.574000 12/06/03
Ethernet Header
 Destination:   FF:FF:FF:FF:FF:FF Ethernet Broadcast
 Source:        00:A0:24:48:60:A5
 Protocol Type: 0x0806 IP ARP
```

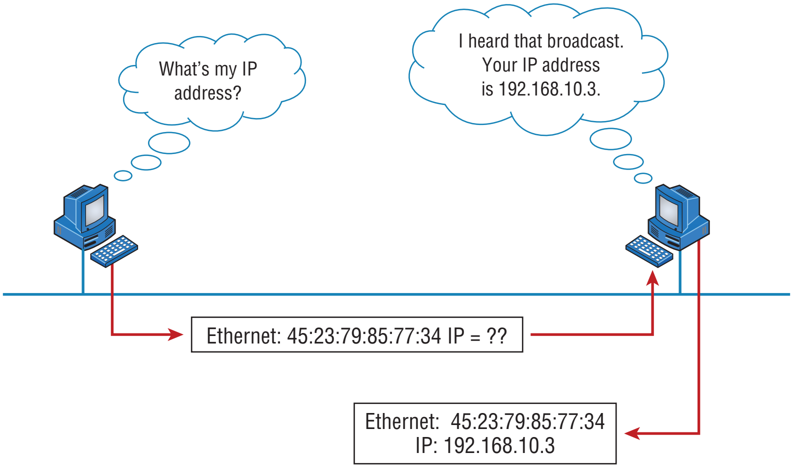
```
ARP - Address Resolution Protocol
 Hardware:                 1 Ethernet (10Mb)
 Protocol:                 0x0800 IP
 Hardware Address Length: 6
 Protocol Address Length: 4
 Operation:                1 ARP Request
 Sender Hardware Address: 00:A0:24:48:60:A5
 Sender Internet Address: 172.16.10.3
 Target Hardware Address: 00:00:00:00:00:00 (ignored)
 Target Internet Address: 172.16.10.10
Extra bytes (Padding):
 ................ 0A 0A 0A 0A 0A 0A 0A 0A 0A 0A 0A 0A 0A
  0A 0A 0A 0A 0A
Frame Check Sequence: 0x00000000
```

Reverse Address Resolution Protocol

When an IP machine happens to be a diskless machine, it has no way of initially knowing its IP address. But it does know its MAC address. *Reverse Address Resolution Protocol (RARP)* discovers the identity of the IP address for diskless machines by sending out a packet that includes its MAC address and a request for the IP address assigned to that MAC address. A designated machine, called a *RARP server*, responds with the answer, and the identity crisis is over. RARP uses the information it does know about the machine's MAC address to learn its IP address and complete the machine's ID portrait.

Figure 6.10 shows a diskless workstation asking for its IP address with a RARP broadcast.

FIGURE 6.10 RARP broadcast example


What's my IP address?
I heard that broadcast. Your IP address is 192.168.10.3.
Ethernet: 45:23:79:85:77:34 IP = ??
Ethernet: 45:23:79:85:77:34
IP: 192.168.10.3

Data Encapsulation

I started to discuss data encapsulation in Chapter 2, but I could only provide an overview at that point in the book because you needed to have a firm understanding of how ports work in a virtual circuit. With the last five chapters of foundational material under your belt, you're ready to get more into the details of encapsulation.

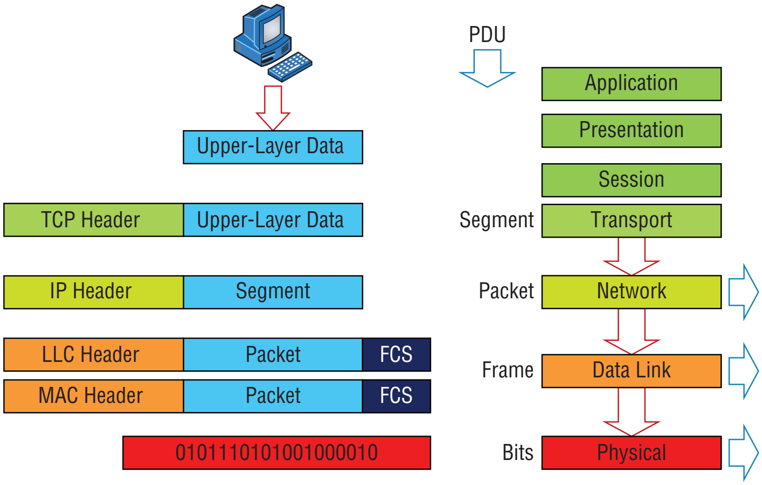
When a host transmits data across a network to another device, the data goes through *encapsulation*: It's wrapped with protocol information at each layer of the OSI model. Each layer communicates only with its peer layer on the receiving device.

To communicate and exchange information, each layer uses *Protocol Data Units (PDUs)*. These hold the control information attached to the data at each layer of the model. They're usually attached to the header in front of the data field but can also be in the trailer, or end, of it.

Each PDU attaches to the data by encapsulating it at each layer of the OSI model, and each has a specific name depending on the information provided in each header. This PDU information is read only by the peer layer on the receiving device. After it's read, it's stripped off, and the data is then handed to the next layer up.

Figure 6.11 shows the PDUs and how they attach control information to each layer. This figure demonstrates how the upper-layer user data is converted for transmission on the network. The data stream is then handed down to the Transport layer, which sets up a virtual circuit to the receiving device by sending over a synch packet. Next, the data stream is broken up into smaller pieces, and a Transport layer header (a PDU) is created and attached to the header of the data field; now the piece of data is called a *segment*. Each segment is sequenced so the data stream can be put back together on the receiving side exactly as it was transmitted.

FIGURE 6.11 Data encapsulation



Each segment is then handed to the Network layer for network addressing and routing through the internetwork. Logical addressing (for example, IP) is used to get each segment to the correct network. The Network layer protocol adds a control header to the segment handed down from the Transport layer, and what we have now is called a *packet* or *datagram*. Remember that the Transport and Network layers work together to rebuild a data stream on a receiving host, but it's not part of their work to place their PDUs on a local network segment—which is the only way to get the information to a router or host.

It's the Data Link layer that's responsible for taking packets from the Network layer and placing them on the network medium (cable or wireless). The Data Link layer encapsulates each packet in a *frame*, and the frame's header carries the hardware address of the source and destination hosts. If the destination device is on a remote network, then the frame is sent to a router to be routed through an internetwork. Once it gets to the destination network, a new frame is used to get the packet to the destination host.

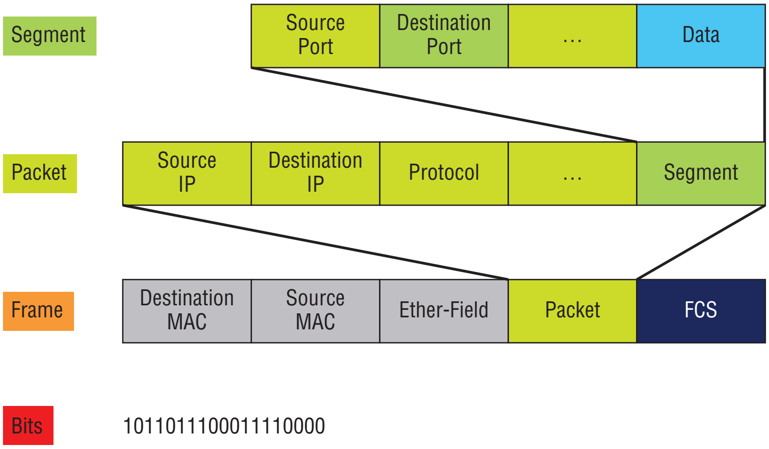
To put this frame on the network, it must first be put into a digital signal. Because a frame is really a logical group of 1s and 0s, the Physical layer is responsible for encoding these digits into a digital signal, which is read by devices on the same local network. The receiving devices will synchronize on the digital signal and extract (decode) the 1s and 0s from the digital signal. At this point, the devices build the frames, run a cyclic redundancy check (CRC), and then check their answer against the answer in the frame's Frame Check Sequence (FCS) field. If it matches, the packet is pulled from the frame and what's left of the frame is discarded. This process is called *de-encapsulation*. The packet is handed to the Network layer, where the address is checked. If the address matches, the segment is pulled from the packet and what's left of the packet is discarded. The segment is processed at the Transport layer, which rebuilds the data stream and acknowledges to the transmitting station that it received each piece. It then happily hands the data stream to the upper-layer application.

In summary, at a transmitting device, the data-encapsulation method works like this:

1. User information is converted to data for transmission on the network.
2. Data is converted to segments, and a reliable connection is set up between the transmitting and receiving hosts.
3. Segments are converted to packets or datagrams, and a logical address is placed in the header so each packet can be routed through an internetwork.
4. Packets or datagrams are converted to frames for transmission on the local network. Hardware (Ethernet) addresses are used to uniquely identify hosts on a local network segment.
5. Frames are converted to bits, and a digital encoding and clocking scheme is used.

To explain this in more detail using the layer addressing, I'll use Figure 6.12.

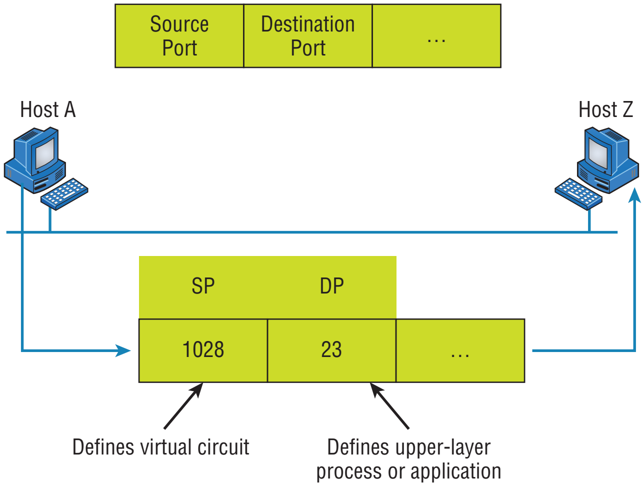
FIGURE 6.12 PDU and layer addressing



Remember that a data stream is handed down from the upper layer to the Transport layer. As technicians, we really don't care who the data stream comes from because that's a programmer's problem. Our job is to rebuild the data stream reliably and hand it to the upper layers on the receiving device.

Before we go further in our discussion of Figure 6.12, let's review port numbers and make sure you understand them. The Transport layer uses port numbers to define both the virtual circuit and the upper-layer process, as you can see from Figure 6.13.

FIGURE 6.13 Port numbers at the Transport layer



The Transport layer takes the data stream, makes segments out of it, and establishes a reliable session by creating a virtual circuit. It then sequences (numbers) each segment and uses acknowledgments and flow control. If you're using TCP, the virtual circuit is defined by the source port number. Remember, the host just makes this up starting at port number 1024 (0 through 1023 are reserved for well-known port numbers). The destination port number defines the upper-layer process (application) that the data stream is handed to when the data stream is reliably rebuilt on the receiving host.

Now that you understand port numbers and how they're used at the Transport layer, let's go back to Figure 6.12. Once the Transport layer header information is added to the piece of data, it becomes a segment and is handed down to the Network layer along with the destination IP address. (The destination IP address was handed down from the upper layers to the Transport layer with the data stream, and it was discovered through a name resolution method at the upper layers—probably DNS.)

The Network layer adds a header, and adds the logical addressing (IP addresses), to the front of each segment. Once the header is added to the segment, the PDU is called a *packet*. The packet has a protocol field that describes where the segment came from (either UDP or TCP) so it can hand the segment to the correct protocol at the Transport layer when it reaches the receiving host.

The Network layer is responsible for finding the destination hardware address that dictates where the packet should be sent on the local network. It does this by using ARP. IP at the Network layer looks at the destination IP address and compares that address to its own source IP address and subnet mask. If it turns out to be a local network request, the hardware address of the local host is requested via an ARP request. If the packet is destined for a remote host, IP will get the IP address of the default gateway from its configuration information, then ARP for the hardware address of the default gateway (router) instead.

The packet, along with the destination hardware address of either the local host or default gateway, is then handed down to the Data Link layer. The Data Link layer will add a header to the front of the packet, and the piece of data then becomes a *frame*. (We call it a frame because both a header and a trailer are added to the packet, which makes the data resemble bookends or a frame, if you will.) This is shown in Figure 6.12. The frame uses an Ether-Type field to describe which protocol the packet came from at the Network layer. Now a CRC is run on the frame, and the answer to the CRC is placed in the FCS field found in the trailer of the frame.

The frame is now ready to be handed down, one bit at a time, to the Physical layer, which will use bit-timing rules to encode the data into a digital signal. Every device on the network segment will synchronize with the clock, extract the 1s and 0s from the digital signal, and build a frame. After the frame is rebuilt, a CRC is run to make sure the frame is okay. If everything turns out to be good, the hosts will check the destination address to see if the frame is for them.

If all this is making your eyes cross and your brain freeze, don't freak—things will become much clearer as we go through the book—really! Soon, I'll be going over exactly how data is encapsulated and routed through an internetwork in even more detail, in an easy-to-understand, step-by-step manner, in Chapter 9, "Introduction to IP Routing."

Summary

Protocols, protocols everywhere—so many different reasons for them, and so many jobs they do for us! And sometimes they even work in conjunction with each other. This can seem like way too much information, but no worries—as you become familiar with the various layers and their functions, I promise it will soon become clear that this hierarchical structure is a seriously tight, robust networking foundation.

Similarly, as you understand the TCP/IP big picture, the reason why all those protocols exist and are necessary will also become much easier to understand. They're really like a team that works jointly, from layer to layer, to make our TCP/IP networks the wonderful, great tools they are.

Exam Essentials

Remember the Process/Application layer protocols. Telnet is a terminal-emulation program that allows you to log into a remote host and run programs. File Transfer Protocol (FTP) is a connection-oriented service that allows you to transfer files. Trivial FTP (TFTP) is a connectionless file transfer program. Simple Mail Transfer Protocol (SMTP) is a send-mail program.

Remember the Host-to-Host layer protocols. Transmission Control Protocol (TCP) is a connection-oriented protocol that provides reliable network service by using acknowledgments and flow control. User Datagram Protocol (UDP) is a connectionless protocol that provides low overhead and is considered unreliable.

Remember the Internet layer protocols. Internet Protocol (IP) is a connectionless protocol that provides logical network addressing and routing through an internetwork. Address Resolution Protocol (ARP) finds a hardware address from a known IP address. Internet Control Message Protocol (ICMP) provides diagnostics and Destination Unreachable messages.

Remember the difference between connection-oriented and connectionless network services. Connection-oriented services use acknowledgments and flow control to create a reliable session. More overhead is used than in a connectionless network service. Connectionless services are used to send data with no acknowledgments or flow control. This is considered unreliable.

Written Lab

Provide the answers to the following questions. You can find the answers in Appendix A.

1. What would an ARP destination MAC address appear as?
2. Name the protocol that uses both TCP ports 20 and 21.
3. What Transport layer protocol does a DNS server use?
4. Which protocol dynamically reports errors to source hosts by using IP directly to build packets?
5. What could cause a server that you can ping not to provide the particular TCP/IP service, such as FTP, HTTP, and so on, that you expect it to offer?
6. What is the well-known port number for RDP?
7. Which ports does the protocol MGCP use?
8. What protocol is at the heart of the `ping` and `tracert` commands in a Windows operating system?
9. Which destination Transport layer protocol and port number does a TFTP client use to transfer files over the network?
10. What well-known port numbers do SMTP, POP3, RDP, and IMAP4 servers use?

Review Questions

You can find the answers to the review questions in Appendix B.

1. The OSI model has seven layers and the DoD has four. At which layer does SMTP work in both models?
   - **A.** Network
   - **B.** Transport
   - **C.** Session
   - **D.** Application
   - **E.** Internet

2. You need to have secure communications using HTTPS. What port number is used by default?
   - **A.** 69
   - **B.** 23
   - **C.** 21
   - **D.** 443

3. You want to implement a mechanism that automates the IP configuration, including IP address, subnet mask, default gateway, and DNS information. Which protocol will you use to accomplish this?
   - **A.** SMTP
   - **B.** SNMP
   - **C.** DHCP
   - **D.** ARP

4. What protocol is used to find the hardware address of a local device?
   - **A.** RARP
   - **B.** ARP
   - **C.** IP
   - **D.** ICMP
   - **E.** BootP

5. You need to log in to a Unix server across a network that is not secure. Which of the following protocols will allow you to remotely administer this server securely?
   - **A.** Telnet
   - **B.** SSH
   - **C.** SFTP
   - **D.** HTTP

6. If you can ping by IP address but not by hostname, or FQDN, which of the following port numbers is related to the server process that is involved?

   A. 21

   B. 23

   C. 53

   D. 69

   E. 80

7. Which of the following describe the DHCP Discover message? (Choose two.)

   A. It uses FF:FF:FF:FF:FF:FF as a Layer 2 broadcast.

   B. It uses UDP as the Transport layer protocol.

   C. It uses TCP as the Transport layer protocol.

   D. It does not use a Layer 2 destination address.

8. What Layer 4 protocol is used for a Telnet connection, and what is the default port number?

   A. IP, 6

   B. TCP, 21

   C. UDP, 23

   D. ICMP, 21

   E. TCP, 23

9. Which statements are true regarding ICMP packets? (Choose two.)

   A. They acknowledge receipt of a TCP segment.

   B. They guarantee datagram delivery.

   C. They can provide hosts with information about network problems.

   D. They are encapsulated within IP datagrams.

   E. They are encapsulated within UDP datagrams.

10. Which of the following services use TCP? (Choose four.)

    A. DHCP

    B. SMTP

    C. SNMP

    D. FTP

    E. HTTP

    F. TFTP

11. Which of the following services use UDP? (Choose three.)
    - A. DHCP
    - B. SMTP
    - C. SNMP
    - D. FTP
    - E. HTTP
    - F. TFTP

12. Which of the following TCP/IP protocols are used at the Application layer of the OSI model? (Choose three.)
    - A. IP
    - B. TCP
    - C. Telnet
    - D. FTP
    - E. TFTP

13. Which of the following protocols is used by email servers to exchange messages with one another?
    - A. POP3
    - B. IMAP
    - C. SMTP
    - D. HTTP

14. You need to have a connection to run applications that are installed on only your desktop computer at your office. Which protocol will provide a GUI interface to your work computer?
    - A. Telnet
    - B. FTP
    - C. RDP
    - D. IMAP
    - E. SMTP

15. Which of the following protocols can use TCP and UDP, permits authentication and secure polling of network devices, and allows for automated alerts and reports on network devices?
    - A. DNS
    - B. SNMP
    - C. SMTP
    - D. TCP

16. You need to transfer files between two hosts. Which protocol can you use?

A. SNMP

B. RIP

C. NTP

D. FTP

17. What layer in the IP stack is equivalent to the Transport layer of the OSI model?

A. Application

B. Host-to-Host

C. Internet

D. Network Access

18. You need to make sure that the time is consistent across all your network devices. What protocol do you need to run on your network?

A. FTP

B. SCP

C. NTP

D. RTP

19. Which of the following allows a server to distinguish among different simultaneous requests from the same host?

A. They use different port numbers.

B. A NAT server changes the IP address for subsequent requests.

C. A server is unable to accept multiple simultaneous sessions from the same host. One session must end before another can begin.

D. The MAC address for each one is unique.

20. Which of the following uses both TCP and UDP?

A. FTP

B. SMTP

C. Telnet

D. DNS

Chapter 7

IP Addressing

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.4 Given a scenario, configure the appropriate IP addressing components**

- Private vs. public
- Loopback and reserved
- Default gateway
- Virtual IP
- Subnet mask
  - Classful
    - Classes A, B, C, D, and E
- Address assignments
  - DHCP
  - DHCPv6
  - Static
  - APIPA
  - EUI64

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Properties of network traffic
  - Broadcast domains
  - Broadcast
  - Multicast
  - Unicast
- Addressing

One of the most important topics in any discussion of TCP/IP is IP addressing. An IP address is a numeric identifier assigned to each machine on an IP network. It designates the specific location of a device on the network.

An IP address is a logical address, not a hardware address—the latter is hard-coded on a network interface card (NIC) and used for finding hosts on a local network. IP addressing was designed to allow hosts on one network to communicate with a host on a different network regardless of the type of LANs the hosts are participating in.

Before we get into the more complicated aspects of IP addressing, you need to understand some of the basics. First I'm going to explain some of the fundamentals of IP addressing and its terminology. Then you'll learn about the hierarchical IP addressing scheme and private IP addresses.

I'll define unicast, multicast, and broadcast addresses and then finish the chapter with a discussion on IPv6. And I promise to make it all as painless as possible.

The reason that we would even discuss IPv6 (besides to cover the objectives, of course) is the lack of IPv4 addresses available for use in future networks, which we need to keep our corporate and private networks and even the Internet running. Basically, we're running out of addresses for all our new hosts! IPv6 will fix this for us.

NOTE

To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

IP Terminology

Throughout this chapter, you'll learn several important terms vital to your understanding of the Internet Protocol. Here are a few to get you started:

Bit A *bit* is one binary digit, either a 1 or a 0.

Byte A *byte* is 7 or 8 bits, depending on whether parity is used. For the rest of this chapter, always assume a byte is 8 bits.

Octet An octet, made up of 8 bits, is just an ordinary 8-bit binary number. In this chapter, the terms *byte* and *octet* are completely interchangeable, and they are typically displayed in decimal up to 255.

Network Address This is the designation used in routing to send packets to a remote network—for example, 10.0.0.0, 172.16.0.0, and 192.168.10.0.

IP Address A logical address used to define a single host; however, IP addresses can be used to reference many or all hosts as well. If you see something written as just IP, it is referring to IPv4. IPv6 will always be written as IPv6.

Broadcast Address The *broadcast address* is used by applications and hosts to send information to all hosts on a network. Examples include 255.255.255.255, which designates all networks and all hosts; 172.16.255.255, which specifies all subnets and hosts on network 172.16.0.0; and 10.255.255.255, which broadcasts to all subnets and hosts on network 10.0.0.0.

NOTE

You will find the terms *subnet mask* and *slash notation* (for example, /24) used a few times in this chapter. These terms will be fully defined and used in Chapter 8, "IP Subnetting, Troubleshooting IP, and Introduction to NAT."

The Hierarchical IP Addressing Scheme

An IP address consists of 32 bits of information. These bits are divided into four sections, referred to as octets or bytes, and four octets sum up to 32 bits (8 × 4 = 32). You can depict an IP address using one of three methods:

- Dotted-decimal, as in 172.16.30.56
- Binary, as in 10101100.00010000.00011110.00111000
- Hexadecimal, as in AC.10.1E.38

Each of these examples validly represents the same IP address. Hexadecimal is used with IPv6, and IP addressing uses dotted-decimal or binary, but you still might find an IP address stored in hexadecimal in some programs. The Windows XP Registry is a good example of a program that stores a machine's IP address in hex.

The 32-bit IP address is known as a structured, or hierarchical, address as opposed to a flat, or nonhierarchical, address. Although either type of addressing scheme can be used, *hierarchical addressing* has been chosen for a very important reason. The major advantage of this scheme is that it can handle a large number of addresses, namely, 4.3 billion (a 32-bit address space with two possible values for each position—either 0 or 1—gives you 2^{32}, or 4,294,967,296). The disadvantage of the flat-addressing scheme, and the reason it's not used for IP addressing, relates to routing. If every address were unique, all routers on the Internet would need to store the address of each and every machine on the Internet. This would make efficient routing impossible, even if only a fraction of all possible addresses were used.

The solution to this problem is to use a two- or three-level hierarchical addressing scheme that is structured by network and host or by network, subnet, and host.

This two- or three-level scheme is comparable to a telephone number. The first section, the area code, designates a very large area. The second section, the prefix, narrows the scope to a local calling area. The final segment, the customer number, zooms in on the specific connection. IP addresses use the same type of layered structure. Rather than all 32 bits being treated as a unique identifier, as in flat addressing, a part of the address is designated as the network address and the other part is designated as either the subnet and host or just the host address.

Next, I'm going to cover IP network addressing and the different classes of addresses used for our networks.

Network Addressing

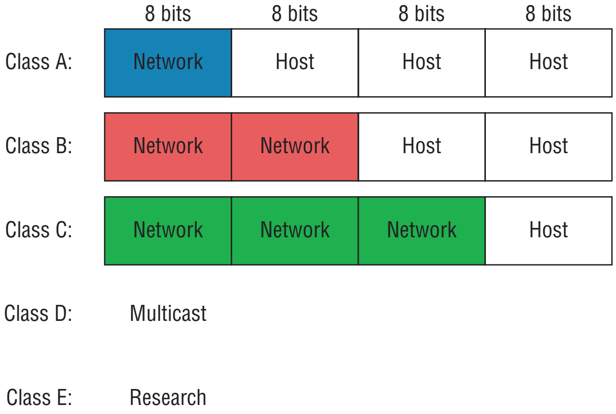
The *network address*—also called the network number—uniquely identifies each network. Every machine on the same network shares that network address as part of its IP address. In the IP address 172.16.30.56, for example, 172.16 is the network address (and in just a minute I'll show you how this is true).

The *host address* is assigned to, and uniquely identifies, each machine on a network. This part of the address must be unique because it identifies a particular machine—an individual—as opposed to a network, which is a group. So in the sample IP address 172.16.30.56, the 30.56 is the host address.

The designers of the Internet decided to create classes of networks based on network size. For the small number of networks possessing a very large number of hosts, they created the rank *Class A network*. At the other extreme is the *Class C network*, which is reserved for the numerous networks with a small number of hosts. The class distinction for networks between very large and very small is predictably the *Class B network*.

Subdividing an IP address into a network and host address is determined by the class designation of your network. Figure 7.1 summarizes the classes of networks—a subject I'll explain in much greater detail throughout this chapter.

FIGURE 7.1 Summary of the three classes of networks



To ensure efficient routing, Internet designers defined a mandate for the leading-bits section of the address for each different network class. For example, since a router knows that a Class A network address always starts with a 0, the router might be able to speed a packet on its way after reading only the first bit of its address. This is where the address schemes define the difference between a Class A, a Class B, and a Class C address. Coming up, I'll discuss the differences between these three classes followed by a discussion of the Class D and Class E addresses. For now, know that Classes A, B, and C are the only ranges that are used to address hosts in our networks.

Class A Addresses

In a Class A network address, the first byte is assigned to the network address, and the three remaining bytes are used for the host addresses. The Class A format is as follows:

```
network.host.host.host
```

For example, in the IP address 49.22.102.70, the 49 is the network address and 22.102.70 is the host address. Every machine on this particular network would begin with the distinctive network address of 49.

Class A network addresses are 1 byte long, with the first bit of that byte reserved and the 7 remaining bits available for manipulation, or addressing. As a result, the theoretical maximum number of Class A networks that can be created is 128. Why? Well, each of the 7 bit positions can be either a 0 or a 1 and 2^7 gives you 128.

The designers of the IP address scheme said that the first bit of the first byte in a Class A network address must always be off, or 0. This means a Class A address must be between 0 and 127 in the first byte, inclusive.

Consider the following network address:

```
0xxxxxxx
```

If we turn the other 7 bits all off and then turn them all on, we'll find the Class A range of network addresses:

```
00000000 = 0
01111111 = 127
```

So, a Class A network is defined in the first octet between 0 and 127, and it can't be less or more.

To complicate matters further, the network address of all 0s (0000 0000) is reserved to designate the default route (see Table 7.1). Additionally, the address 127, which is reserved for diagnostics, can't be used either, which means that you can really only use the numbers 1 to 126 to designate Class A network addresses. This means the actual number of usable Class A network addresses is 128 minus 2, or 126.

TABLE 7.1 Reserved IP addresses

Address	Function
Network address of all 0s	Interpreted to mean "this network or segment."
Network address of all 1s	Interpreted to mean "all networks."
Network 127.0.0.1	Reserved for loopback tests. Designates the local host and allows that host to send a test packet to itself without generating network traffic.
Host address of all 0s	Interpreted to mean "network address" or any host on specified network.
Host address of all 1s	Interpreted to mean "all hosts" on the specified network; for example, 126.255.255.255 means "all hosts" on network 126 (Class A address).
Entire IP address set to all 0s	Used by Cisco routers to designate the default route. Could also mean "any network."
Entire IP address set to all 1s (same as 255.255.255.255)	Broadcast to all hosts on the current network; sometimes called an "all 1s broadcast" or limited broadcast.

Each Class A address has 3 bytes (24 bit positions) for the host address of a machine. This means there are 2^{24}—or 16,777,216—unique combinations and, therefore, precisely that many potential unique host addresses for each Class A network. Because host addresses with the two patterns of all 0s and all 1s are reserved, the actual maximum usable number of hosts for a Class A network is 2^{24} minus 2, which equals 16,777,214. Either way, you can see that's a seriously huge number of hosts to have on a network segment!

Here's an example of how to figure out the valid host IDs in a Class A network address:

- All host bits off is the network address: 10.0.0.0.
- All host bits on is the broadcast address: 10.255.255.255.

The valid hosts are the numbers in between the network address and the broadcast address: 10.0.0.1 through 10.255.255.254. Notice that 0s and 255s can be valid host IDs. All you need to remember when trying to find valid host addresses is that the host bits can't ever be all turned off or all turned on at the same time.

Class B Addresses

In a Class B network address, the first 2 bytes are assigned to the network address and the remaining 2 bytes are used for host addresses. The format is as follows:

network.network.host.host

For example, in the IP address 172.16.30.56, the network address is 172.16 and the host address is 30.56.

With a network address being 2 bytes (8 bits each), we're left with 2^{16} unique combinations. But the Internet designers decided that all Class B network addresses should start with the binary digit 1, then 0. This leaves 14 bit positions available to manipulate, so in reality, we get 16,384 (that is, 2^{14}) unique Class B network addresses.

In a Class B network, the RFCs state that the first bit of the first byte must always be turned on but the second bit must always be turned off. If we turn the other 6 bits all off and then all on, we will find the range for a Class B network:

```
10000000 = 128
10111111 = 191
```

As you can see, a Class B network is defined when the first byte is configured from 128 to 191.

A Class B address uses 2 bytes for host addresses. This is 2^{16} minus the two reserved patterns (all 0s and all 1s), for a total of 65,534 possible host addresses for each Class B network.

Here's an example of how to find the valid hosts in a Class B network:

- All host bits turned off is the network address: 172.16.0.0.
- All host bits turned on is the broadcast address: 172.16.255.255.

The valid hosts would be the numbers in between the network address and the broadcast address: 172.16.0.1 through 172.16.255.254.

Class C Addresses

The first 3 bytes of a Class C network address are dedicated to the network portion of the address, with only 1 measly byte remaining for the host address. Here's the format:

```
network.network.network.host
```

Using the example IP address 192.168.100.102, the network address is 192.168.100 and the host address is 102.

In a Class C network address, the first 3 bit positions are always the binary 110. The calculation is as follows: 3 bytes, or 24 bits, minus 3 reserved positions leaves 21 positions. Hence, there are 2^{21}, or 2,097,152, possible Class C networks.

For Class C networks, the RFCs define the first 2 bits of the first octet as always turned on, but the third bit can never be on. Following the same process as the previous classes, convert from binary to decimal to find the range. Here's the range for a Class C network:

```
11000000 = 192
11011111 = 223
```

So, if you see an IP address with a range from 192 up to 223, you'll know it's a Class C IP address.

Each unique Class C network has 1 byte to use for host addresses. This gets us to 2^8, or 256, minus the two reserved patterns of all 0s and all 1s for a total of 254 available host addresses for each Class C network.

Here's an example of how to find a valid host ID in a Class C network:

- All host bits turned off is the network ID: 192.168.100.0.
- All host bits turned on is the broadcast address: 192.168.100.255.

The valid hosts would be the numbers in between the network address and the broadcast address: 192.168.100.1 through 192.168.100.254.

Class D and E Addresses

Addresses with the first octet of 224 to 255 are reserved for Class D and E networks. Class D (224–239) is used for multicast addresses and Class E (240–255) for scientific purposes. But they're really beyond the scope of this book, so I'm not going to go into detail about them here. But you do need to know that the multicast range is from 224.0.0.0 through 239.255.255.255.

Special Purposes of Network Addresses

Some IP addresses are reserved for special purposes, so network administrators can't ever assign them to hosts. Table 7.1 listed the members of this exclusive little club and the reasons they're included in it.

Private IP Addresses (RFC 1918)

The people who created the IP addressing scheme also created what we call *private IP addresses*. These addresses can be used on a private network, but they're not routable through the Internet. This is designed for the purpose of creating a measure of much-needed security, but it also conveniently saves valuable IP address space.

If every host on every network had to have real routable IP addresses, we would have run out of available IP addresses to hand out years ago. But by using private IP addresses, ISPs, corporations, and home users need only a relatively tiny group of bona fide IP addresses to connect their networks to the Internet. This is economical because they can use private IP addresses on their inside networks and get along just fine.

To accomplish this task, the ISP and the corporation—the end users, no matter who they are—need to use something called Network Address Translation (NAT), which basically takes a private IP address and converts it for use on the Internet. NAT provides security in that these IP addresses cannot be seen by external users. External users will only be able to see the public IP address to which the private IP address has been mapped. Moreover, multiple devices in the same private network can use the same, real IP address to transmit out onto the Internet. Doing things this way saves megatons of address space—a very good thing for us all!

Table 7.2 lists the reserved private addresses.

TABLE 7.2 Reserved IP address space

Address class	Reserved address space
Class A	10.0.0.0 through 10.255.255.255
Class B	172.16.0.0 through 172.31.255.255
Class C	192.168.0.0 through 192.168.255.255

Real World Scenario

So, What Private IP Address Should I Use?

That's a really great question: Should you use Class A, Class B, or even Class C private addressing when setting up your network? Let's take Acme Corporation in San Francisco as an example. This company is moving into a new building and needs a whole new network (what a treat this is!). It has 14 departments, with about 70 users in each. You could probably squeeze three or four Class C addresses to use, or maybe you could use a Class B, or even a Class A just for fun.

The rule of thumb in the consulting world is, when you're setting up a corporate network—regardless of how small it is—you should use a Class A network address because it gives you the most flexibility and growth options. For example, if you used the 10.0.0.0 network address with a /24 mask, then you'd have 65,536 networks, each with 254 hosts. Lots of room for growth with that network! You would then subnet this network address space using Classless Internet Domain Routing (CIDR), which provides only the needed amount of hosts to each department or building without wasting IP addresses. (A /24 tells you that a subnet mask has 24 bits out of 32 bits turned on for subnetting a network. This will be covered, as well as CIDR, in more detail in Chapter 8.)

But if you're setting up a home network, you'd opt for a Class C address because it is the easiest for people to understand and configure. Using the default Class C mask gives you one network with 254 hosts—plenty for a home network.

With the Acme Corporation, a nice 10.1.*x*.0 with a /24 mask (the *x* is the subnet for each department) makes this easy to design, install, and troubleshoot.

Virtual IP

When a public IP address is substituted for the actual private IP address that has been assigned to the network interface of the device, the public IP address becomes an example of what is called a *virtual IP address*. This means it doesn't correspond to an actual physical network interface.

There are other examples of such virtual IP addresses. For example, when a web proxy server substitutes its IP address for the sender's IP address before sending a packet to the Internet, it is another example of creating a virtual IP address.

APIPA

I discussed this in Chapter 6, "Introduction to the Internet Protocol," but it is worth repeating here. What happens if you have a few hosts connected together with a switch or hub and you don't have a DHCP server? You can add static IP information to a host or you can let Windows provide what is called Automatic Private IP Addressing (APIPA). I don't recommend this, but APIPA is a "feature," so you do need to remember it, hence mentioning it two chapters in a row!

With APIPA, clients can automatically self-configure an IP address and subnet mask, which is the minimum information needed for hosts to communicate when a DHCP server isn't available. In this way, it could be thought of as a DHCP failover scheme. If all of the hosts set themselves with an APIPA address, they could communicate with one another but unfortunately not with any addresses that were statically configured, such as default gateways!

The IP address range for APIPA is 169.254.0.1 through 169.254.255.254. The client also configures itself with a default Class B subnet mask of 255.255.0.0.

However, when you're in your corporate network and you're running a DHCP server and your host displays that it is using this IP address range, this means that either your DHCP client on the host is not working or the DHCP server is down or can't be reached because of a network issue. For example, if you plug a DHCP client into a port that is disabled, the host will receive an APIPA address. I don't know anyone who has seen a host in the APIPA address range and been happy about it!

IPv4 Address Types

Most people use *broadcast* as a generic term, and most of the time, we understand what they mean. But not always. For example, you might say, "The host broadcasted through a router to a DHCP server," but, well, it's pretty unlikely that this would ever really happen. What you probably mean—using the correct technical jargon—is, "The DHCP client broadcasted for an IP address; a router then forwarded this as a unicast packet to the DHCP server." Oh, and remember that with IPv4, broadcasts are pretty important, but with IPv6, there aren't any broadcasts sent at all—as you'll see in a bit!

Okay, I've referred to broadcast addresses throughout earlier chapters, and even showed you some examples of various IP addresses. But I really haven't gone into the different terms and uses associated with them yet, and it's about time I did. So here are the four IPv4 address types that I'd like to define for you:

Layer 2 Broadcasts These are sent to all nodes on a LAN.

Broadcasts (Layer 3) These are sent to all nodes on the network.

Unicast This is an address for a single interface, and these are used to send packets to a single destination host.

Multicast These are packets sent from a single source and transmitted to many devices on different networks. Referred to as *one-to-many*.

Layer 2 Broadcasts

First, understand that Layer 2 broadcasts are also known as hardware broadcasts—they only go out on a LAN, and they don't go past the LAN boundary (router).

The typical hardware address is 6 bytes (48 bits) and looks something like 0c.43.a4.f3.12.c2. The broadcast would be all 1s in binary, which would be all *F*s in hexadecimal, as in FF.FF.FF.FF.FF.FF.

Layer 3 Broadcasts

Then there are the plain old broadcast addresses at Layer 3. Broadcast messages are meant to reach all hosts on a broadcast domain. These are the network broadcasts that have all host bits on.

Here's an example that you're already familiar with: The network address of 172.16.0.0 would have a broadcast address of 172.16.255.255—all host bits on. Broadcasts can also be "any network and all hosts," as indicated by 255.255.255.255.

A good example of a broadcast message is an Address Resolution Protocol (ARP) request. When a host has a packet, it knows the logical address (IP) of the destination. To get the packet to the destination, the host needs to forward the packet to a default gateway if the destination resides on a different IP network. If the destination is on the local network, the source will forward the packet directly to the destination. Because the source doesn't have the MAC address to which it needs to forward the frame, it sends out a broadcast, something that every device in the local broadcast domain will listen to. This broadcast says, in essence, "If you are the owner of IP address 192.168.2.3, please forward your MAC address to me," with the source giving the appropriate information.

Unicast Address

A unicast address is assigned to a single interface, and this term is used in both IPv4 and IPv6 to describe your host interface IP address.

Multicast Address (Class D)

Multicast is a different beast entirely. At first glance, it appears to be a hybrid of unicast and broadcast communication, but that isn't quite the case. Multicast does allow point-to-multipoint communication, which is similar to broadcasts, but it happens in a different manner. The crux of *multicast* is that it enables multiple recipients to receive messages without flooding the messages to all hosts on a broadcast domain. However, this is not the default behavior—it's what we can do with multicasting if it's configured correctly!

Multicast works by sending messages or data to IP multicast group addresses. Routers then forward copies (unlike broadcasts, which are not forwarded) of the packet out every interface that has hosts subscribed to a particular group address. This is where multicast differs from broadcast messages—with multicast communication, copies of packets, in theory, are sent only to subscribed hosts. When I say in theory, this means that the hosts will receive, for example, a multicast packet destined for 224.0.0.10 (this is an EIGRP packet and only a router running the EIGRP protocol will read it). All hosts on the broadcast LAN (Ethernet is a broadcast multi-access LAN technology) will pick up the frame, read the destination address, and immediately discard the frame, unless they are in the multicast group. This saves PC processing, not LAN bandwidth. Multicasting can cause severe LAN congestion, in some instances, if not implemented carefully.

There are several different groups that users or applications can subscribe to. The range of multicast addresses starts with 224.0.0.0 and goes through 239.255.255.255. As you can see, this range of addresses falls within IP Class D address space based on classful IP assignment.

Internet Protocol Version 6 (IPv6)

People refer to IPv6 as "the next-generation Internet protocol," and it was originally created as the answer to IPv4's inevitable, looming address-exhaustion crisis. Though you've probably heard a thing or two about IPv6 already, it has been improved even further in the quest to bring us the flexibility, efficiency, capability, and optimized functionality that can truly meet our ever-increasing needs. The capacity of its predecessor, IPv4, pales in comparison—and that's the reason it will eventually fade into history completely.

The IPv6 header and address structure has been completely overhauled, and many of the features that were basically just afterthoughts and addendums in IPv4 are now included as full-blown standards in IPv6. It's well equipped, poised, and ready to manage the mind-blowing demands of the Internet to come.

Why Do We Need IPv6?

Well, the short answer is because we need to communicate and our current system isn't really cutting it anymore—kind of like how the Pony Express couldn't compete with airmail. Just look at how much time and effort we've invested in coming up with slick new ways to conserve bandwidth and IP addresses.

It's reality: the number of people and devices that connect to networks increases each and every day. That's not a bad thing at all—we're finding new and exciting ways to communicate with more people all the time, something that's become integral to our culture today. In fact, it's now pretty much a basic human need. But the forecast isn't exactly blue skies and sunshine because, as I alluded to in this chapter's introduction, IPv4, upon which our ability to communicate is presently dependent, is going to run out of addresses for us to use. IPv4 has only about 4.3 billion addresses available—in theory—and we know that we don't even get to use all of those. There really are only about 250 million addresses that can be assigned to devices. Sure, the use of Classless Inter-Domain Routing (CIDR) and NAT has helped to delay the inevitable dearth of addresses, but the truth is we will run out of them, and it's going to happen within a few years. China is barely online, and we know a huge population of people and corporations there surely want to be. There are a lot of reports that give us all kinds of numbers, but all you really need to think about to convince yourself that I'm not just being an alarmist is the fact that there are about 7.2 billion people in the world today, and it's estimated that just over 10 percent of that population is connected to the Internet—wow! IPv6 to the rescue!

That statistic is basically screaming at us the ugly truth that, based on IPv4's capacity, every person can't have a single computer with an IP address—let alone all the other devices we use with them. I have more than one computer, and it's pretty likely you do, too. And I'm not even including in the mix phones, laptops, game consoles, fax machines, routers, switches, and a mother lode of other devices we use every day! So I think I've made it pretty clear that we've got to do something before we run out of addresses and lose the ability to connect with each other as we know it. And that "something" just happens to be implementing IPv6.

The Benefits of and Uses for IPv6

What's so fabulous about IPv6? Is it really the answer to our coming dilemma? Is it really worth it to upgrade from IPv4? All good questions—you may even think of a few more. Of course, there's going to be that group of people with the time-tested and well-known "resistance-to-change syndrome," but don't listen to them. If we had done that years ago, we'd still be waiting weeks, even months for our mail to arrive via horseback. Instead, just know that the answer is a resounding YES! Not only does IPv6 give us lots of addresses (3.4×10^{38} = definitely enough), but there are many other features built into this version that make it well worth the cost, time, and effort required to migrate to it.

Today's networks, as well as the Internet, have a ton of unforeseen requirements that simply were not considerations when IPv4 was created. We've tried to compensate with a collection of add-ons that can actually make implementing them more difficult than mandating them by a standard. By default, IPv6 has improved upon and included many of those features as standard and mandatory. One of these sweet new standards is IPSec—a feature that provides end-to-end security, and that I'll cover in Chapter 13, "Authentication and Access Control." Another little beauty is known as *mobility*, and as its name suggests, it allows a device to roam from one network to another without dropping connections.

But it's the efficiency features that are really going to rock the house! For starters, the header in an IPv6 packet has half the fields, and they are aligned to 64 bits, which gives us some seriously souped-up processing speed—compared to IPv4, lookups happen at light speed. Most of the information that used to be bound into the IPv4 header was taken out, and now you can choose to put it, or parts of it, back into the header in the form of optional extension headers that follow the basic header fields.

And of course there's that whole new universe of addresses (3.4×10^{38}) we talked about already. But where did we get them? Did that *Criss Angel Mindfreak* dude just show up and, blammo, they all materialized? The obvious answer is no, but that huge proliferation of addresses had to come from somewhere, right? Well, it just so happens that IPv6 gives us a substantially larger address space, meaning the address is a whole lot bigger—four times bigger, as a matter of fact! An IPv6 address is actually 128 bits in length, and no worries—I'm going to break down the address piece by piece and show you exactly what it looks like coming up in the next section, "IPv6 Addressing and Expressions." For now, let me just say that all that additional room permits more levels of hierarchy inside the address space and a more flexible address architecture. It also makes routing much more efficient and scalable because the addresses can be aggregated a lot more effectively. And IPv6 also allows multiple addresses for hosts and networks. Plus, the new version of IP now includes an expanded use of multicast communication (one device sending to many hosts or to a select group), which will also join in to boost efficiency on networks because communications will be more specific.

IPv4 uses broadcasts very prolifically, causing a bunch of problems, the worst of which is of course the dreaded broadcast storm—an uncontrolled deluge of forwarded broadcast traffic that can bring an entire network to its knees and devour every last bit of bandwidth. Another nasty thing about broadcast traffic is that it interrupts each and every device on the network. When a broadcast is sent out, every machine has to stop what it's doing and analyze the traffic, whether the broadcast is meant for it or not.

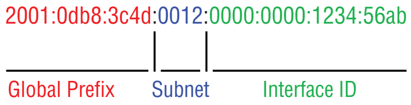
But smile, everyone: There is no such thing as a broadcast in IPv6 because it uses multicast traffic instead. And there are two other types of communication as well: unicast, which is the same as it is in IPv4, and a new type called *anycast*. Anycast communication allows the same address to be placed on more than one device so that when traffic is sent to one device addressed in this way, it is routed to the nearest host that shares the same address. This is just the beginning—we'll get more into the various types of communication later in this chapter in the section "Address Types."

IPv6 Addressing and Expressions

Just as understanding how IP addresses are structured and used is critical with IPv4 addressing, it's also vital when it comes to IPv6. You've already read about the fact that at 128 bits, an IPv6 address is much larger than an IPv4 address. Because of this, as well as because of the new ways the addresses can be used, you've probably guessed that IPv6 will be more complicated to manage. But no worries! As I said, I'll break it down into the basics and show you what the address looks like, how you can write it, and what many of its common uses are. It's going to be a little weird at first, but before you know it, you'll have it nailed.

So let's take a look at Figure 7.2, which has a sample IPv6 address broken down into sections.

FIGURE 7.2 IPv6 address example



As you can now see, the address is truly much larger—but what else is different? Well, first, notice that it has eight groups of numbers instead of four, and also that those groups are separated by colons instead of periods. And hey, wait a second…there are letters in that address! Yep, the address is expressed in hexadecimal just like a MAC address is, so you could say this address has eight 16-bit hexadecimal colon-delimited blocks. That's already quite a mouthful, and you probably haven't even tried to say the address out loud yet.

One other thing I want to point out is for when you set up your test network to play with IPv6, because I know you're going to want to do that. When you use a web browser to make an HTTP connection to an IPv6 device, you have to type the address into the browser with brackets around the literal address. Why? Well, a colon is already being used by the browser for specifying a port number. So basically, if you don't enclose the address in brackets, the browser will have no way to identify the information.

Here's an example of how this looks:

```
http://[2001:0db8:3c4d:0012:0000:0000:1234:56ab]/default.html
```

Now obviously, if you could, you would rather use names to specify a destination (like `www.lammle.com`); but even though it's definitely going to be a pain in the rear, you just have to accept the fact that sometimes you have to bite the bullet and type in the address number. It should be pretty clear that DNS is going to become extremely important when implementing IPv6.

Shortened Expression

The good news is, there are a few tricks to help rescue you when you're writing these monster addresses. For one thing, you can actually leave out parts of the address to abbreviate it, but to get away with doing that you have to follow a couple of rules. First, you can drop any leading zeros in each of the individual blocks. After you do that, the sample address from earlier would then look like this:

```
2001:db8:3c4d:12:0:0:1234:56ab
```

That's a definite improvement—at least you don't have to write all of those extra zeros! But what about whole blocks that don't have anything in them except zeros? Well, you can kind of lose those, too—at least some of them. Again referring to our sample address, you can remove the two blocks of zeros by replacing them with double colons, like this:

```
2001:db8:3c4d:12::1234:56ab
```

Cool—you replaced the blocks of all zeros with double colons. The rule you have to follow to get away with this is that you can only replace one contiguous block of zeros in an address. So if my address has four blocks of zeros and each of them is separated, I don't get to replace them all. Check out this example:

```
2001:0000:0000:0012:0000:0000:1234:56ab
```

And just know that you *can't* do this:

```
2001::12::1234:56ab
```

Instead, this is the best that you can do:

```
2001::12:0:0:1234:56ab
```

The reason why this example is your best shot is that if you remove two sets of zeros, the device looking at the address will have no way of knowing where the zeros go back in. Basically, the router would look at the incorrect address and say, "Well, do I place two blocks into the first set of double colons and two into the second set, or do I place three blocks into the first set and one block into the second set?" And on and on it would go because the information the router needs just isn't there.

Address Types

We're all familiar with IPv4's unicast, broadcast, and multicast addresses, which basically define who or at least how many other devices we're talking to. But as I mentioned, IPv6 introduces the anycast address type. Broadcasts, as we know them, have been eliminated in IPv6 because of their cumbersome inefficiency.

Since a single interface can have multiple types of IPv6 addresses assigned for various purposes, let's find out what each of these types of IPv6 addresses are and the communication methods of each:

Unicast Packets addressed to a unicast address are delivered to a single interface, same as in IPv4. For load balancing, multiple interfaces can use the same address.

Global Unicast Addresses These are your typical publicly routable addresses, and they're used the same way globally unique addresses are in IPv4.

Link-Local Addresses These are like the APIPA addresses in IPv4 in that they're not meant to be routed and are unique for each link (LAN). Think of them as a handy tool that gives you the ability to throw a temporary LAN together for meetings or for creating a small LAN that's not going to be routed but still needs to share and access files and services locally. However, link-local is used on every LAN that connects to a router interface as well.

Unique Local Addresses These addresses are also intended for nonrouting purposes, but they are nearly globally unique, so it's unlikely you'll ever have one of them overlap with any other address. Unique local addresses were designed to replace site-local addresses, so they basically do almost exactly what IPv4 private addresses do—allow communication throughout a site while being routable to multiple local networks. The difference between link-local and unique local is that unique local can be routed within your organization or company.

Multicast Again, as in IPv4, packets addressed to a multicast address are delivered to all interfaces identified by the multicast address. Sometimes people call them *one-to-many addresses*. It's really easy to spot multicast addresses in IPv6 because they always start with *FF*.

Anycast Like multicast addresses, an anycast address identifies multiple interfaces, but there's a big difference: The anycast packet is delivered to only one address—actually, to the first IPv6 address it finds defined in terms of routing distance. And again, this address is special because you can apply a single address to more than one interface. You could call them one-to-one-of-many addresses, but just saying anycast is a lot easier. This is also referred to as one-to-nearest addressing.

You're probably wondering if there are any special, reserved addresses in IPv6 because you know they're there in IPv4. Well, there are—plenty of them! Let's go over them now.

Special Addresses

I'm going to list some of the addresses and address ranges that you should definitely make a point to remember in Table 7.3 because you'll eventually use them. They're all special or reserved for specific use, but unlike IPv4, IPv6 gives us a galaxy of addresses, so reserving a few here and there doesn't hurt a thing.

TABLE 7.3 Special IPv6 addresses

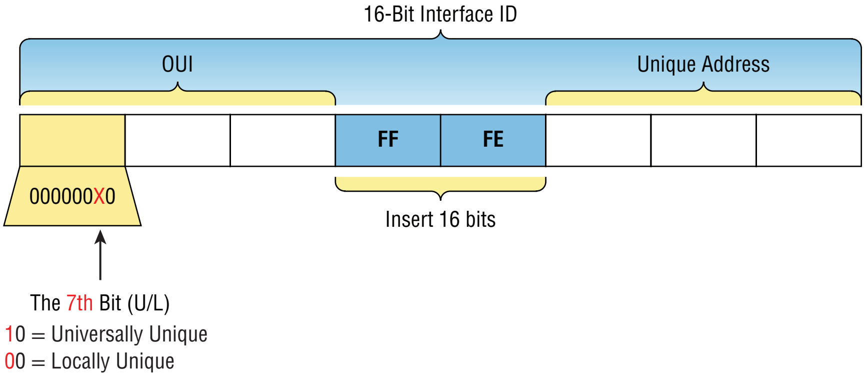
Address	Meaning
0:0:0:0:0:0:0:0	Equals ::. This is the equivalent of IPv4's 0.0.0.0 and is typically the source address of a host before the host receives an IP address when you're using DHCP-driven stateful configuration.
0:0:0:0:0:0:0:1	Equals ::1. The equivalent of 127.0.0.1 in IPv4.
0::FFFF:192.168.100.1	This is how an IPv4 address would be written in a mixed IPv6/IPv4 network environment.
2000::/3	The global unicast address range allocated for Internet access.
FC00::/7	The unique local unicast range.
FE80::/10	The link-local unicast range.
FF00::/8	The multicast range.
3FFF:FFFF::/32	Reserved for examples and documentation.
2001:0DB8::/32	Also reserved for examples and documentation.
2002::/16	Used with 6to4 tunneling, which is an IPv4-to-IPv6 transition system. The structure allows IPv6 packets to be transmitted over an IPv4 network without the need to configure explicit tunnels.

Stateless Autoconfiguration (EUI-64)

Autoconfiguration is an especially useful solution because it allows devices on a network to address themselves with a link-local unicast address as well as with a global unicast address. This process happens through first learning the prefix information from the router and then appending the device's own interface address as the interface ID. But where does it get that interface ID? Well, you know every device on an Ethernet network has a physical MAC address, which is exactly what's used for the interface ID. But since the interface ID in an IPv6 address is 64 bits in length and a MAC address is only 48 bits, where do the extra 16 bits come from? The MAC address is padded in the middle with the extra bits—it's padded with FF:FE.

For example, let's say I have a device with a MAC address that looks like this: 0060:d673:1987. After it's been padded, it would look like this: 0260:d6FF:FE73:1987. Figure 7.3 illustrates what an EUI-64 address looks like.

FIGURE 7.3 EUI-64 interface ID assignment



So where did that 2 in the beginning of the address come from? Another good question. You see that part of the process of padding, called modified EUI-64 format, changes the Universal/Local (U/L) bit to specify if the address is locally unique or globally unique. And the bit that gets changed is the 7th bit in the address.

The reason for modifying the U/L bit is that, when using manually assigned addresses on an interface, you can simply assign the address 2001:db8:1:9::1/64 instead of the much longer 2001:db8:1:9:0200::1/64. Also, if you are going to manually assign link-local addresses, you can assign the short address fe80::1 instead of the long fe80::0200:0:0:1 or fe80:0:0:0:0200::1. So, even though at first glance it seems the IETF made this harder for you to simply understand IPv6 addressing by flipping the 7th bit, in reality this made addressing much simpler. Also, since most people don't typically override the burned-in address, the U/L bit is by default a 0, which means that you'll see this inverted to a 1 most of the time. But because you're studying the exam objectives, you'll need to look at inverting it both ways.

Here are a few examples:

- MAC address 0**0**90:2716:fd0f
- IPv6 EUI-64 address: 2001:0db8:0:1:0**2**90:27ff:fe16:fd0f

That one was easy! Too easy for the exam objectives, so let's do another:

- MAC address a**a**12:bcbc:1234
- IPv6 EUI-64 address: 2001:0db8:0:1:a**8**12:bcff:febc:1234

101010**1**0 represents the first 8 bits of the MAC address (aa), which when inverting the 7th bit becomes 101010**0**0. The answer becomes a8. I can't tell you how important this is for you to understand, so bear with me and work through a couple more!

- MAC address 0**c**0c:dede:1234
- IPv6 EUI-64 address: 2001:0db8:0:1:0**e**0c:deff:fede:1234

0c is 00001100 in the first 8 bits of the MAC address, which then becomes 00001110 when flipping the 7th bit. The answer is then 0e. Let's practice one more:

- MAC address 0**b**34:ba12:1234
- IPv6 EUI-64 address: 2001:0db8:0:1:0**9**34:baff:fe12:1234

0b in binary is 000010**1**1, the first 8 bits of the MAC address, which then becomes 000010**0**1. The answer is 09.

NOTE

Pay extra-special attention to this EUI-64 address assignment and be able to convert the 7th bit based on the EUI-64 rules! Written Lab 7.3 will help you practice this.

DHCPv6 (Stateful)

DHCPv6 works pretty much the same way DHCP does in v4, with the obvious difference that it supports IPv6's new addressing scheme. And it might come as a surprise, but there are a couple of other options that DHCP still provides for us that autoconfiguration doesn't. And no, I'm not kidding—in autoconfiguration, there's absolutely no mention of DNS servers, domain names, or many of the other options that DHCP has always generously provided for us via IPv4. This is a big reason that the odds favor DHCP's continued use in IPv6 into the future at least partially—maybe even most of the time!

This means that you're definitely going to need another server around to supply and dispense all the additional, required information—maybe to even manage the address assignment, if needed!

Migrating to IPv6

We certainly have talked a lot about how IPv6 works and how we can configure it to work on our networks, but what is doing that going to cost us? And how much work is it really going to take? Good questions for sure, but the answers to them won't be the same for everyone. This is because how much you are going to end up having to pony up is highly dependent upon what you've got going on already in terms of your infrastructure. Obviously, if you've been making your really old routers and switches "last" and therefore have to upgrade every one of them so that they're IPv6 compliant, that could very well turn out to be a good-sized chunk of change! Oh, and that sum doesn't even include server and computer operating systems (OSs) and the blood, sweat, and maybe even tears spent on making all your applications compliant. So, my friend, it could cost you quite a bit! The good news is that unless you've really let things go, many OSs and network devices have been IPv6 compliant for a few years—we just haven't been using all their features until now.

Then there's that other question about the amount of work and time. Straight up—this one could still be pretty intense. No matter what, it's going to take you some time to get all of your systems moved over and make sure that things are working correctly. And if you're talking about a huge network with tons of devices, well, it could take a really long time! But don't panic—that's why migration strategies have been created, to allow for a gradual integration. I'm going to show you three of the primary transition strategies available to us. The first is called dual stacking, which allows a device to have both the IPv4 and IPv6 protocol stacks running so it's capable of continuing on with its existing communications and simultaneously running newer IPv6 communications as they're implemented. The next strategy is the 6to4 tunneling approach; this is your choice if you have an all-IPv6 network that must communicate over an IPv4 network to reach another IPv6 network. I'll surprise you with the third one just for fun!

Dual Stacking

This is the most common type of migration strategy because, well, it's the easiest on us—it allows our devices to communicate using either IPv4 or IPv6. Dual stacking lets you upgrade your devices and applications on the network one at a time. As more and more hosts and devices on the network are upgraded, more of your communication will happen over IPv6, and after you've arrived—everything's running on IPv6 and you get to remove all the old IPv4 protocol stacks you no longer need.

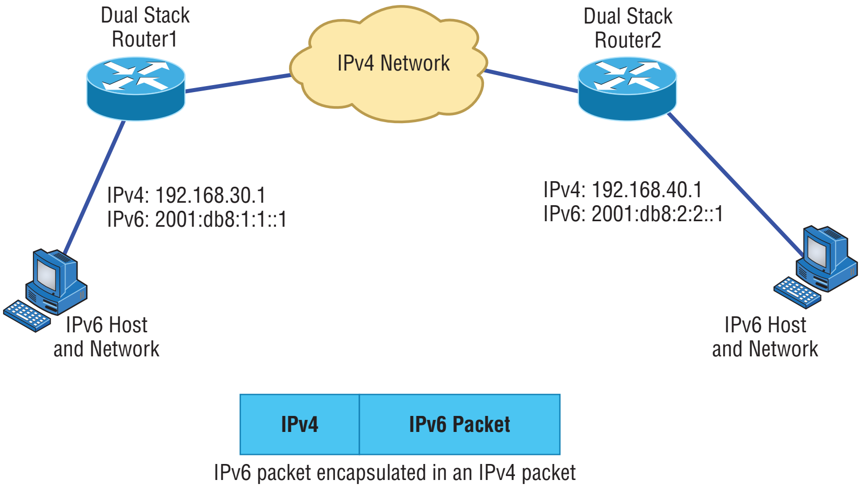
6to4 Tunneling

6to4 tunneling is really useful for carrying IPv6 packets over a network that's still running IPv4. It's quite possible that you'll have IPv6 subnets or other portions of your network that are all IPv6, and those networks will have to communicate with each other. Not so complicated, but when you consider that you might find this happening over a WAN or some other network that you don't control, well, that could be a bit ugly. So what do we do about this if we don't control the whole tamale? Create a tunnel that will carry the IPv6 traffic for us across the IPv4 network, that's what.

The whole idea of tunneling isn't a difficult concept, and creating tunnels really isn't as hard as you might think. All it really comes down to is snatching the IPv6 packet that's happily traveling across the network and sticking an IPv4 header onto the front of it. Kind of like catch-and-release fishing, except for the fish doesn't get something plastered on its face before being thrown back into the stream.

To get a picture of this, take a look at Figure 7.4.

FIGURE 7.4 A 6to4 tunnel



Nice—but to make this happen, we're going to need a couple of dual-stacked routers, which I just demonstrated for you, so you should be good to go. Now we have to add a little configuration to place a tunnel between those routers. Tunnels are pretty simple—we just have to tell each router where the tunnel begins and where we want it to end up. The opposite of this would be a *4to6 tunnel*, which is rare to find because this means your whole business network is IPv4 (okay, this sounds normal so far) but you're traversing an IPv6-only Internet to get to another IPv4 network. Not so common at the time of this writing.

One important note here—if the IPv4 network that you're traversing in this 6to4 situation has a NAT translation point, it would absolutely break the tunnel encapsulation we've just created! Over the years, NAT has been upgraded a lot so that it can handle specific protocols and dynamic connections, and without one of these upgrades, NAT likes to demolish most connections. And since this transition strategy isn't present in most NAT implementations, that means trouble.

But there is a way around this little problem, (the third strategy I told you about) and it's called *Teredo*, which allows all your tunnel traffic to be placed in UDP packets. NAT doesn't blast away at UDP packets, so they won't get broken as other protocol packets do. So with Teredo in place and your packets disguised under their UDP cloak, the packets will easily slip by NAT alive and well!

Miredo is a tunneling technique used on native IPv6 Linux and BSD Unix machines to communicate on the IPv4 Internet directly without a dual-stack router or 6to4 tunnel. This is rarely used.

Summary

In this chapter, I covered the very basics of both IPv4 and IPv6 and how they work in an internetwork (remember that if the acronym *IP* is used alone, it is referring to just IPv4). As you now know by reading this chapter, even when discussing and configuring the basics, there is a lot to understand—and we just scratched the surface. But trust me when I say this—you now know more than you'll need to meet the Network+ objectives.

I discussed in detail the difference between each class of address and how to find a network address, broadcast address, and valid host range.

I explained why we need IPv6 and the benefits associated with it. I followed that up by covering addressing with IPv6 as well as how to use the shortened expressions. And during the discussion on addressing with IPv6, I showed you the different address types, plus the special addresses reserved in IPv6.

The next chapter is very important, but it's one that some people find rather challenging, so take a break and get ready for a really fun but long chapter on IP subnetting. I promise not to torture you too much!

Exam Essentials

Remember the Class A range. The IP range for a Class A network is 1 through 126. This provides 8 bits of network addressing and 24 bits of host addressing by default.

Remember the Class B range. The IP range for a Class B network is 128 through 191. Class B addressing provides 16 bits of network addressing and 16 bits of host addressing by default.

Remember the Class C range. The IP range for a Class C network is 192 through 223. Class C addressing provides 24 bits of network addressing and 8 bits of host addressing by default.

Remember the private IP ranges. The Class A private address range is 10.0.0.0 through 10.255.255.255.

The Class B private address range is 172.16.0.0 through 172.31.255.255.

The Class C private address range is 192.168.0.0 through 192.168.255.255.

Remember the APIPA range. The IP address range for APIPA is 169.254.0.1 through 169.254.255.254. The client also configures itself with a default Class B subnet mask of 255.255.0.0.

Understand why we need IPv6. Without IPv6, the world would soon be depleted of IP addresses.

Understand link-local. Link-local addresses are like an IPv4 APIPA IP address, but it can't be routed at all, not even in your organization.

Understand unique local. This, like link-local, is like a private IP address in IPv4 and cannot be routed to the Internet. However, the difference between link-local and unique local is that unique local can be routed within your organization or company.

Remember IPv6 addressing. IPv6 addressing is not like IPv4 addressing. IPv6 addressing has much more address space and the address is 128 bits long, represented in hexadecimal, unlike an IPv4 address, which is only 32 bits long and represented in decimal.

Understand and be able to read a EUI-64 address with the 7th bit inverted. Hosts can use autoconfiguration to obtain an IPv6 address, and one of the ways is through what is called EUI-64. This takes the unique MAC address of a host and inserts FF:FE in the middle of the address to change a 48-bit MAC address to a 64-bit interface ID. In addition to the 16 bits being inserted into the interface ID, the 7th bit of the first byte is inverted, typically from a 0 to a 1. Practice this with Written Lab 7.3.

Written Labs

You can find the answers to the written labs in Appendix A.

Written Lab 7.1

Provide the answers to the following questions:

1. What is the valid range used for a Class C private IP address?
2. Name some of the benefits of IPv6 over IPv4.
3. What is the term for the autoconfiguration technology responsible for addresses that start with 169.254?
4. What defines a unicast address?
5. What defines a multicast address?
6. What is the name for a 48-bit (6-byte) numerical address physically assigned to a network interface, such as a NIC?
7. What gives IPv6 the ability to reference more addresses than IPv4?
8. What is the private address range for Class B networks?
9. What is the Class C range of values for the first octet in decimal and in binary?
10. What is the 127.0.0.1 address used for?

Written Lab 7.2

In this lab, write the answers to the following IPv6 questions:

1. Which type of packet is addressed and delivered to only a single interface?
2. Which type of address is used just like a regular public routable address in IPv4?
3. Which type of address is not meant to be routed?
4. Which type of address is not meant to be routed to the Internet but is still globally unique?
5. Which type of address is meant to be delivered to multiple interfaces?
6. Which type of address identifies multiple interfaces, but packets are delivered only to the first address it finds?
7. Which addressing type is also referred to as one-to-nearest?
8. IPv4 had a loopback address of 127.0.0.1. What is the IPv6 loopback address?
9. What does a link-local address always start with?
10. What does a unique local unicast range start with?

Written Lab 7.3

In this lab, you will practice inverting the 7th bit of a EUI-64 address. Use the prefix 2001:db8:1:1/64 for each address.

1. Convert the following MAC address into a EUI-64 address: 0b0c:abcd:1234
2. Convert the following MAC address into a EUI-64 address: 060c:32f1:a4d2
3. Convert the following MAC address into a EUI-64 address: 10bc:abcd:1234
4. Convert the following MAC address into a EUI-64 address: 0d01:3a2f:1234
5. Convert the following MAC address into a EUI-64 address: 0a0c:abac:caba

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following addresses is not allowed on the Internet?
   - **A.** 191.192.168.1
   - **B.** 191.168.169.254
   - **C.** 172.32.255.0
   - **D.** 172.31.12.251

2. A host automatically configured with an address from which of the following ranges indicates an inability to contact a DHCP server?
   - **A.** 169.254.0.*x* with a mask of 255.255.255.0
   - **B.** 169.254.*x*.*x* with a mask of 255.255.0.0
   - **C.** 169.254.*x*.*x* with a mask of 255.255.255.0
   - **D.** 169.255.*x*.*x* with a mask of 255.255.0.0

3. Which statement regarding private IP addresses is most accurate?
   - **A.** Private addresses cannot be used in intranets that require routing.
   - **B.** Private addresses must be assigned by a registrar or ISP.
   - **C.** A remote host across the Internet cannot ping your host if it has a private address.
   - **D.** Private addresses can only be used by a single administrative domain.

4. Which of the following is a valid Class A address?
   - **A.** 191.10.0.1
   - **B.** 127.10.0.1
   - **C.** 128.10.0.1
   - **D.** 126.10.0.1

5. Which of the following is a valid Class B address?
   - **A.** 10.1.1.1
   - **B.** 126.1.1.1
   - **C.** 129.1.1.1
   - **D.** 192.168.1.1

6. Which of the following describes a broadcast address?
   - **A.** All network bits are on (1s).
   - **B.** All host bits are on (1s).
   - **C.** All network bits are off (0s).
   - **D.** All host bits are off (0s).

7. Which of the following is a Layer 2 broadcast?
   - A. FF.FF.FF.EE.EE.EE
   - B. FF.FF.FF.FF.FF.FF
   - C. 255.255.255.255
   - D. 255.0.0.0

8. In a Class C IP address, how long is the network address?
   - A. 8 bits
   - B. 16 bits
   - C. 24 bits
   - D. 32 bits

9. Which of the following is true when describing a unicast address?
   - A. Packets addressed to a unicast address are delivered to a single interface.
   - B. These are your typical publicly routable addresses, just like regular publicly routable addresses in IPv4.
   - C. These are like private addresses in IPv4 in that they are not meant to be routed.
   - D. These addresses are meant for nonrouting purposes, but they are almost globally unique, so it is unlikely they will have an address overlap.

10. A host is rebooted and you view the IP address that it was assigned. The address is 169.123.13.34. Which of the following happened?
    - A. The host received an APIPA address.
    - B. The host received a multicast address.
    - C. The host received a public address.
    - D. The host received a private address.

11. An IPv4 address uses 32 bits. How many bits is an IPv6 address?
    - A. 64
    - B. 128
    - C. 192
    - D. 255

12. Which of the following is true when describing a multicast address?
    - A. Packets addressed to a unicast address from a multicast address are delivered to a single interface.
    - B. Packets are delivered to all interfaces identified by the address. This is also called a one-to-many address.
    - C. It identifies multiple interfaces and is delivered to only one address. This address can also be called one-to-one-of-many.
    - D. These addresses are meant for nonrouting purposes, but they are almost globally unique so it is unlikely they will have an address overlap.

13. Which of the following is true when describing an anycast address?
    - A. Packets addressed to a unicast address from an anycast address are delivered to a single interface.
    - B. Packets are delivered to all interfaces identified by the address. This is also called a one-to-many address.
    - C. This address identifies multiple interfaces, and the anycast packet is delivered to only one address: the closest one. This address can also be called one-to-nearest.
    - D. These addresses are meant for nonrouting purposes, but they are almost globally unique so it is unlikely they will have an address overlap.

14. You want to ping the loopback address of your local host. Which two addresses could you type? (Choose two.)
    - A. `ping 127.0.0.1`
    - B. `ping 0.0.0.0`
    - C. `ping ::1`
    - D. `trace 0.0.::1`

15. What two statements about IPv6 addresses are true? (Choose two.)
    - A. Leading zeros are required.
    - B. Two colons (::) are used to represent successive hexadecimal fields of zeros.
    - C. Two colons (::) are used to separate fields.
    - D. A single interface will have multiple IPv6 addresses of different types.

16. What two statements about IPv4 and IPv6 addresses are true? (Choose two.)
    - A. An IPv6 address is 32 bits long, represented in hexadecimal.
    - B. An IPv6 address is 128 bits long, represented in decimal.
    - C. An IPv4 address is 32 bits long, represented in decimal.
    - D. An IPv6 address is 128 bits long, represented in hexadecimal.

17. Which of the following is a Class C network address?
    - A. 10.10.10.0
    - B. 127.0.0.1
    - C. 128.0.0.0
    - D. 192.255.254.0

18. Which of the following are private IP addresses? (Choose two.)
    - A. 12.0.0.1
    - B. 168.172.19.39
    - C. 172.20.14.36
    - D. 172.33.194.30
    - E. 192.168.24.43

19. IPv6 unicast routing is running on the Corp router. Which of the following addresses would be used as the EUI-64 address?

```
Corp#sh int f0/0
FastEthernet0/0 is up, line protocol is up
Hardware is AmdFE, address is 000d.bd3b.0d80 (bia 000d.bd3b.0d80)
[output cut]
```

A. FF02::3c3d:0d:bdff:fe3b:0d80

B. FE80::3c3d:2d:bdff:fe3b:0d80

C. FE80::3c3d:0d:bdff:fe3b:0d80

D. FE80::3c3d:2d:ffbd:3bfe:0d80

20. Which of the following is an invalid IP address for a host?

A. 10.0.0.1

B. 128.0.0.1

C. 224.0.0.1

D. 172.0.0.1

Chapter

8

IP Subnetting, Troubleshooting IP, and Introduction to NAT

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- NAT/PAT
- Port forwarding

✓ **1.4 Given a scenario, configure the appropriate IP addressing components**

- Subnetting
- Default gateway
- Classful
  - Classes A, B, C, D, and E
- Classless
  - VLSM
  - CIDR notation (IPv4 vs. IPv6)

This chapter's focus will really zoom in on IP addressing to ensure that you have it nailed down tight. This is an integral aspect of networking, and it's important to your success on the exams and as a professional, too!

We'll start with subnetting an IP network. You're going to have to really apply yourself because it takes time and practice in order to do subnetting correctly and quickly. So be patient and do whatever it takes to get this stuff dialed in. This chapter truly is important—possibly the most important chapter in this book for you to understand. Make it part of you!

I'll thoroughly cover IP subnetting from the very beginning. I know this might sound weird to you, but I think you'll be much better off if you can try to forget everything you've learned about subnetting before reading this chapter—especially if you've been to a Microsoft class!

I'll also take you through IP address troubleshooting and walk you through each of the steps recommended when you're faced with troubleshooting an IP network. Finally, I'll finish up with an introduction to Network Address Translation (NAT)—there are various types of NAT, and you need to know when you would use each one.

So get psyched—you're about to go for quite a ride! This chapter will truly help you understand IP addressing and networking, so don't get discouraged or give up. If you stick with it, I promise that one day you'll look back on this and be really glad you decided to stay the course. It's one of those things that after you understand it, you'll laugh at that time, way back when, when you thought this was hard. So, are you ready now? Let's go!

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Subnetting Basics

In Chapter 7, "IP Addressing," you learned how to define and find the valid host ranges used in a Class A, Class B, or Class C network address by turning the host bits all off and then all on. This is very good, but here's the catch: You were defining only one network. What would happen if you wanted to take one network address range and create six networks from it? You would have to do something called *subnetting*, because that's what allows you to take one larger network and break it into a bunch of smaller networks.

There are loads of reasons in favor of subnetting, including the following benefits:

Reduced Network Traffic We all appreciate less traffic of any kind. With networks, it's no different. Without trusty routers, packet traffic could grind the entire network down to a near standstill. With routers, most traffic will stay on the local network; only packets destined for other networks will pass through the router. Routers create broadcast domains. The more broadcast domains you create, the smaller the broadcast domains and the less network traffic on each network segment.

Optimized Network Performance This is the very cool reward you get when you reduce network traffic!

Simplified Management It's easier to identify and isolate network problems in a group of smaller connected networks than within one gigantic network.

Facilitated Spanning of Large Geographical Distances Because WAN links are considerably slower and more expensive than LAN links, a single large network that spans long distances can create problems in every area previously listed. Connecting multiple smaller networks makes the system more efficient.

Next, we're going to move on to subnetting a network address. This is the good part—ready?

How to Create Subnets

To create subnetworks, you take bits from the host portion of the IP address and reserve them to define the subnet address. This means fewer bits for hosts, so the more subnets, the fewer bits are left available for defining hosts.

Soon, I'll show you how to create subnets, starting with Class C addresses. But before you actually implement subnetting, you really need to determine your current requirements as well as plan for future conditions.

Follow these steps—they're your recipe for solid design:

1. Determine the number of required network IDs:
   - One for each subnet
   - One for each wide area network (WAN) connection
2. Determine the number of required host IDs per subnet:
   - One for each TCP/IP host
   - One for each router interface
3. Based on the previous requirements, create the following:
   - One subnet mask for your entire network
   - A unique subnet ID for each physical segment
   - A range of host IDs for each subnet

Understanding the Powers of 2

By the way, powers of 2 are really important to memorize for use with IP subnetting. To review powers of 2, remember that when you see a number with another number to its upper right (an exponent), this means you should multiply the number by itself as many times as the upper number specifies. For example, 2^3 is 2 × 2 × 2, which equals 8. Here's a list of powers of 2 that you should commit to memory:

$2^1 = 2$

$2^2 = 4$

$2^3 = 8$

$2^4 = 16$

$2^5 = 32$

$2^6 = 64$

$2^7 = 128$

$2^8 = 256$

$2^9 = 512$

$2^{10} = 1{,}024$

$2^{11} = 2{,}048$

$2^{12} = 4{,}096$

$2^{13} = 8{,}192$

$2^{14} = 16{,}384$

If you hate math, don't get stressed out about knowing all these exponents—it's helpful to know them, but it's not absolutely necessary. Here's a little trick, because you're working with 2s: Each successive power of 2 is double the previous one.

For example, all you have to do to remember the value of 2^9 is to first know that $2^8 = 256$. Why? Because when you double 2 to the eighth power (256), you get 2^9 (or 512). To determine the value of 2^{10}, simply start at $2^8 = 256$, and then double it twice.

You can go the other way as well. If you needed to know what 2^6 is, for example, you just cut 256 in half two times: once to reach 2^7 and then one more time to reach 2^6. Not bad, right?

Subnet Masks

For the subnet address scheme to work, every machine on the network must know which part of the host address will be used as the subnet address. This is accomplished by assigning a *subnet mask* to each machine. A subnet mask is a 32-bit value that allows the recipient of IP packets to distinguish the network ID portion of the IP address from the host ID portion of the IP address.

The network administrator creates a 32-bit subnet mask composed of 1s and 0s. The 1s in the subnet mask represent the positions that refer to the network, or subnet, addresses.

Not all networks need subnets, meaning they use the default subnet mask. This is basically the same as saying that a network doesn't have a subnet address. Table 8.1 shows the default subnet masks for Classes A, B, and C. These default masks cannot and do not change. In other words, you can't make a Class B subnet mask read 255.0.0.0. If you try, the host will read that address as invalid and usually won't even let you type it in. For a Class A network, you can't change the first byte in a subnet mask; it must read 255.0.0.0 at a minimum. Similarly, you cannot assign 255.255.255.255, because this is all 1s—a broadcast address. A Class B address must start with 255.255.0.0, and a Class C has to start with 255.255.255.0. Check out Table 8.1.

TABLE 8.1 Default subnet masks

Class	Format	Default subnet mask
A	*network.host.host.host*	255.0.0.0
B	*network.network.host.host*	255.255.0.0
C	*network.network.network.host*	255.255.255.0

Classless Inter-Domain Routing (CIDR)

Another term you need to know is *Classless Inter-Domain Routing (CIDR)*. It's basically the method that Internet service providers (ISPs) use to allocate a number of addresses to a company or a home connection. They provide addresses in a certain block size; I'll be going into that in greater detail later in this chapter. Another term for the use of different length subnet masks in the network is *variable length subnet masking (VLSM)*.

When you receive a block of addresses from an ISP, what you get will look something like this: 192.168.10.32/28. This is telling you what your subnet mask is. The slash notation (/) means how many bits are turned on (1s). Obviously, the maximum could only be /32 because a byte is 8 bits and there are 4 bytes in an IP address: 4 × 8 = 32. But keep in mind that the largest subnet mask available (regardless of the class of address) can only be a /30 because you have to keep at least 2 bits for host bits.

Take, for example, a Class A default subnet mask, which is 255.0.0.0. This means that the first byte of the subnet mask is all ones (1s), or 11111111. When referring to a slash notation, you need to count all the 1s bits to figure out your mask. The 255.0.0.0 is considered a /8 because it has 8 bits that are 1s—that is, 8 bits that are turned on.

A Class B default mask would be 255.255.0.0, which is a /16 because 16 bits are (1s): 11111111.11111111.00000000.00000000.

Table 8.2 offers a listing of every available subnet mask and its equivalent CIDR slash notation.

TABLE 8.2 CIDR values

Subnet Mask	CIDR Value
255.0.0.0	/8
255.128.0.0	/9
255.192.0.0	/10
255.224.0.0	/11
255.240.0.0	/12
255.248.0.0	/13
255.252.0.0	/14
255.254.0.0	/15
255.255.0.0	/16
255.255.128.0	/17
255.255.192.0	/18
255.255.224.0	/19
255.255.240.0	/20
255.255.248.0	/21
255.255.252.0	/22
255.255.254.0	/23
255.255.255.0	/24
255.255.255.128	/25

Subnet Mask	CIDR Value
255.255.255.192	/26
255.255.255.224	/27
255.255.255.240	/28
255.255.255.248	/29
255.255.255.252	/30

Although according to RFC 1518, any device or software that claims to be CIDR compliant will allow supernetting, meaning a traditionally Class C address can be used with a /23 subnet mask, in almost all cases. The /8 through /15 can be used only with Class A network addresses; /16 through /23 can be used by Class A and B network addresses; /24 through /30 can be used by Class A, B, and C network addresses. This is a big reason most companies use Class A network addresses. By being allowed the use of all subnet masks, they gain the valuable benefit of maximum flexibility for their network design.

Subnetting Class C Addresses

There are many different ways to subnet a network. The right way is the way that works best for you. In a Class C address, only 8 bits are available for defining the hosts. Remember that subnet bits start at the left and go to the right, without skipping bits. This means that the only Class C subnet masks can be those listed here:

Binary	Decimal	CIDR
00000000	0	/24
10000000	128	/25
11000000	192	/26
11100000	224	/27
11110000	240	/28
11111000	248	/29
11111100	252	/30

We can’t use a /31 or /32 because, remember, we have to leave at least 2 host bits for assigning IP addresses to hosts.

Get ready for something special. I'm going to teach you an alternate method of subnetting that makes it a whole lot easier to subnet larger numbers in no time. And trust me, you really do need to be able to subnet fast!

Subnetting a Class C Address: The Fast Way!

When you've chosen a possible subnet mask for your network and need to determine the number of subnets, valid hosts, and broadcast addresses of a subnet that the mask provides, all you need to do is answer five simple questions:

- How many subnets does the chosen subnet mask produce?
- How many valid hosts per subnet are available?
- What are the valid subnets?
- What's the broadcast address of each subnet?
- What are the valid hosts in each subnet?

At this point, it's important that you both understand and have memorized your powers of 2. Please refer to the sidebar "Understanding the Powers of 2" earlier in this chapter if you need some help. Here's how you get the answers to those five big questions:

- *How many subnets?* 2^x = number of subnets. x is the number of masked bits, or the 1s. For example, in 11000000, the number of 1s gives us 2^2 subnets. In this example, there are 4 subnets.
- *How many hosts per subnet?* $2^y - 2$ = number of hosts per subnet. y is the number of unmasked bits, or the 0s. For example, in 11000000, the number of 0s gives us $2^6 - 2$ hosts. In this example, there are 62 hosts per subnet. You need to subtract 2 for the subnet address and the broadcast address, which are not valid hosts.
- *What are the valid subnets?* 256 – *subnet mask* = *block size*, or increment number. An example would be 256 – 192 = 64. The block size of a 192 mask is always 64. Start counting at zero in blocks of 64 until you reach the subnet mask value, and these are your subnets. 0, 64, 128, 192. Easy, huh?
- *What's the broadcast address for each subnet?* Now here's the really easy part. Because we counted our subnets in the last section as 0, 64, 128, and 192, the broadcast address is always the number right before the next subnet. For example, the 0 subnet has a broadcast address of 63 because the next subnet is 64. The 64 subnet has a broadcast address of 127 because the next subnet is 128. And so on. And remember, the broadcast address of the last subnet is always 255.
- *What are the valid hosts?* Valid hosts are the numbers between the subnets, omitting all the 0s and all the 1s. For example, if 64 is the subnet number and 127 is the broadcast address, then 65–126 is the valid host range—it's *always* the numbers between the subnet address and the broadcast address.

I know this can truly seem confusing. But it really isn't as hard as it seems to be at first—just hang in there! Why not try a few and see for yourself?

Subnetting Practice Examples: Class C Addresses

Here's your opportunity to practice subnetting Class C addresses using the method I just described. Exciting, isn't it? We're going to start with the first Class C subnet mask and work through every subnet that we can using a Class C address. When we're done, I'll show you how easy this is with Class A and B networks too!

Practice Example #1C: 255.255.255.128 (/25)

Because 128 is 10000000 in binary, there is only 1 bit for subnetting, and there are 7 bits for hosts. We're going to subnet the Class C network address 192.168.10.0.

192.168.10.0 = Network address

255.255.255.128 = Subnet mask

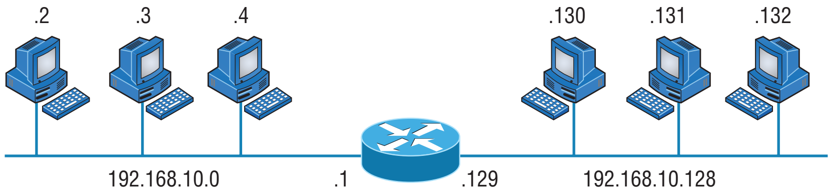
Now, let's answer the big five:

- *How many subnets?* Because 128 is 1 bit on (10000000), the answer is $2^1 = 2$.
- *How many hosts per subnet?* We have 7 host bits off (1**0000000**), so the equation is $2^7 - 2 = 126$ hosts.
- *What are the valid subnets?* 256 – 128 = 128. Remember, we'll start at zero and count in our block size, so our subnets are 0, 128.
- *What's the broadcast address for each subnet?* The number right before the value of the next subnet is all host bits turned on and equals the broadcast address. For the 0 subnet, the next subnet is 128, so the broadcast address of the 0 subnet is 127.
- *What are the valid hosts?* These are the numbers between the subnet and broadcast address. The easiest way to find the hosts is to write out the subnet address and the broadcast address. This way, the valid hosts are obvious. The following table shows the 0 and 128 subnets, the valid host ranges of each, and the broadcast address of both subnets:

Subnet	**0**	**128**
First host	1	129
Last host	126	254
Broadcast	127	255

Before moving on to the next example, take a look at Figure 8.1. Okay, looking at a Class C /25, it's pretty clear there are two subnets. But so what—why is this significant? Well actually, it's not, but that's not the right question. What you really want to know is what you would do with this information!

FIGURE 8.1 Implementing a Class C /25 logical network



```
Router#show ip route
[output cut]
C 192.168.10.0 is directly connected to Ethernet 0.
C 192.168.10.128 is directly connected to Ethernet 1.
```

The key to understanding subnetting is to understand the very reason you need to do it. And I'm going to demonstrate this by going through the process of building a physical network—and let's add a router. (We now have an internetwork, as I truly hope you already know!) Because we added that router, in order for the hosts on our internetwork to communicate, they must now have a logical network addressing scheme. We could use IPv6, but IPv4 is still the most popular, and it also just happens to be what we're studying at the moment, so that's what we're going with.

Now take a look back at Figure 8.1. By the way, the output you see below the diagram is the routing table of the router, which was displayed by executing the `show ip route` command on the router. There are two physical networks, so we're going to implement a logical addressing scheme that allows for two logical networks. As always, it's a really good idea to look ahead and consider any likely growth scenarios—both short and long term, but for this example, a /25 will do the trick.

Practice Example #2C: 255.255.255.192 (/26)

In this second example, we're going to subnet the network address 192.168.10.0 using the subnet mask 255.255.255.192.

192.168.10.0 = Network address

255.255.255.192 = Subnet mask

It's time to answer the big five:

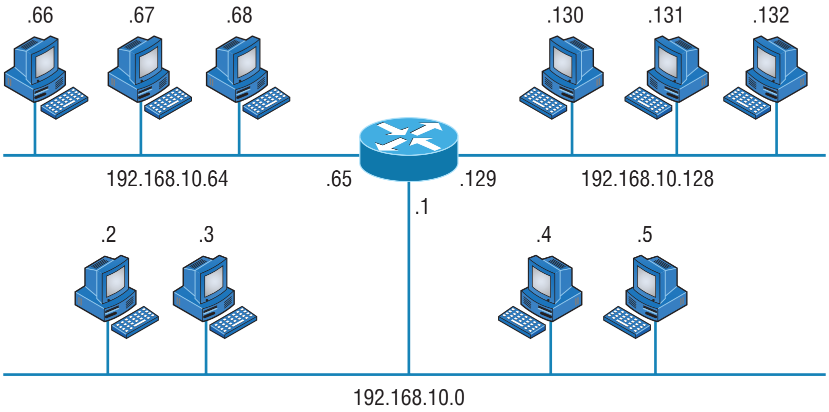
- *How many subnets?* Because 192 is 2 bits on (**11**000000), the answer is 2^2 = 4 subnets.
- *How many hosts per subnet?* We have 6 host bits off (11**000000**), so the equation is $2^6 - 2$ = 62 hosts.
- *What are the valid subnets?* 256 – 192 = 64. Remember, we start at zero and count in our block size, so our subnets are 0, 64, 128, and 192.
- *What's the broadcast address for each subnet?* The number right before the value of the next subnet is all host bits turned on and equals the broadcast address. For the 0 subnet, the next subnet is 64, so the broadcast address for the 0 subnet is 63.

- *What are the valid hosts?* These are the numbers between the subnet and broadcast address. The easiest way to find the hosts is to write out the subnet address and the broadcast address. This way, the valid hosts are obvious. The following table shows the 0, 64, 128, and 192 subnets, the valid host ranges of each, and the broadcast address of each subnet:

The subnets (do this first)	**0**	**64**	**128**	**192**
Our first host (perform host addressing last)	1	65	129	193
Our last host	62	126	190	254
The broadcast address (do this second)	63	127	191	255

Again, before getting into the next example, you can see that we can now subnet a /26. And what are you going to do with this fascinating information? Implement it! We'll use Figure 8.2 to practice a /26 network implementation.

FIGURE 8.2 Implementing a Class C /26 logical network



```
Router#show ip route
[output cut]
C 192.168.10.0 is directly connected to Ethernet 0
C 192.168.10.64 is directly connected to Ethernet 1
C 192.168.10.128 is directly connected to Ethernet 2
```

The /26 mask provides four subnetworks, and we need a subnet for each router interface. With this mask, in this example, we actually have room to add another router interface.

Practice Example #3C: 255.255.255.224 (/27)

This time, we'll subnet the network address 192.168.10.0 and subnet mask 255.255.255.224.

192.168.10.0 = Network address

255.255.255.224 = Subnet mask

- *How many subnets?* 224 is 11100000, so our equation is $2^3 = 8$.
- *How many hosts?* $2^5 - 2 = 30$.
- *What are the valid subnets?* 256 – 224 = 32. We just start at zero and count to the subnet mask value in blocks (increments) of 32: 0, 32, 64, 96, 128, 160, 192, and 224.
- *What's the broadcast address for each subnet (always the number right before the next subnet)?*
- *What are the valid hosts (the numbers between the subnet number and the broadcast address)?*

To answer the last two questions, first just write out the subnets, and then write out the broadcast address—the number right before the next subnet. Last, fill in the host address. The following table gives you all the subnets for the 255.255.255.224 Class C subnet mask:

The subnet address	**0**	**32**	**64**	**96**	**128**	**160**	**192**	**224**
The first valid host	1	33	65	97	129	161	193	225
The last valid host	30	62	94	126	158	190	222	254
The broadcast address	31	63	95	127	159	191	223	255

Practice Example #4C: 255.255.255.240 (/28)

Let's practice on another one:

192.168.10.0 = Network address

255.255.255.240 = Subnet mask

- *Subnets?* 240 is 11110000 in binary. $2^4 = 16$.
- *Hosts?* 4 host bits, or $2^4 - 2 = 14$.
- *Valid subnets?* 256 – 240 = 16. 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, 240.
- *Broadcast address for each subnet?*
- *Valid hosts?*

To answer the last two questions, check out the following table. It gives you the subnets, valid hosts, and broadcast address for each subnet. First, find the address of each subnet using the block size (increment). Second, find the broadcast address of each subnet increment (it's always the number right before the next valid subnet); then, just fill in the host address. The following table shows the available subnets, hosts, and broadcast address provided by a Class C network 255.255.255.240 mask:

Subnet	**0**	**16**	**32**	**48**	**64**	**80**	**96**	**112**	**128**	**144**	**160**	**176**	**192**	**208**	**224**	**240**
First host	1	17	33	49	65	81	97	113	129	145	161	177	193	209	225	241
Last host	14	30	46	62	78	94	110	126	142	158	174	190	206	222	238	254
Broadcast	15	31	47	63	79	95	111	127	143	159	175	191	207	223	239	255

Practice Example #5C: 255.255.255.248 (/29)

Let's keep practicing:

192.168.10.0 = Network address

255.255.255.248 = Subnet mask

- *Subnets?* 248 in binary = 11111000. 2^5 = 32.
- *Hosts?* $2^3 - 2 = 6$.
- *Valid subnets?* 256 – 248 = 8, start at zero: 0, 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 88, 96, 104, 112, 120, 128, 136, 144, 152, 160, 168, 176, 184, 192, 200, 208, 216, 224, 232, 240, and 248.
- *Broadcast address for each subnet?*
- *Valid hosts?*

Take a look at the following table. It shows some of the subnets (first four and last four only), valid hosts, and broadcast address for the Class C 255.255.255.248 mask:

Subnet	**0**	**8**	**16**	**24**	**…**	**224**	**232**	**240**	**248**
First host	1	9	17	25	…	225	233	241	249
Last host	6	14	22	30	…	230	238	246	254
Broadcast	7	15	23	31	…	231	239	247	255

Practice Example #6C: 255.255.255.252 (/30)

I know, I know—but just one more:

192.168.10.0 = Network address

255.255.255.252 = Subnet mask

- *Subnets?* 64.
- *Hosts?* 2.
- *Valid subnets?* 0, 4, 8, 12, and so on, all the way to 252.
- *Broadcast address for each subnet (always the number right before the next subnet)?*
- *Valid hosts (the numbers between the subnet number and the broadcast address)?*

The following table shows you the subnet, valid host, and broadcast address of the first four and last four subnets in the 255.255.255.252 Class C subnet:

Subnet	0	4	8	**12**	**…**	**240**	**244**	**248**	**252**
First host	1	5	9	13	…	241	245	249	253
Last host	2	6	10	14	…	242	246	250	254
Broadcast	3	7	11	15	…	243	247	251	255

Subnetting in Your Head: Class C Addresses

It really is possible to subnet in your head by looking at a valid IP address and subnet mask. This is extremely important for IP addressing and troubleshooting. Even if you don't believe me that you can subnet in your head, I'll show you how. And it's not all that hard either—take the following example: What is the subnet, broadcast address, and valid host range that this host IP address is a part of?

192.168.10.33 = Host address

255.255.255.224 = Subnet mask

Real World Scenario

Should We Really Use This Mask That Provides Only Two Hosts?

Imagine you are the network administrator for Acme Corporation in San Francisco, with dozens of WAN links connecting to your corporate office. Right now your network is a classful network, which means that the same subnet mask is on each host and router interface. You've read about classless routing where you can have different size masks, but you don't know what to use on your point-to-point WAN links. Is 255.255.255.252 (/30) a helpful mask in this situation?

Yes, this is a very helpful mask in wide area networks.

If you use the 255.255.255.0 mask, then each network will have 254 hosts, but you only use two addresses with a WAN link! That is a waste of 252 hosts per subnet. If you use the 255.255.255.252 mask, then each subnet has only 2 hosts, and you don't waste precious addresses.

First, determine the subnet and broadcast address of this IP address. You can do this by answering question 3 of the big five questions: 256 – 224 = 32. Start at zero: 0, 32, 64. The address of 33 falls between the two subnets of 32 and 64 and must be part of the 192.168.10.32 subnet. The next subnet is 64, so the broadcast address of the 32 subnet is 63. (Remember that the broadcast address of a subnet is always the number right before the next subnet.) The valid host range is 33–62 (the numbers between the subnet and broadcast address). I told you this is easy!

Okay, let's try another one. What is the subnet, broadcast address, and valid host range that this host IP address is a part of?

192.168.10.33 = Host address

255.255.255.240 = Subnet mask

256 – 240 = 16. Start at zero and count till you pass the valid host in the problem: 0, 16, 32, 48. Bingo—the host address is between the 32 and 48 subnets. The subnet is 192.168.10.32, and the broadcast address is 47 (the next subnet is 48). The valid host range is 33–46 (the numbers between the subnet number and the broadcast address).

We need to do more, just to make sure you have this down.

You have a host address of 192.168.10.174 with a mask of 255.255.255.240. What is the subnet, broadcast address, and valid host range that this host IP address is a part of?

The mask is 240, so we need our block size: 256 – 240 = 16. Just keep adding 16 until we pass the host address of 174, starting at zero, of course: 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176. The host address of 174 is between 160 and 176, so the subnet is 160. The broadcast address is 175; the valid host range is 161–174. That was a tough one.

Let's do one more just for fun. This is the easiest one of all Class C subnetting:

192.168.10.17 = Host address

255.255.255.252 = Subnet mask

What subnet and broadcast address is this IP address a part of? 256 – 252 = 4. Start at zero (always start at zero unless told otherwise): 0, 4, 8, 12, 16, 20, and so on. You've got it! The host address is between the 16 and 20 subnets. The subnet is 192.168.10.16, and the broadcast address is 19. The valid host range is 17–18.

Now that you're all over Class C subnetting, let's move on to Class B subnetting. But before we do, let's do a quick review.

So What Do You Know Now?

Here's where you can really apply what you've learned so far and begin committing it all to memory. This is a very cool section that I've been using in my classes for years. It will really help you nail down subnetting!

When you see a subnet mask or slash notation (CIDR), you should know the following when working with Class C networks.

/25

What do you know about a /25?

- 128 mask
- 1 bit on and 7 bits off (10000000)
- Block size of 128
- 2 subnets, each with 126 hosts

/26

And what do you know about a /26?

- 192 mask
- 2 bits on and 6 bits off (11000000)
- Block size of 64
- 4 subnets, each with 62 hosts

/27

What about a /27?

- 224 mask
- 3 bits on and 5 bits off (11100000)
- Block size of 32
- 8 subnets, each with 30 hosts

/28

And what about a /28?

- 240 mask
- 4 bits on and 4 bits off
- Block size of 16
- 16 subnets, each with 14 hosts

/29

What do you know about a /29?

- 248 mask
- 5 bits on and 3 bits off
- Block size of 8
- 32 subnets, each with 6 hosts

/30

And last, what about a /30?

- 252 mask
- 6 bits on and 2 bits off
- Block size of 4
- 64 subnets, each with 2 hosts

Regardless of whether you have a Class A, Class B, or Class C address, the /30 mask will provide you with only two hosts, ever. This mask is suited almost exclusively for use on point-to-point links.

If you can memorize this “So What Do You Know Now?” section, you’ll be much better off in your day-to-day job and in your studies. Try saying it out loud, which helps you memorize things—yes, your significant other and/or coworkers will think you’ve lost it, but they probably already do if you’re in the networking field. And if you’re not yet in the networking field but are studying all this to break into it, you might as well have people start thinking you’re a little “different” now because they will eventually anyway.

It’s also helpful to write these on some type of flashcards and have people test your skill. You’d be amazed at how fast you can get subnetting down if you memorize block sizes as well as this “So What Do You Know Now?” section.

Subnetting Class B Addresses

Before we dive into this, let’s look at all the possible Class B subnet masks. Notice that we have a lot more possible subnet masks than we do with a Class C network address:

255.255.0.0	(/16)
255.255.128.0	(/17)
255.255.192.0	(/18)
255.255.224.0	(/19)
255.255.240.0	(/20)
255.255.248.0	(/21)
255.255.252.0	(/22)
255.255.254.0	(/23)
255.255.255.0	(/24)
255.255.255.128	(/25)
255.255.255.192	(/26)
255.255.255.224	(/27)
255.255.255.240	(/28)
255.255.255.248	(/29)
255.255.255.252	(/30)

We know the Class B network address has 16 bits available for host addressing. This means we can use up to 14 bits for subnetting (because we have to leave at least 2 bits for host addressing). Using a /16 means you are not subnetting with Class B, but it is a mask you can use.

NOTE

By the way, do you notice anything interesting about that list of subnet values—a pattern, maybe? Ah-ha! That’s exactly why I had you memorize the binary-to-decimal numbers at the beginning of this section. Because subnet mask bits start on the left and move to the right and bits can’t be skipped, the numbers are always the same regardless of the class of address. Memorize this pattern.

The process of subnetting a Class B network is pretty much the same as it is for a Class C, except that you have more host bits and you start in the third octet.

Use the same subnet numbers for the third octet with Class B that you used for the fourth octet with Class C, but add a 0 to the network portion and a 255 to the broadcast section in the fourth octet. The following table shows you an example host range of two subnets used in a Class B 240 (/20) subnet mask:

First subnet	Second Subnet
16.0	32.0
31.255	47.255

Notice that these are the same numbers we used in the fourth octet with a /28 mask, but we moved them to the third octet and added a .0 and .255 at the end. Just add the valid hosts between the numbers, and you're set!

Subnetting Practice Examples: Class B Addresses

This section will give you an opportunity to practice subnetting Class B addresses. Again, I have to mention that this is the same as subnetting with Class C, except we start in the third octet—with the exact same numbers!

Practice Example #1B: 255.255.128.0 (/17)

Let's take a look at our first example:

172.16.0.0 = Network address

255.255.128.0 = Subnet mask

- *Subnets?* $2^1 = 2$ (same as Class C).
- *Hosts?* $2^{15} - 2 = 32{,}766$ (7 bits in the third octet, and 8 in the fourth).
- *Valid subnets?* 256 – 128 = 128. 0, 128. Remember that subnetting in Class B starts in the third octet, so the subnet numbers are really 0.0 and 128.0, as shown in the next table. These are the exact numbers we used with Class C; we use them in the third octet and add a 0 in the fourth octet for the network address.
- *Broadcast address for each subnet?*

The following table shows the two subnets available, the valid host range, and the broadcast address of each:

Subnet	0.0	128.0
First host	0.1	128.1
Last host	127.254	255.254
Broadcast	127.255	255.255

Notice that we just added the fourth octet's lowest and highest values and came up with the answers. And again, it's done exactly the same way as for a Class C subnet. We just use the same numbers in the third octet and added 0 and 255 in the fourth octet—pretty simple, huh? I really can't say this enough: It's not hard. The numbers never change. We just use them in different octets!

Practice Example #2B: 255.255.192.0 (/18)

Let's take a look at a second example with Class B.

172.16.0.0 = Network address

255.255.192.0 = Subnet mask

- *Subnets?* $2^2 = 4$.
- *Hosts?* $2^{14} - 2 = 16{,}382$ (6 bits in the third octet, and 8 in the fourth).
- *Valid subnets?* 256 – 192 = 64. 0, 64, 128, 192. Remember that we're in the third octet, so the subnet numbers are really 0.0, 64.0, 128.0, and 192.0, as shown in the next table.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the four subnets available, the valid host range, and the broadcast address of each:

Subnet	**0.0**	**64.0**	**128.0**	**192.0**
First host	0.1	64.1	128.1	192.1
Last host	63.254	127.254	191.254	255.254
Broadcast	63.255	127.255	191.255	255.255

Again, it's pretty much the same as it is for a Class C subnet—we just added 0 and 255 in the fourth octet for each subnet in the third octet.

Practice Example #3B: 255.255.240.0 (/20)

Let's take a look:

172.16.0.0 = Network address

255.255.240.0 = Subnet mask

- *Subnets?* $2^4 = 16$.
- *Hosts?* $2^{12} - 2 = 4094$.
- *Valid subnets?* 256 – 240 = 0, 16, 32, 48, and so on, up to 240. Notice that these are the same numbers as a Class C 240 mask—we just put them in the third octet and add a 0 and 255 in the fourth octet.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first four subnets, valid hosts, and broadcast address in a Class B 255.255.240.0 mask:

Subnet	**0.0**	**16.0**	**32.0**	**48.0**
First host	0.1	16.1	32.1	48.1
Last host	15.254	31.254	47.254	63.254
Broadcast	15.255	31.255	47.255	63.255

Practice Example #4B: 255.255.254.0 (/23)

Let's take a look:

172.16.0.0 = Network address

255.255.254.0 = Subnet mask

- *Subnets?* 2^7 = 128.
- *Hosts?* 2^9 – 2 = 510.
- *Valid subnets?* 256 – 254 = 0, 2, 4, 6, 8, and so on, up to 254.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first five subnets, valid hosts, and broadcast address in a Class B 255.255.254.0 mask:

Subnet	**0.0**	**2.0**	**4.0**	**6.0**	**8.0**
First host	0.1	2.1	4.1	6.1	8.1
Last host	1.254	3.254	5.254	7.254	9.254
Broadcast	1.255	3.255	5.255	7.255	9.255

Practice Example #5B: 255.255.255.0 (/24)

Contrary to popular belief, 255.255.255.0 used with a Class B network address is not called a Class B network with a Class C subnet mask. It's amazing how many people see this mask used in a Class B network and think it's a Class C subnet mask. This is a Class B subnet mask with 8 bits of subnetting—it's considerably different from a Class C mask. Subnetting this address is fairly simple:

172.16.0.0 = Network address

255.255.255.0 = Subnet mask

- *Subnets?* 2^8 = 256.
- *Hosts?* 2^8 – 2 = 254.
- *Valid subnets?* 256 – 255 = 1. 0, 1, 2, 3, and so on, all the way to 255.

- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first four and last two subnets, the valid hosts, and the broadcast address in a Class B 255.255.255.0 mask:

Subnet	**0.0**	**1.0**	**2.0**	**3.0**	**...**	**254.0**	**255.0**
First host	0.1	1.1	2.1	3.1	...	254.1	255.1
Last host	0.254	1.254	2.254	3.254	...	254.254	255.254
Broadcast	0.255	1.255	2.255	3.255	...	254.255	255.255

Practice Example #6B: 255.255.255.128 (/25)

This is one of the hardest subnet masks you can play with. And worse, it actually is a really good subnet to use in production because it creates over 500 subnets with a whopping 126 hosts for each subnet—a nice mixture. So, don't skip over it!

172.16.0.0 = Network address

255.255.255.128 = Subnet mask

- *Subnets?* 2^9 = 512.
- *Hosts?* 2^7 – 2 = 126.
- *Valid subnets?* Now for the tricky part. 256 – 255 = 1. 0, 1, 2, 3, and so on for the third octet. But you can't forget the one subnet bit used in the fourth octet. Remember when I showed you how to figure one subnet bit with a Class C mask? You figure this out the same way. (Now you know why I showed you the 1-bit subnet mask in the Class C section—to make this part easier.) You actually get two subnets for each third octet value, hence the 512 subnets. For example, if the third octet is showing subnet 3, the two subnets would actually be 3.0 and 3.128.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows how you can create subnets, valid hosts, and broadcast addresses using the Class B 255.255.255.128 subnet mask (the first eight subnets are shown, and then the last two subnets):

Subnet	**0.0**	**0.128**	**1.0**	**1.128**	**2.0**	**2.128**	**3.0**	**3.128**	**...**	**255.0**	**255.128**
First host	0.1	0.129	1.1	1.129	2.1	2.129	3.1	3.129	...	255.1	255.129
Last host	0.126	0.254	1.126	1.254	2.126	2.254	3.126	3.254	...	255.126	255.254
Broadcast	0.127	0.255	1.127	1.255	2.127	2.255	3.127	3.255	...	255.127	255.255

Practice Example #7B: 255.255.255.192 (/26)

Now, this is where Class B subnetting gets easy. Because the third octet has a 255 in the mask section, whatever number is listed in the third octet is a subnet number. However, now that we have a subnet number in the fourth octet, we can subnet this octet just as we did with Class C subnetting. Let's try it:

172.16.0.0 = Network address

255.255.255.192 = Subnet mask

- *Subnets?* 2^{10} = 1024.
- *Hosts?* $2^6 - 2$ = 62.
- *Valid subnets?* 256 – 192 = 64. The subnets are shown in the following table. Do these numbers look familiar?
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first eight subnet ranges, valid hosts, and broadcast address:

Subnet	**0.0**	**0.64**	**0.128**	**0.192**	**1.0**	**1.64**	**1.128**	**1.192**
First host	0.1	0.65	0.129	0.193	1.1	1.65	1.129	1.193
Last host	0.62	0.126	0.190	0.254	1.62	1.126	1.190	1.254
Broadcast	0.63	0.127	0.191	0.255	1.63	1.127	1.191	1.255

Notice that for each subnet value in the third octet, you get subnets 0, 64, 128, and 192 in the fourth octet.

Practice Example #8B: 255.255.255.224 (/27)

This is done the same way as the preceding subnet mask, except that we have more subnets and fewer hosts per subnet available.

172.16.0.0 = Network address

255.255.255.224 = Subnet mask

- *Subnets?* 2^{11} = 2048.
- *Hosts?* $2^5 - 2$ = 30.
- *Valid subnets?* 256 – 224 = 32. 0, 32, 64, 96, 128, 160, 192, 224.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first eight subnets:

Subnet	**0.0**	**0.32**	**0.64**	**0.96**	**0.128**	**0.160**	**0.192**	**0.224**
First host	0.1	0.33	0.65	0.97	0.129	0.161	0.193	0.225
Last host	0.30	0.62	0.94	0.126	0.158	0.190	0.222	0.254
Broadcast	0.31	0.63	0.95	0.127	0.159	0.191	0.223	0.255

This next table shows the last eight subnets:

Subnet	**255.0**	**255.32**	**255.64**	**255.96**	**255.128**	**255.160**	**255.192**	**255.224**
First host	255.1	255.33	255.65	255.97	255.129	255.161	255.193	255.225
Last host	255.30	255.62	255.94	255.126	255.158	255.190	255.222	255.254
Broadcast	255.31	255.63	255.95	255.127	255.159	255.191	255.223	255.255

Subnetting in Your Head: Class B Addresses

Are you nuts? Subnet Class B addresses in our heads? It's actually easier than writing it out—I'm not kidding! Let me show you the steps:

1. What subnet and broadcast address is the IP address 172.16.10.33 255.255.255.224 (/27) a member of?

   The interesting octet is the fourth octet. 256 – 224 = 32. 32 + 32 = 64. Bingo: 33 is between 32 and 64. However, remember that the third octet is considered part of the subnet, so the answer is the 10.32 subnet. The broadcast is 10.63 because 10.64 is the next subnet. That was a pretty easy one.

2. What subnet and broadcast address is the IP address 172.16.66.10 255.255.192.0 (/18) a member of?

   The interesting octet is the third octet instead of the fourth octet. 256 – 192 = 64. 0, 64, 128. The subnet is 172.16.64.0. The broadcast must be 172.16.127.255 because 128.0 is the next subnet.

NOTE

Notice in the last example I started counting at zero. This is called *ip subnet-zero*. It is a command that if executed on a router, allows us to use the zero subnet as our first subnet. This may or may not be enabled on your router. If it is not enabled, then you cannot start counting subnets at zero. Most routers, if not all routers these days, support ip subnet-zero.

3. What subnet and broadcast address is the IP address 172.16.50.10 255.255.224.0 (/19) a member of?

   256 – 224 = 0, 32, 64 (remember, we always start counting at zero). The subnet is 172.16.32.0, and the broadcast must be 172.16.63.255 because 64.0 is the next subnet.

4. What subnet and broadcast address is the IP address 172.16.46.255 255.255.240.0 (/20) a member of?

   256 – 240 = 16. The third octet is interesting to us. 0, 16, 32, 48. This subnet address must be in the 172.16.32.0 subnet, and the broadcast must be 172.16.47.255 because 48.0 is the next subnet. So, yes, 172.16.46.255 is a valid host.

5. What subnet and broadcast address is the IP address 172.16.45.14 255.255.255.252 (/30) a member of?

   Where is the interesting octet? 256 – 252 = 0, 4, 8, 12, 16 (in the fourth octet). The subnet is 172.16.45.12, with a broadcast of 172.16.45.15 because the next subnet is 172.16.45.16.

6. What is the subnet and broadcast address of the host 172.16.88.255/20?

   What is a /20? If you can't answer this, you can't answer this question, can you? A /20 is 255.255.240.0, which gives us a block size of 16 in the third octet, and because no subnet bits are on in the fourth octet, the answer is always 0 and 255 in the fourth octet. 0, 16, 32, 48, 64, 80, 96. Bingo: 88 is between 80 and 96, so the subnet is 80.0 and the broadcast address is 95.255.

7. A router receives a packet on an interface with a destination address of 172.16.46.191/26. What will the router do with this packet?

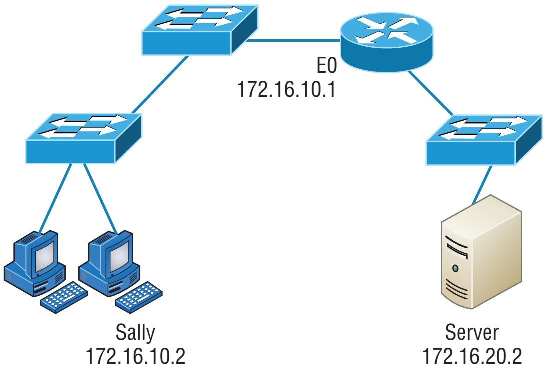
   Discard it. Do you know why? 172.16.46.191/26 is a 255.255.255.192 mask, which gives us a block size of 64. Our subnets are then 0, 64, 128, 192. 191 is the broadcast address of the 128 subnet, so a router, by default, will discard any broadcast packets.

Troubleshooting IP Addressing

Troubleshooting IP addressing is obviously an important skill because running into trouble somewhere along the way is pretty much a sure thing, and it's going to happen to you. No—I'm not a pessimist; I'm just keeping it real. Because of this nasty fact, it will be great when you can save the day because you can both figure out (diagnose) the problem and fix it on an IP network whether you're at work or at home!

Let's use Figure 8.3 as an example of your basic IP trouble—poor Sally can't log in to the Windows server. Do you deal with this by calling the Microsoft team to tell them their server is a pile of junk and causing all your problems? Tempting, but probably not such a great idea—let's first double-check our network instead. Check out Figure 8.3.

FIGURE 8.3 Basic IP troubleshooting



Let's get started by going over the basic troubleshooting steps. They're pretty simple, but important nonetheless. Pretend you're at Sally's host and she's complaining that she can't communicate to a server that just happens to be on a remote network:

1. Open a command prompt window on Sally's host, and ping 127.0.0.1.

```
C:\>ping 127.0.0.1
Pinging 127.0.0.1 with 32 bytes of data:
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Ping statistics for 127.0.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

   This is the diagnostic, or loopback, address, and if you get a successful ping, your IP stack is considered to be initialized. If it fails, then you have an IP stack failure and need to reinstall TCP/IP on the host.

NOTE

If you ping the loopback address and receive an "unable to contact IP driver, error code 2" message, you need to reinstall the TCP/IP protocol suite on the host.

2. Now, from the same command prompt window, ping the IP address of the local host.

```
C:\>ping 172.16.10.2
Pinging 172.16.10.2 with 32 bytes of data:
Reply from 172.16.10.2: bytes=32 time<1ms TTL=128
Reply from 172.16.10.2: bytes=32 time<1ms TTL=128
Reply from 172.16.10.2: bytes=32 time<1ms TTL=128
Reply from 172.16.10.2: bytes=32 time<1ms TTL=128
Ping statistics for 172.16.10.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

If that's successful, your network interface card (NIC) is functioning. If it fails, there is a problem with the NIC. Success here doesn't mean that a cable is plugged into the NIC, only that the IP protocol stack on the host can communicate to the NIC (via the LAN driver).

3. From the command prompt window, ping the default gateway (router).

```
C:\>ping 172.16.10.1
Pinging 172.16.10.1 with 32 bytes of data:
Reply from 172.16.10.1: bytes=32 time<1ms TTL=128
Reply from 172.16.10.1: bytes=32 time<1ms TTL=128
Reply from 172.16.10.1: bytes=32 time<1ms TTL=128
Reply from 172.16.10.1: bytes=32 time<1ms TTL=128
Ping statistics for 172.16.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

If the ping works, it means that the NIC is plugged into the network and can communicate on the local network. If it fails, you have a local physical network problem that could be anywhere from the NIC to the router.

4. If steps 1 through 3 were successful, try to ping the remote server.

```
C:\>ping 172.16.20.2
Pinging 172.16.20.2 with 32 bytes of data:
Reply from 172.16.20.2: bytes=32 time<1ms TTL=128
Reply from 172.16.20.2: bytes=32 time<1ms TTL=128
Reply from 172.16.20.2: bytes=32 time<1ms TTL=128
Reply from 172.16.20.2: bytes=32 time<1ms TTL=128
Ping statistics for 172.16.20.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

If that works, then you know that you have IP communication between the local host and the remote server. You also know that the remote physical network is working.

If the user still can't communicate with the server after steps 1 through 4 are successful, you probably have some type of name resolution problem and need to check your Domain Name System (DNS) settings. But if the ping to the remote server fails, then you know you have some type of remote physical network problem and need to go to the server and work through steps 1 through 3 until you find the snag.

Before we move on to determining IP address problems and how to fix them, I just want to mention some basic yet handy DOS commands that you can use to help troubleshoot your network from both a PC and a Cisco router (the commands might do the same thing, but they are implemented differently):

Packet InterNet Groper (`ping`) Uses an Internet Control Message Protocol (ICMP) echo request and replies to test if a host IP stack is initialized and alive on the network.

`Traceroute` Displays the list of routers on a path to a network destination by using Time-to-Live (TTL) time-outs and ICMP error messages. This command will work on a router, MAC, or Linux box but not from a Windows command prompt.

`Tracert` Same command as `traceroute`, but it's a Microsoft Windows command and will not work on other devices, like a Cisco router or Unix box.

`arp -a` Displays IP-to-MAC-address mappings on a Windows PC.

`ipconfig /all` Used only from a DOS prompt. Shows you the PC network configuration.

Once you've gone through all these steps and used the appropriate DOS commands, if necessary, what do you do if you find a problem? How do you go about fixing an IP address configuration error? That's exactly what you're going to learn about next—how to determine specific IP address problems and what you can do to fix them.

Determining IP Address Problems

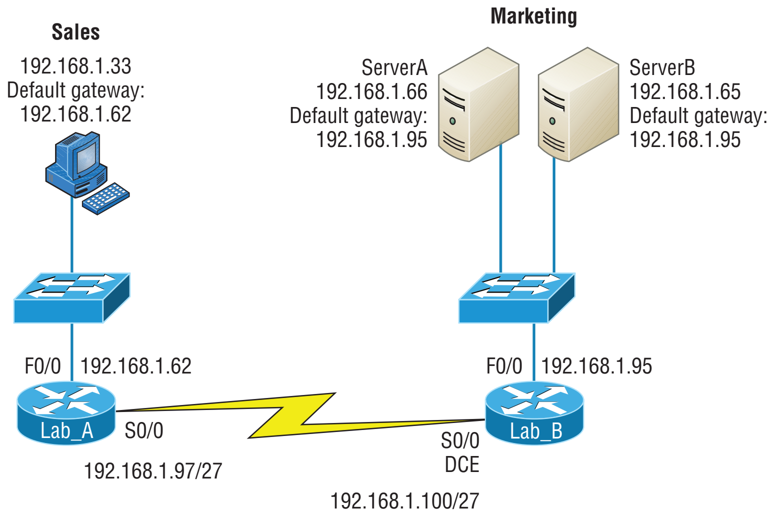
It's common for a host, router, or other network device to be configured with the wrong IP address, subnet mask, or default gateway. Because this happens way too often, I'm going to teach you how to both determine and fix IP address configuration errors.

Once you've worked through the four basic steps of troubleshooting and determined there's a problem, you obviously then need to find and fix it. It really helps to draw out the network and IP addressing scheme. If it's already done, consider yourself lucky and go buy a lottery ticket because although it should be done, it rarely is. And if it is, it's usually outdated or inaccurate anyway. Typically it is not done, and you'll probably just have to bite the bullet and start from scratch.

Once you have your network accurately drawn out, including the IP addressing scheme, you need to verify each host's IP address, mask, and default gateway address to determine the problem. (I'm assuming that you don't have a physical problem or that if you did, you've already fixed it.)

Let's check out the example illustrated in Figure 8.4. A user in the sales department calls and tells you that she can't get to ServerA in the marketing department. You ask her if she can get to ServerB in the marketing department, but she doesn't know because she doesn't have rights to log on to that server. What do you do?

FIGURE 8.4 IP address problem 1

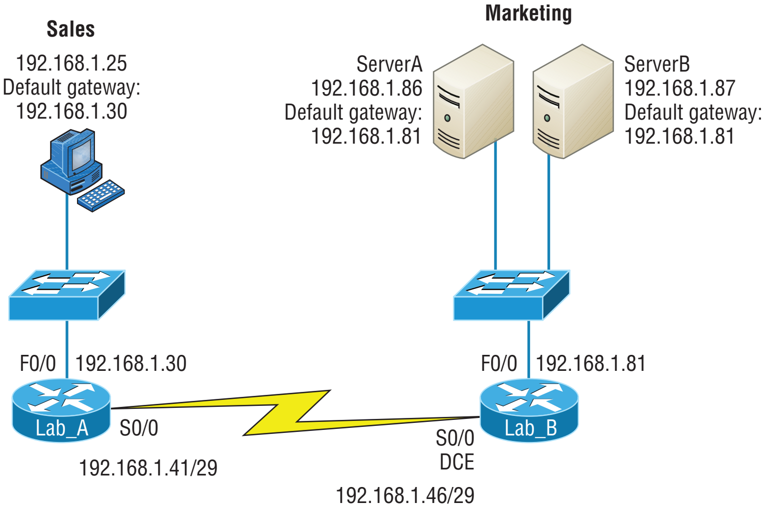


You ask the client to go through the four troubleshooting steps that you learned about in the preceding section. Steps 1 through 3 work, but step 4 fails. By looking at the figure, can you determine the problem? Look for clues in the network drawing. First, the WAN link between the Lab_A router and the Lab_B router shows the mask as a /27. You should already know that this mask is 255.255.255.224 and then determine that all networks are using this mask. The network address is 192.168.1.0. What are our valid subnets and hosts? 256 – 224 = 32, so this makes our subnets 0, 32, 64, 96, 128, and so on. So, by looking at the figure, you can see that subnet 32 is being used by the sales department, the WAN link is using subnet 96, and the marketing department is using subnet 64.

Now you have to determine what the valid host ranges are for each subnet. From what you learned at the beginning of this chapter, you should now be able to easily determine the subnet address, broadcast addresses, and valid host ranges. The valid hosts for the Sales LAN are 33 through 62—the broadcast address is 63 because the next subnet is 64, right? For the Marketing LAN, the valid hosts are 65 through 94 (broadcast 95), and for the WAN link, 97 through 126 (broadcast 127). By looking at the figure, you can determine that the default gateway on the Lab_B router is incorrect. That address is the broadcast address of the 64 subnet, so there's no way it could be a valid host.

Did you get all that? Maybe we should try another one, just to make sure. Figure 8.5 shows a network problem. A user in the Sales LAN can't get to ServerB. You have the user run through the four basic troubleshooting steps and find that the host can communicate to the local network but not to the remote network. Find and define the IP addressing problem.

FIGURE 8.5 IP address problem 2



If you use the same steps used to solve the last problem, you can see first that the WAN link again provides the subnet mask to use— /29, or 255.255.255.248. You need to determine what the valid subnets, broadcast addresses, and valid host ranges are to solve this problem.

The 248 mask is a block size of 8 (256 – 248 = 8), so the subnets both start and increment in multiples of 8. By looking at the figure, you see that the Sales LAN is in the 24 subnet, the WAN is in the 40 subnet, and the Marketing LAN is in the 80 subnet. Can you see the problem yet? The valid host range for the Sales LAN is 25–30, and the configuration appears correct. The valid host range for the WAN link is 41–46, and this also appears correct. The valid host range for the 80 subnet is 81–86, with a broadcast address of 87 because the next subnet is 88. ServerB has been configured with the broadcast address of the subnet.

Now that you can figure out misconfigured IP addresses on hosts, what do you do if a host doesn't have an IP address and you need to assign one? What you need to do is look at other hosts on the LAN and figure out the network, mask, and default gateway. Let's take a look at a couple of examples of how to find and apply valid IP addresses to hosts.

You need to assign a server and router IP addresses on a LAN. The subnet assigned on that segment is 192.168.20.24/29, and the router needs to be assigned the first usable address and the server the last valid host ID. What are the IP address, mask, and default gateway assigned to the server?

To answer this, you must know that a /29 is a 255.255.255.248 mask, which provides a block size of 8. The subnet is known as 24, the next subnet in a block of 8 is 32, so the broadcast address of the 24 subnet is 31, which makes the valid host range 25–30:

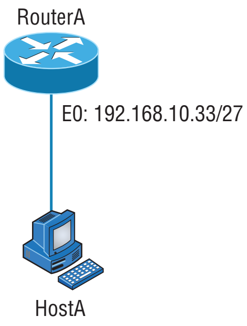
Server IP address: 192.168.20.30

Server mask: 255.255.255.248

Default gateway: 192.168.20.25 (router's IP address)

As another example, let's take a look at Figure 8.6 and solve this problem.

FIGURE 8.6 Find the valid host.



Look at the router's IP address on Ethernet0. What IP address, subnet mask, and valid host range could be assigned to the host?

The IP address of the router's Ethernet0 is 192.168.10.33/27. As you already know, a /27 is a 224 mask with a block size of 32. The router's interface is in the 32 subnet. The next subnet is 64, so that makes the broadcast address of the 32 subnet 63 and the valid host range 33–62:

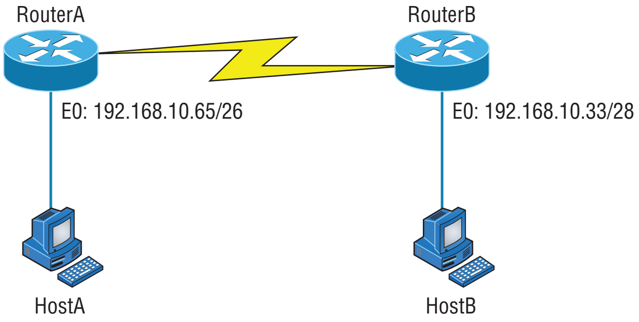
Host IP address: 192.168.10.34–62 (any address in the range except for 33, which is assigned to the router)

Mask: 255.255.255.224

Default gateway: 192.168.10.33

Figure 8.7 shows two routers with Ethernet configurations already assigned. What are the host addresses and subnet masks of hosts A and B?

FIGURE 8.7 Find the valid host #2.



RouterA has an IP address of 192.168.10.65/26 and RouterB has an IP address of 192.168.10.33/28. What are the host configurations? RouterA Ethernet0 is in the 192.168.10.64 subnet, and RouterB Ethernet0 is in the 192.168.10.32 network:

HostA IP address: 192.168.10.66–126

HostA mask: 255.255.255.192

HostA default gateway: 192.168.10.65

HostB IP address: 192.168.10.34–46

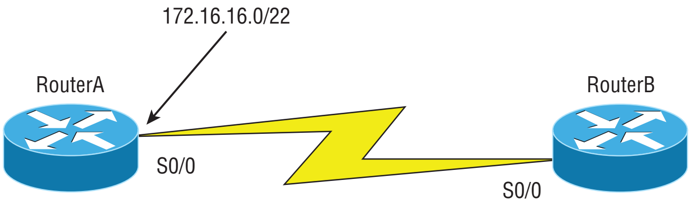
HostB mask: 255.255.255.240

HostB default gateway: 192.168.10.33

Just a couple more examples, and then this section is history. Hang in there!

Figure 8.8 shows two routers; you need to configure the S0/0 interface on RouterA. The network assigned to the serial link is 172.16.16.0/22. What IP address can be assigned?

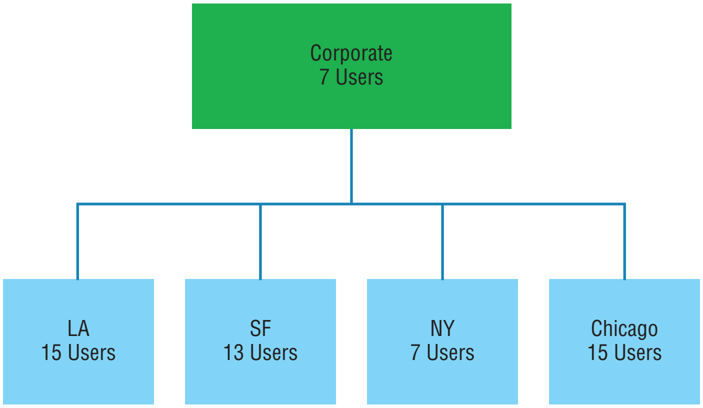
FIGURE 8.8 Find the valid host address #3.



First, you must know that a /22 CIDR is 255.255.252.0, which makes a block size of 4 in the third octet. Because 16 is listed, the available range is 16.1 through 19.254; so, for example, the IP address S0/0 could be 172.16.18.255 because that's within the range.

Okay, last one! You have one Class C network ID, and you need to provide one usable subnet per city while allowing enough usable host addresses for each city specified in Figure 8.9. What is your mask?

FIGURE 8.9 Find the valid subnet mask.



Actually, this is probably the easiest thing you've done all day! I count 5 subnets needed, and the Chicago office needs 15 users (always look for the network that needs the most hosts). What block size is needed for the Chicago office? 32. (Remember, you cannot use a block size of 16 because you always have to subtract 2!) What mask provides you with a block size of 32? 224. Bingo! This provides 8 subnets, each with 30 hosts.

Introduction to Network Address Translation (NAT)

Similar to Classless Inter-Domain Routing (CIDR), the original intention for NAT was to slow the depletion of available IP address space by allowing many private IP addresses to be represented by some smaller number of public IP addresses.

Since then, it's been discovered that NAT is also a useful tool for network migrations and mergers, server load sharing, and creating "virtual servers." So I'm going to describe the basics of NAT functionality and the terminology common to NAT.

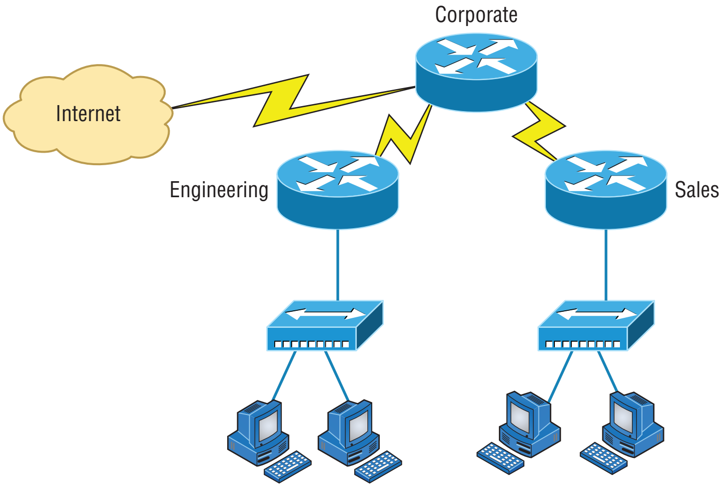
At times, NAT really decreases the overwhelming amount of public IP addresses required in your networking environment. And NAT comes in very handy when two companies that have duplicate internal addressing schemes merge. NAT is also great to have around when an organization changes its ISP and the networking manager doesn't want the hassle of changing the internal address scheme.

Here's a list of situations when it's best to have NAT on your side:

- You need to connect to the Internet and your hosts don't have globally unique IP addresses.
- You change to a new ISP that requires you to renumber your network.
- You need to merge two intranets with duplicate addresses.

You typically use NAT on a border router. For an illustration of this, see Figure 8.10, where NAT would be configured on the Corporate router.

FIGURE 8.10 Where to configure NAT



Now you may be thinking, "NAT's totally cool. It's the grooviest, greatest network gadget, and I just gotta have it." Well, hang on a minute. There are truly some serious snags related to NAT use. Oh, don't get me wrong: It really can save you sometimes, but there's a dark side you need to know about too. For a visual of the pros and cons linked to using NAT, check out Table 8.3.

TABLE 8.3 Advantages and disadvantages of implementing NAT

Advantages	Disadvantages
Conserves legally registered addresses.	Translation introduces switching path delays.
Reduces address overlap occurrences.	Loss of end-to-end IP traceability.
Increases flexibility when connecting to the Internet.	Certain applications will not function with NAT enabled.
Eliminates address renumbering as the network changes.	

Types of Network Address Translation

In this section, I'm going to go over the three types of NAT with you:

Static NAT (SNAT) This type of NAT is designed to allow one-to-one mapping between local and global addresses. Keep in mind that the static version requires you to have one real Internet IP address for every host on your network.

Dynamic NAT (DNAT) This version gives you the ability to map an unregistered IP address to a registered IP address from a pool of registered IP addresses. You don't have to statically configure your router to map an inside-to-an-outside address as you would using static NAT, but you do have to have enough real, bona fide IP addresses for everyone who's going to be sending packets to and receiving them from the Internet.

Overloading This is the most popular type of NAT configuration. Understand that overloading really is a form of dynamic NAT that maps multiple unregistered IP addresses to a single registered IP address—many-to-one—by using different ports. Now, why is this so special? Well, because it's also known as Port Address Translation (PAT). And by using PAT (NAT Overload), you get to have thousands of users connect to the Internet using only one real global IP address—pretty slick, yeah? Seriously, NAT Overload is the real reason we haven't run out of valid IP address on the Internet. Really—I'm not joking.

NAT Names

The names we use to describe the addresses used with NAT are pretty simple. Addresses used after NAT translations are called *global* addresses. These are usually the public addresses used on the Internet, but remember, you don't need public addresses if you aren't going on the Internet.

Local addresses are the ones we use before network translation. So, the inside local address is actually the private address of the sending host that's trying to get to the Internet, while the outside local address is the address of the destination host. The latter is usually a public address (web address, mail server, and so on) and is how the packet begins its journey.

After translation, the inside local address is then called the *inside global address*, and the outside global address then becomes the name of the destination host. Check out Table 8.4, which lists all this terminology, for a clear picture of the various names used with NAT.

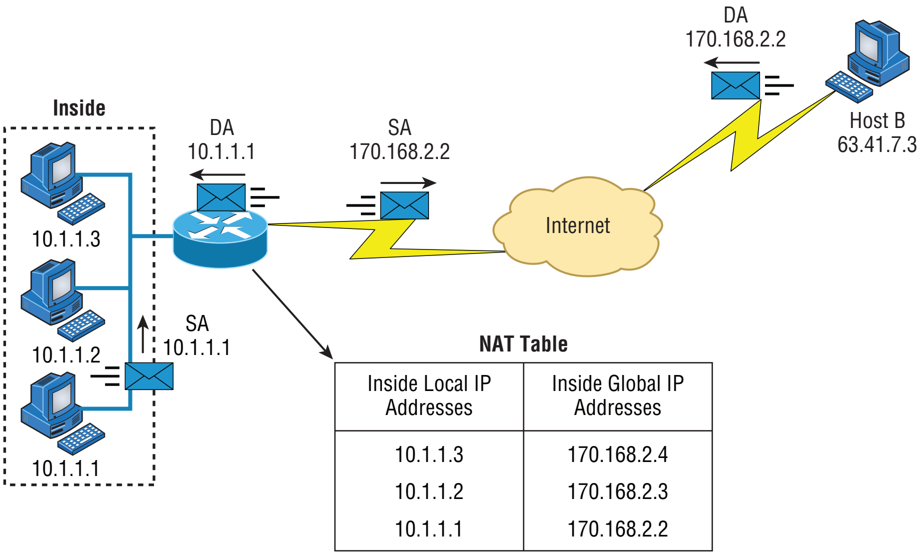
TABLE 8.4 NAT terms

Name	Meaning
Inside local	Name of the inside source address before translation
Outside local	Name of the destination host before translation
Inside global	Name of the inside host after translation
Outside global	Name of the outside destination host after translation

How NAT Works

Now it's time to look at how this whole NAT thing works. I'm going to start by using Figure 8.11 to describe the basic translation of NAT.

FIGURE 8.11 Basic NAT translation



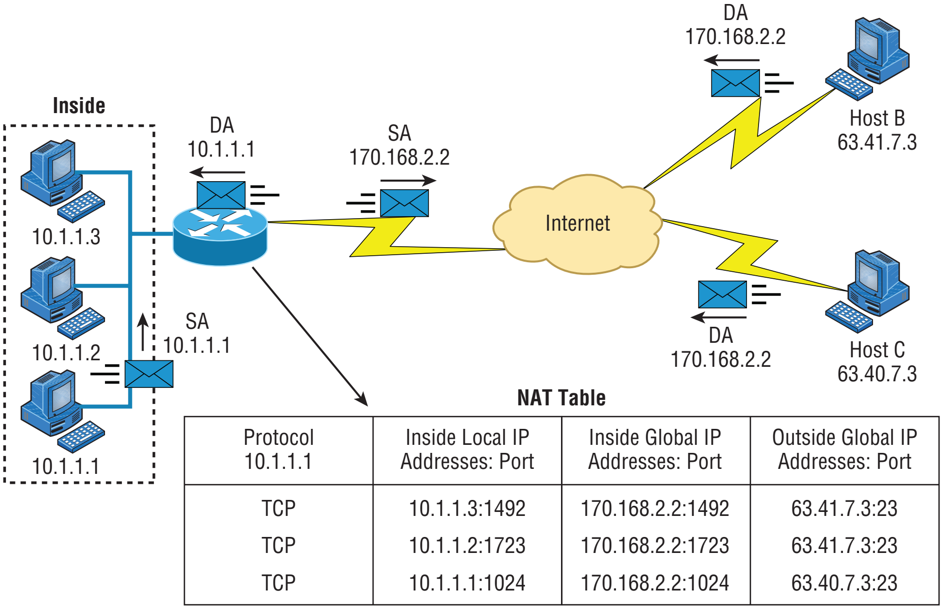
Inside Local IP Addresses	Inside Global IP Addresses
10.1.1.3	170.168.2.4
10.1.1.2	170.168.2.3
10.1.1.1	170.168.2.2

In the example shown in Figure 8.11, host 10.1.1.1 sends an outbound packet to the border router configured with NAT. The router identifies the IP address as an inside local IP address destined for an outside network, translates the address, and documents the translation in the NAT table.

The packet is sent to the outside interface with the new translated source address. The external host returns the packet to the destination host, and the NAT router translates the inside global IP address back to the inside local IP address using the NAT table. This is as simple as it gets.

Let's take a look at a more complex configuration using overloading, or what is also referred to as PAT. I'll use Figure 8.12 to demonstrate how PAT works.

FIGURE 8.12 NAT overloading example (PAT)



Protocol 10.1.1.1	Inside Local IP Addresses: Port	Inside Global IP Addresses: Port	Outside Global IP Addresses: Port
TCP	10.1.1.3:1492	170.168.2.2:1492	63.41.7.3:23
TCP	10.1.1.2:1723	170.168.2.2:1723	63.41.7.3:23
TCP	10.1.1.1:1024	170.168.2.2:1024	63.40.7.3:23

With overloading, all inside hosts get translated to one single IP address, hence the term *overloading*. Again, the reason we have not run out of available IP addresses on the Internet is because of overloading (PAT).

Take a look at the NAT table in Figure 8.12 again. In addition to the inside local IP address and outside global IP address, we now have port numbers. These port numbers help the router identify which host should receive the return traffic.

Port numbers are used at the Transport layer to identify the local host in this example. If we had to use IP addresses to identify the source hosts, that would be called *static NAT*, and we would run out of addresses. PAT allows us to use the Transport layer to identify the hosts, which in turn allows us to use (theoretically) up to 65,000 hosts with one real IP address.

One last thing: We've been discussing translating IP addresses using some type of network address translation. However, using a router or firewall, you can also perform port forwarding, which is translating the port number of a packet to a new destination. The destination may be a predetermined network port (using any IP protocol, but typically TCP or UDP ports) on a host within a private network behind a NAT router. Based on the received port number, a remote host can communicate to servers behind the NAT gateway to the local network.

You're done, the diva has sung, the chicken has crossed the road…whew! Take a good break, and then come back and go through the written lab and review questions.

Summary

Did you read Chapter 7 and this chapter and understand everything on the first pass? If so, that is fantastic—congratulations! The thing is, you probably got lost a couple of times—and as I told you, that's what usually happens, so don't stress. Don't feel bad if you have to read each chapter more than once, or even 10 times, before you're truly good to go.

This chapter provided you with an important understanding of IP subnetting. After reading this chapter, you should be able to subnet IP addresses in your head.

You should also understand the basic troubleshooting methods. You must remember the four steps you take when trying to narrow down exactly where a network/IP addressing problem is and then know how to proceed systematically in order to fix it. In addition, you should be able to find valid IP addresses and subnet masks by looking at a network diagram.

I finished this chapter with an introduction to Network Address Translation. I discussed the difference between static and dynamic NAT and NAT overloading.

Exam Essentials

Remember the steps to subnet in your head. Understand how IP addressing and subnetting work. First, determine your block size by using the 256-subnet mask math. Then, count your subnets and determine the broadcast address of each subnet—it is always the number right before the next subnet. Your valid hosts are the numbers between the subnet address and the broadcast address.

Understand the various block sizes. This is an important part of understanding IP addressing and subnetting. The valid block sizes are always 4, 8, 16, 32, 64, 128, and so on. You can determine your block size by using the 256-subnet mask math.

Remember the four diagnostic steps. The four simple steps for troubleshooting are ping the loopback address, ping the NIC, ping the default gateway, and ping the remote device.

You must be able to find and fix an IP addressing problem. Once you go through the four troubleshooting steps, you should be able to determine the IP addressing problem by drawing out the network and finding the valid and invalid hosts addressed in your network.

Understand basic NAT terminology. You want to know the difference between inside local and inside global. Inside local is before translation, and inside global is after translation. Inside global is defined as a registered address that represents an inside host to an outside network. You should also understand PAT and how it works by using different port numbers to map multiple private IP addresses to a single registered IP address.

Written Lab

You can find the answers to the written labs in Appendix A.

Write the subnet mask, subnet address, broadcast address, and valid host range for question 1 through question 6:

1. 192.168.100.25/30
2. 192.168.100.37/28
3. 192.168.100.66/27
4. 192.168.100.17/29
5. 192.168.100.99/26
6. 192.168.100.99/25
7. You have a Class B network and need 29 subnets. What is your mask?
8. What is the broadcast address of 192.168.192.10/29?
9. How many hosts are available with a Class C /29 mask?
10. What is the subnet for host ID 172.16.3.65/23?

Review Questions

You can find the answers to the review questions in Appendix B.

1. What is the maximum number of IP addresses that can be assigned to hosts on a local subnet that uses the 255.255.255.224 subnet mask?

   A. 14

   B. 15

   C. 16

   D. 30

   E. 31

   F. 62

2. You have a Class A host of 10.0.0.110/25. It needs to communicate to a host with an IP address of 10.0.0.210/25. Which of the following devices do you need to use in order for these hosts to communicate?

   A. A Layer 2 switch

   B. Router

   C. DNS server

   D. Hub

3. What is the subnetwork address for a host with the IP address 200.10.5.68/28?

   A. 200.10.5.56

   B. 200.10.5.32

   C. 200.10.5.64

   D. 200.10.5.0

4. The network address of 172.16.0.0/19 provides how many subnets and hosts?

   A. 7 subnets, 30 hosts each

   B. 7 subnets, 2,046 hosts each

   C. 7 subnets, 8,190 hosts each

   D. 8 subnets, 30 hosts each

   E. 8 subnets, 2,046 hosts each

   F. 8 subnets, 8,190 hosts each

5. You receive a call from a user who is complaining that they cannot get on the Internet. You have them verify their IP address, mask, and default gateway. The IP address is 10.0.37.144, with a subnet mask of 255.255.254.0. The default gateway is 10.0.38.1. What is the problem?

   A. Incorrect DNS server address

   B. Invalid subnet mask

   C. Incorrect gateway IP

   D. IP address and mask not compatible

6. If a host on a network has the address 172.16.45.14/30, what is the subnetwork this host belongs to?

   A. 172.16.45.0

   B. 172.16.45.4

   C. 172.16.45.8

   D. 172.16.45.12

   E. 172.16.45.16

7. On a network, which mask should you use on point-to-point WAN links in order to reduce the waste of IP addresses?

   A. /27

   B. /28

   C. /29

   D. /30

   E. /31

8. On which of the following devices are you most likely to be able to implement NAT?

   A. Hub

   B. Ethernet switch

   C. Router

   D. Bridge

9. You have an interface on a router with the IP address of 192.168.192.10/29. Including the router interface, how many hosts can have IP addresses on the LAN attached to the router interface?

   A. 6

   B. 8

   C. 30

   D. 62

   E. 126

10. When configuring the IP settings on a computer on one subnet to ensure that it can communicate with a computer on another subnet, which of the following is desirable?

    A. Configure the computer with the same default gateway as the other computer.

    B. Configure the computer with the same subnet mask as the other computer.

    C. Configure the computer with a default gateway that matches the IP address of the interface of the router that is attached to the same subnet as the computer.

    D. Configure the computer with a subnet mask that matches the IP address of the interface of the router that is attached to the same subnet as the computer.

11. You have an interface on a router with the IP address of 192.168.192.10/29. What is the broadcast address the hosts will use on this LAN?

A. 192.168.192.15

B. 192.168.192.31

C. 192.168.192.63

D. 192.168.192.127

E. 192.168.192.255

12. What is the highest usable address on the 172.16.1.0/24 network?

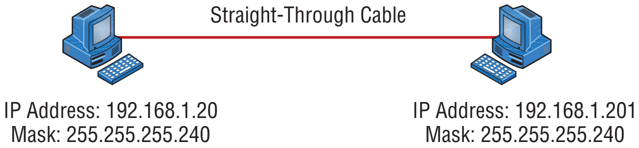
A. 172.16.1.255

B. 172.16.1.254

C. 172.16.1.253

D. 172.16.1.23

13. A network administrator is connecting two hosts directly through their Ethernet interfaces, as shown in the illustration. Ping attempts between the hosts are unsuccessful. What can be done to provide connectivity between the hosts? (Choose two.)



A. A crossover cable should be used in place of the straight-through cable.

B. A rollover cable should be used in place of the straight-through cable.

C. The subnet masks should be set to 255.255.255.192.

D. A default gateway needs to be set on each host.

E. The subnet masks should be set to 255.255.255.0.

14. If an Ethernet port on a router was assigned an IP address of 172.16.112.1/25, what would be the subnet address of this host?

A. 172.16.112.0

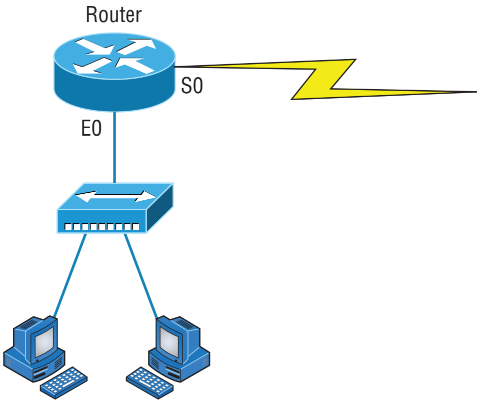
B. 172.16.0.0

C. 172.16.96.0

D. 172.16.255.0

E. 172.16.128.0

15. Using the following illustration, what would be the IP address of E0 if you were using the eighth subnet? The network ID is 192.168.10.0/28, and you need to use the last available IP address in the range. The 0 subnet should not be considered valid for this question.



- **A.** 192.168.10.142
- **B.** 192.168.10.66
- **C.** 192.168.100.254
- **D.** 192.168.10.143
- **E.** 192.168.10.126

16. Using the illustration in question 15, what would be the IP address of E0 if you were using the first subnet? The network ID is 192.168.10.0/28, and you need to use the last available IP address in the range. Again, the 0 subnet should not be considered valid for this question.

- **A.** 192.168.10.24
- **B.** 192.168.10.62
- **C.** 192.168.10.30
- **D.** 192.168.10.127

17. If you are forced to replace a router that has failed to the point that you are unable to access its current configuration to aid in setting up interface addresses on the new router, which of the following can you reference for assistance?

- **A.** The default gateway settings on computers from each subnet that the old router interconnected.
- **B.** The router's configuration that was periodically cached on the DHCP server.
- **C.** The router's configuration that was periodically cached on the DNS server.
- **D.** The new router will auto-configure itself with the correct settings.

18. You have a network with a subnet of 172.16.17.0/22. Which of the following is a valid host address?

    A. 172.16.17.1 255.255.255.252

    B. 172.16.0.1 255.255.240.0

    C. 172.16.20.1 255.255.254.0

    D. 172.16.16.1 255.255.255.240

    E. 172.16.18.255 255.255.252.0

    F. 172.16.0.1 255.255.255.0

19. Your router has the following IP address on Ethernet0: 172.16.2.1/23. Which of the following can be valid host IDs on the LAN interface attached to the router? (Choose two.)

    A. 172.16.0.5

    B. 172.16.1.100

    C. 172.16.1.198

    D. 172.16.2.255

    E. 172.16.3.0

    F. 172.16.3.255

20. You have one IP address provided from your ISP with a /30 mask. However, you have 300 users that need to access the Internet. What technology will you use to implement a solution?

    A. PAT

    B. VPN

    C. DNS

    D. LANs

Introduction to IP Routing

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Routing
  - Routing protocols (IPv4 and IPv6)
  - Distance-vector routing protocols
    - RIP
    - EIGRP
  - Link-state routing protocols
    - OSPF
  - Hybrid
    - BGP
- Routing types
  - Static
  - Dynamic
  - Default

IP routing is the process of moving packets from one network to another network using routers. The IP routing process is a super-important subject to understand because it pertains to all routers and configurations that use IP.

Before you read this chapter, you need to understand the difference between a routing protocol and a routed protocol. A *routing protocol* is a tool used by routers to dynamically find all the networks in the internetwork as well as to ensure that all routers have the same routing table. Basically, a routing protocol determines the path of a packet through an internetwork. Examples of routing protocols are Routing Information Protocol (RIP), Routing Information Protocol version 2 (RIPv2), Enhanced Interior Gateway Routing Protocol (EIGRP), and Open Shortest Path First (OSPF).

Once all routers know about all networks, a *routed protocol* can be used to send user data (packets) through the established internetwork. Routed protocols are assigned to an interface and determine the method of packet delivery. Examples of routed protocols are Internet Protocol (IP) and Internet Protocol version 6 (IPv6).

In this chapter, I'm going to describe IP routing with routers. I will explain, in a step-by-step fashion, the IP routing process. I will also explain static and dynamic routing on a conceptual level, with more details about dynamic routing in Chapter 10, "Routing Protocols."

NOTE

To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Routing Basics

Once you create an internetwork by connecting your wide area networks (WANs) and local area networks (LANs) to a router, you need to configure logical network addresses, such as IP addresses, to all hosts on the internetwork so that they can communicate via routers across that internetwork.

In IT, routing essentially refers to the process of taking a packet from one device and sending it through the network to another device on a different network. Routers don't really care about hosts—they care only about networks and the best path to each network. The logical network address of the destination host is used to get packets to a network through a routed network, and then the hardware address of the host is used to deliver the packet from a router to the correct destination host.

If your network has no routers, then it should be apparent that, well, you are not routing. But if you do have them, they're there to route traffic to all the networks in your internetwork. To be capable of routing packets, a router must know at least the following information:

- Destination network address
- Neighbor routers from which it can learn about remote networks
- Possible routes to all remote networks
- The best route to each remote network
- How to maintain and verify routing information

The router learns about remote networks from neighbor routers or from an administrator. The router then builds a *routing table* (a map of the internetwork) that describes how to find the remote networks. If a network is directly connected, then the router already knows how to get to it.

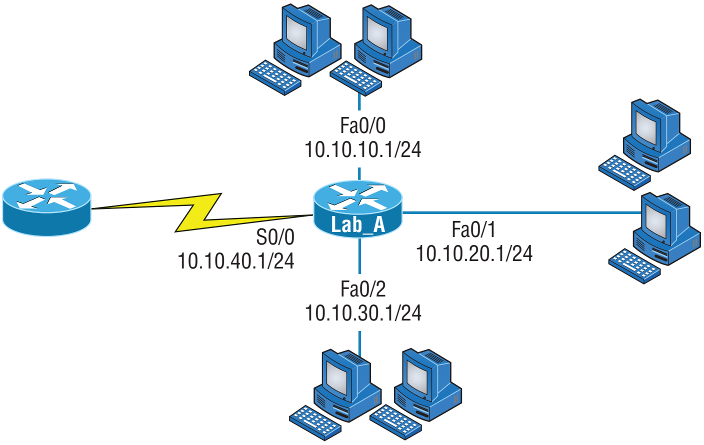
If a network isn't directly connected to the router, the router must use one of two ways to learn how to get to it. One way is called *static routing*, which can be a ton of work because it requires someone to hand-type all network locations into the routing table. The other way is dynamic routing.

In *dynamic routing*, a protocol on one router communicates with the same protocol running on neighbor routers. The routers then update each other about all the networks they know about and place this information into the routing table. If a change occurs in the network, the dynamic routing protocols automatically inform all routers about the event. If static routing is used, the administrator is responsible for updating all changes by hand into all routers. Understandably, in a large network, it's common to find that a combination of both dynamic and static routing is being used.

Before we jump into the IP routing process, let's take a look at a simple example that demonstrates how a router uses the routing table to route packets out of an interface. We'll be going into a more detailed study of this process in a minute.

Figure 9.1 shows a simple two-router network. Lab_A has one serial interface and three LAN interfaces.

FIGURE 9.1 A simple routing example



Looking at Figure 9.1, can you figure out which interface Lab_A will use to forward an IP datagram to a host with an IP address of 10.10.10.10?

By using the Cisco IOS command `show ip route`, we can see the routing table (map of the internetwork) that router Lab_A will use to make all forwarding decisions:

```
Router_A#show ip route
[output cut]
Gateway of last resort is not set
C      10.10.10.0/24 is directly connected, FastEthernet0/0
C      10.10.20.0/24 is directly connected, FastEthernet0/1
C      10.10.30.0/24 is directly connected, FastEthernet0/2
C      10.10.40.0/24 is directly connected, Serial 0/0
```

The `C` in the routing table output means that the networks listed are "directly connected," and until we add a routing protocol—something like RIP, EIGRP, and so on—to the routers in our internetwork, or use static routes, we'll have only directly connected networks in our routing table.

So, let's get back to the original question: By looking at the figure and the output of the routing table, can you tell what Lab_A will do with a received packet that has a destination IP address of 10.10.10.10? If you answered, "The router will packet-switch the packet to interface FastEthernet 0/0, and this interface will then frame the packet and send it out on the network segment," you're right.

Just because we can, let's look at a different example. Based on the output of the next routing table, which interface will a packet with a destination address of 10.10.10.14 be forwarded to?

```
Router_A#sh ip route
[output cut]
Gateway of last resort is not set
C      10.10.10.16/28 is directly connected, FastEthernet0/0
C      10.10.10.8/29 is directly connected, FastEthernet0/1
C      10.10.10.4/30 is directly connected, FastEthernet0/2
C      10.10.10.0/30 is directly connected, Serial 0/0
```

First, you can see that the network is subnetted and that each interface has a different mask. And I have to tell you, you positively can't answer this question if you can't subnet—no way! Here's the answer: 10.10.10.14 would be a host in the 10.10.10.8/29 subnet connected to the FastEthernet 0/1 interface. Don't freak if this one left you staring vacantly. Instead, if you're struggling, go back and reread Chapter 8, "IP Subnetting, Troubleshooting IP, and Introduction to NAT," until you get it. This should then make perfect sense to you.

NOTE

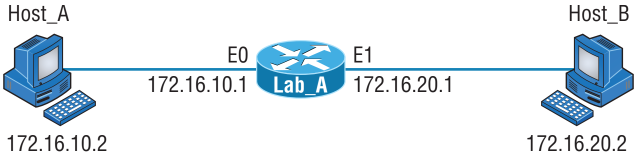
When the routing tables of all routers in the network are complete (because they include information about all the networks in the internetwork), they are considered *converged*, or in a steady state. This is covered in more detail in Chapter 10.

Now, let's get into this process in more detail.

The IP Routing Process

The IP routing process is actually pretty simple, and it doesn't change, regardless of the size of your network. I'm going to use Figure 9.2 to give you a picture of this step-by-step process. The question I'm asking is this: What happens when Host_A wants to communicate with Host_B on a different network? I'll go through how to answer that question by breaking down the process with headings to make it easier to understand. First, check out Figure 9.2.

FIGURE 9.2 IP routing example using two hosts and one router



Suppose that a user on Host_A pings Host_B's IP address. Routing doesn't get any simpler than this, but it still involves a lot of steps. Let's work through them.

A packet is created on the host:

1. Internet Control Message Protocol (ICMP) creates an echo request payload (which is just the alphabet in the data field).
2. ICMP hands that payload to IP, which then creates a packet. At a minimum, this packet contains an IP source address, an IP destination address, and a Protocol field with 01h. (Remember that Cisco likes to use *0x* in front of hex characters, so this could look like 0x01.) All of that tells the receiving host whom it should hand the payload to when the destination is reached. In this example, it's ICMP.

The packet is forwarded:

3. After the packet is created, IP determines whether the destination IP address is on the local network or a remote one.
4. Because IP has discovered that this is a remote request, the packet needs to be sent to the default gateway so the packet can be routed to the correct remote network. The Registry in Windows is parsed to find the configured default gateway.

5. The default gateway of host 172.16.10.2 (Host_A) is configured to 172.16.10.1. For this packet to be sent to the default gateway, the hardware address of the router's interface Ethernet 0 (configured with the IP address of 172.16.10.1) must be known. Why? So the packet can be handed down to the Data Link layer, framed, and sent to the router's interface that's connected to the 172.16.10.0 network. Because hosts only communicate via hardware addresses on the local LAN, it's important to recognize that for Host_A to communicate to Host_B, it has to send packets to the Media Access Control (MAC) address of the default gateway on the local network.

NOTE MAC addresses are always local on the LAN and never go through and past a router.

6. The Address Resolution Protocol (ARP) cache of the host is checked to see whether the IP address of the default gateway has already been resolved to a hardware address. If it has, the packet is then free to be handed to the Data Link layer for framing. (The hardware-destination address is also handed down with that packet.) To view the ARP cache on your host, use the following command:

```
C:\>arp -a
Interface: 172.16.10.2 --- 0x3
  Internet Address      Physical Address      Type
  172.16.10.1          00-15-05-06-31-b0     dynamic
```

If the hardware address isn't already in the ARP cache of the host, an ARP broadcast is sent out onto the local network to search for the hardware address of 172.16.10.1. The router responds to that request and provides the hardware address of Ethernet 0, and the host caches this address.

7. After the packet and destination hardware address have been handed to the Data Link layer, the LAN driver is used to provide media access via the type of LAN being used (in this example, it's Ethernet). A frame is then generated, encapsulating the packet with control information. Within that frame are the hardware-destination and source addresses plus, in this case, an Ether-Type field that describes the Network layer protocol that handed the packet to the Data Link layer—in this instance, IP. At the end of the frame is something called a Frame Check Sequence (FCS) field that houses the result of the cyclic redundancy check (CRC). The frame would look something like what I've detailed in Figure 9.3. It contains Host_A's hardware (MAC) address and the hardware-destination address of the default gateway. It does not include the remote host's MAC address—remember that because it's important!

FIGURE 9.3 Frame used from Host_A to the Lab_A router when Host_B is pinged

Destination MAC (Router's E0 MAC Address)	Source MAC (Host_A MAC Address)	Ether-Type field	Packet	FCS (CRC)

8. When the frame is completed, it's handed down to the Physical layer to be placed onto the physical medium one bit at a time. In this example, the physical medium is twisted-pair wire.

The router receives the packet:

9. Every device within the collision domain receives these bits and builds the frame. They each run a CRC and check the answer in the FCS field. If the answers don't match, the frame is discarded. But if the CRC matches, then the hardware-destination address is checked to see if it matches, too (in this example, it's the router's interface, Ethernet 0). If it's a match, then the Ether-Type field is checked to find the protocol used at the Network layer.
10. The packet is pulled from the frame, and what is left of the frame is discarded. The packet is then handed to the protocol listed in the Ether-Type field—it's given to IP.

The router routes the packet:

11. IP receives the packet and checks the IP destination address. Because the packet's destination address doesn't match any of the addresses configured on the receiving router's interfaces, the router will look up the destination IP network address in its routing table.
12. The routing table must have an entry for the network 172.16.20.0 or the packet will be discarded immediately and an ICMP message will be sent back to the originating device with a Destination Unreachable message.
13. If the router does find an entry for the destination network in its table, the packet is switched to the exit interface—in this example, interface Ethernet 1. The following output displays the Lab_A router's routing table. The `C` means "directly connected." No routing protocols are needed in this network because all networks (all two of them) are directly connected:

```
Lab_A>sh ip route
Codes:C - connected,S - static,I - IGRP,R - RIP,M - mobile,B -
   BGP, D - EIGRP,EX - EIGRP external,O - OSPF,IA - OSPF inter
   area, N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external
type 2, E1 - OSPF external type 1, E2 - OSPF external type 2,
E - EGP,i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia
   - IS-IS intearea * - candidate default, U - per-user static
   route, o - ODR P - periodic downloaded static route
```

```
Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.10.0 is directly connected, Ethernet0
C       172.16.20.0 is directly connected, Ethernet1
```

14. The router packet-switches the packet to the Ethernet 1 buffer.

15. Now that the packet is in the Ethernet 1 buffer, IP needs to know the hardware address of the destination host and first checks the ARP cache. If the hardware address of Host_B has already been resolved and is in the router's ARP cache, then the packet and the hardware address are handed down to the Data Link layer to be framed. Let's take a look at the ARP cache on the Lab_A router by using the `show ip arp` command:

    ```
    Lab_A#sh ip arp
    Protocol  Address     Age(min) Hardware Addr  Type   Interface
    Internet  172.16.20.1   -     00d0.58ad.05f4  ARPA   Ethernet1
    Internet  172.16.20.2   3     0030.9492.a5dd  ARPA   Ethernet1
    Internet  172.16.10.1   -     0015.0506.31b0  ARPA   Ethernet0
    Internet  172.16.10.2  12     0030.9492.a4ac  ARPA   Ethernet0
    ```

    The dash (-) means that this is the physical interface on the router. From this output, we can see that the router knows the 172.16.10.2 (Host_A) and 172.16.20.2 (Host_B) hardware addresses. Cisco routers will keep an entry in the ARP table for four hours. But if the hardware address hasn't already been resolved, the router then sends an ARP request out E1 looking for the hardware address of 172.16.20.2. Host_B responds with its hardware address, and the packet and hardware-destination address are both sent to the Data Link layer for framing.

16. The Data Link layer creates a frame with the destination and source hardware address, Ether-Type field, and FCS field at the end. The frame is handed to the Physical layer to be sent out on the physical medium one bit at a time.

Finally, the remote host receives the packet:

17. Host_B receives the frame and immediately runs a CRC. If the result matches what's in the FCS field, the hardware-destination address is then checked. If the host finds a match, the Ether-Type field is then checked to determine the protocol that the packet should be handed to at the Network layer—IP, in this example.

18. At the Network layer, IP receives the packet and checks the IP destination address. Because there's finally a match made, the Protocol field is checked to find out whom the payload should be given to.

19. The payload is handed to ICMP, which understands that this is an echo request. ICMP responds to this by immediately discarding the packet and generating a new payload as an echo reply.

The destination host becomes a source host:

20. A packet is created, including the source and destination IP addresses, Protocol field, and payload. The destination device is now Host_A.
21. IP checks to see whether the destination IP address is a device on the local LAN or on a remote network. Because the destination device is on a remote network, the packet needs to be sent to the default gateway.
22. The default gateway IP address is found in the Registry of the Windows device, and the ARP cache is checked to see whether the hardware address has already been resolved from an IP address.
23. After the hardware address of the default gateway is found, the packet and destination hardware addresses are handed down to the Data Link layer for framing.
24. The Data Link layer frames the packet of information and includes the following in the header:
    - The destination and source hardware addresses
    - The Ether-Type field with 0x0800 (IP) in it
    - The FCS field with the CRC result in tow
25. The frame is now handed down to the Physical layer to be sent out over the network medium one bit at a time.

Time for the router to route another packet:

26. The router's Ethernet 1 interface receives the bits and builds a frame. The CRC is run, and the FCS field is checked to make sure the answers match.
27. When the CRC is found to be okay, the hardware-destination address is checked. Because the router's interface is a match, the packet is pulled from the frame, and the Ether-Type field is checked to see which protocol at the Network layer the packet should be delivered to.
28. The protocol is determined to be IP, so it gets the packet. IP runs a CRC check on the IP header first and then checks the destination IP address.

NOTE

IP does not run a complete CRC the way the Data Link layer does—it only checks the header for errors.

Because the IP destination address doesn't match any of the router's interfaces, the routing table is checked to see whether it has a route to 172.16.10.0. If it doesn't have a route over to the destination network, the packet will be discarded immediately. (This is the source point of confusion for a lot of administrators—when a ping fails, most people think the packet never reached the destination host. But as we see here, that's not *always* the case. All it takes is just one of the remote routers to be lacking a route back to the originating host's network and—*poof!*—the packet is dropped on the *return trip*, not on its way to the host.)

NOTE Just a quick note to mention that when (if) the packet is lost on the way back to the originating host, you will typically see a Request Timed Out message because it is an unknown error. If the error occurs because of a known issue, such as a route that is not in the routing table on the way to the destination device, you will see a Destination Unreachable message. This should help you determine if the problem occurred on the way to the destination or on the way back.

29. In this case, the router does know how to get to network 172.16.10.0—the exit interface is Ethernet 0—so the packet is switched to interface Ethernet 0.
30. The router checks the ARP cache to determine whether the hardware address for 172.16.10.2 has already been resolved.
31. Because the hardware address to 172.16.10.2 is already cached from the originating trip to Host_B, the hardware address and packet are handed to the Data Link layer.
32. The Data Link layer builds a frame with the destination and source hardware addresses and then puts IP in the Ether-Type field. A CRC is run on the frame, and the result is placed in the FCS field.
33. The frame is then handed to the Physical layer to be sent out onto the local network one bit at a time.

The original source host, now the destination host, receives the reply packet:

34. The destination host receives the frame, runs a CRC, checks the hardware destination address, and looks in the Ether-Type field to find out whom to hand the packet to.
35. IP is the designated receiver, and after the packet is handed to IP at the Network layer, IP checks the Protocol field for further direction. IP finds instructions to give the payload to ICMP, and ICMP determines the packet to be an ICMP echo reply.
36. ICMP acknowledges that it has received the reply by sending an exclamation point (!) to the user interface. ICMP then attempts to send four more echo requests to the destination host.

You've just been introduced to "Todd's 36 easy steps to understanding IP routing." The key point to understand here is that if you had a much larger network, the process would be the *same*. In a really big internetwork, the packet just goes through more hops before it finds the destination host.

It’s super important to remember that when Host_A sends a packet to Host_B, the destination hardware address used is the default gateway’s Ethernet interface. Why? Because frames can’t be placed on remote networks—only local networks. So packets destined for remote networks must go through the default gateway.

Let’s take a look at Host_A’s ARP cache now by using the `arp -a` command from the DOS prompt:

```
C:\ >arp -a
Interface: 172.16.10.2 --- 0x3
  Internet Address      Physical Address      Type
  172.16.10.1           00-15-05-06-31-b0     dynamic
  172.16.20.1           00-15-05-06-31-b0     dynamic
```

Did you notice that the hardware (MAC) address that Host_A uses to get to Host_B is the Lab_A E0 interface?

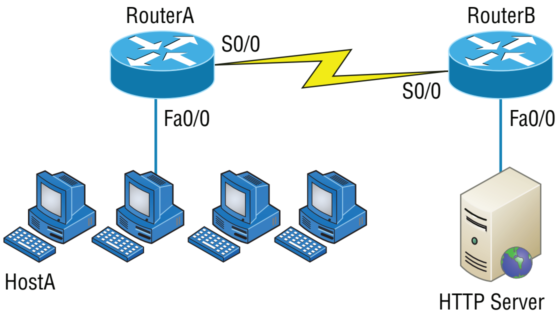
Hardware addresses are *always* local, and they never pass a router’s interface. Understanding this process is as important to internetworking as breathing air is to you, so carve this into your memory!

Testing Your IP Routing Understanding

I want to make sure you understand IP routing because it’s really that important. So, I’m going to use this section to test your understanding of the IP routing process by having you look at a couple of figures and answer some very basic IP routing questions.

Figure 9.4 shows a LAN connected to RouterA, which is, in turn, connected via a WAN link to RouterB. RouterB has a LAN connected with an HTTP server attached. Take a look.

FIGURE 9.4 IP routing example 1



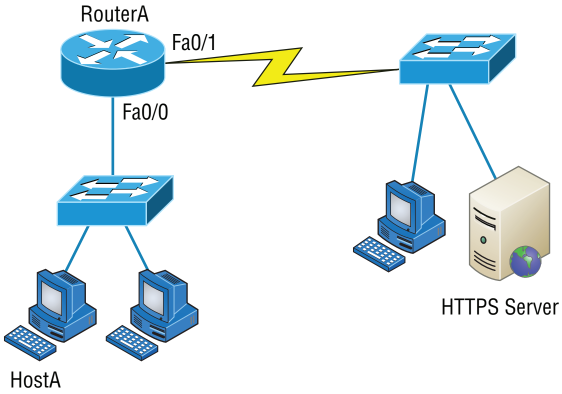
The critical information you need to glean from this figure is exactly how IP routing will occur in this example. Okay—we'll cheat a bit. I'll give you the answer, but then you should go back over the figure and see if you can answer example 2 without looking at my answers:

1. The destination address of a frame, from HostA, will be the MAC address of the Fa0/0 interface of the RouterA router.
2. The destination address of a packet will be the IP address of the network interface card (NIC) of the HTTP server.
3. The destination port number in the segment header will have a value of 80.

That example was a pretty simple one, and it was also very to the point. One thing to remember is that if multiple hosts are communicating to the server using HTTP, they must all use a different source port number. That is how the server keeps the data separated at the Transport layer.

Let's mix it up a little and add another internetworking device into the network and then see if you can find the answers. Figure 9.5 shows a network with only one router but two switches.

FIGURE 9.5 IP routing example 2



What you want to understand about the IP routing process here is what happens when HostA sends data to the HTTPS server:

1. The destination address of a frame from HostA will be the MAC address of the Fa0/0 interface of the RouterA router.
2. The destination address of a packet will be the IP address of the NIC of the HTTPS server.
3. The destination port number in the segment header will have a value of 443.

Notice that neither switch was used as either a default gateway or another destination. That's because switches have nothing to do with routing. I wonder how many of you chose the switch as the default gateway (destination) MAC address for HostA. If you did, don't feel bad—just take another look with that fact in mind. It's very important to remember that the destination MAC address will always be the router's interface—if your packets are destined for outside the LAN, as they were in these last two examples.

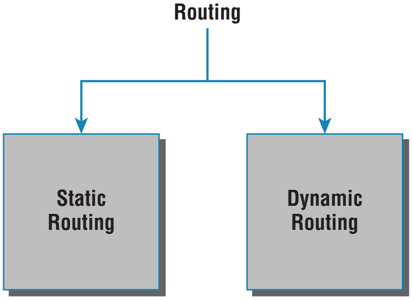
Static and Dynamic Routing

How does a router send packets to remote networks when the only way it can send them is by looking at the routing table to find out how to get to the remote networks? And what happens when a router receives a packet for a network that isn't listed in the routing table? It doesn't send a broadcast looking for the remote network—the router just discards the packet.

There are several ways to configure the routing tables to include all the networks so that packets will be forwarded. Understand that what's best for one network isn't necessarily what's best for another. Knowing about and being able to recognize the different types of routing will really help you come up with the best solution for your specific environment and business requirements.

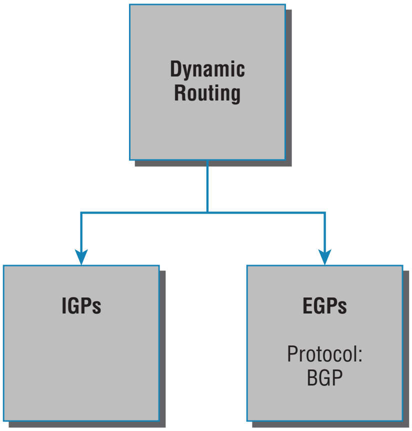
Looking at Figure 9.6, you can see that we can configure a router with either static or dynamic routing. If we choose static routing, then we have to go to each router and type in each network and the path that IP will use to send packets. However, static routing does not scale well in large networks, but dynamic routing does because network routes are automatically added to the routing table via the routing protocol.

FIGURE 9.6 Routing options



Dynamic routing protocols break up into many different categories or types of protocols, as shown in Figure 9.7. The first split in the dynamic protocol branch is the division of interior gateway protocols (IGPs) and exterior gateway protocols (EGPs). We are going to talk about each protocol and category but for now the difference between IGP and EGP is interior or exterior routing of an autonomous system (AS).

FIGURE 9.7 Dynamic routing options



An *autonomous system* is a collection of networks or subnets that are in the same administrative domain. This is another way of saying an administrative domain is within your company's network, and you control or administer all the subnets that are within it. You control and set the policy for what happens in the network or autonomous system. I hope you can now see that an IGP operates and routes within an AS and an EGP works outside or between more than one AS.

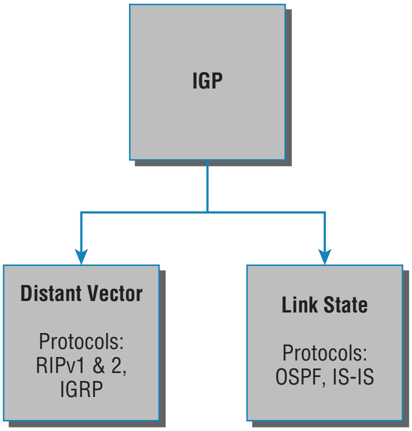
The most popular protocol for an EGP is Border Gateway Protocol (BGP), which is typically used by ISPs or really large corporations. As an administrator of a small to medium network, you'll probably never use BGP. (BGP will be discussed in Chapter 10.)

Now that we have that out of the way, let's talk about all the great things that dynamic routing protocols do for us. The thing that comes to mind first is the amount of time and energy we save configuring routers. We won't have to go to every single router and define for it, with a static route, what and where every destination network is. If that were the only way to configure routing, there would probably be a lot fewer of us interested in doing this for a living. Thankfully, we have routing protocols that do much of the work for us. We still have to know what the routing protocols are going to do and how they will do it, but the protocols will take care of most of the updating and sending information to each other.

That is the end of the EGP branch of the tree, but the IGP branch continues to split out as we go down further. Looking at Figure 9.8, with the IGP split, you can see that there are two primary categories: distance vector (DV) and link state (LS) routing protocols.

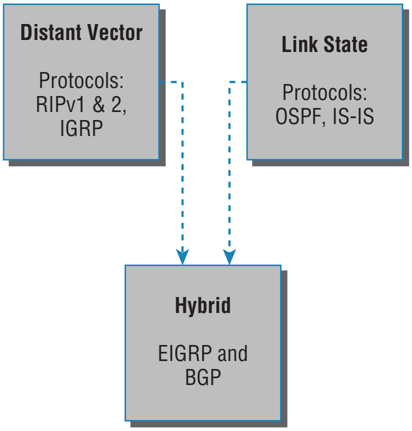
No worries—I'm going to discuss all of these types of protocols in Chapter 10, "Routing Protocols." But in the distance vector category, for example, we have RIP and Interior Gateway Routing Protocol (IGRP). Under the link state category are the nonproprietary OSPF and Intermediate System-to-Intermediate System (IS-IS) that were designed to work in larger internetworks.

FIGURE 9.8 DV and LS routing protocols



Now, in Figure 9.9, you can see from the diagram that there is a third category: the hybrid protocol category.

FIGURE 9.9 Hybrid routing



The only protocol under this category is EIGRP. It is Cisco proprietary and uses the features of both DV and LS. The Network+ objectives list BGP as a hybrid routing protocol as well because it can work on internal networks as well as external, but it's really an EGP; just keep this in mind.

Now that we have a handle on IP routing, let's move on to Chapter 10 and discuss the IGP routing protocols introduced in this chapter.

Summary

This chapter covered the IP routing process in detail. It's extremely important that you really understand the basics we covered in this chapter because everything that's done on a router typically will have some type of IP routing configured and running.

You learned in this chapter how IP routing uses frames to transport packets between routers and to the destination host. Understanding the process of how packets and frames traverse a network is critical to your fundamental understanding of IP routing.

After I covered the basics of IP routing, I went through some examples to test your understanding and to emphasize the importance of the IP routing fundamentals that you need. I finished the chapter with an introduction to static and dynamic routing and explained IGP and EGP as well as the difference between distance vector and link state routing protocols. In the next chapter, we'll continue with dynamic routing by discussing the various dynamic routing protocols.

Exam Essentials

Understand the basic IP routing process. You need to remember that the frame changes at each hop but that the packet is never changed or manipulated in any way until it reaches the destination device.

Understand that MAC addresses are always local. A MAC (hardware) address will only be used on a local LAN. It will never pass a router's interface.

Understand that a frame carries a packet to only two places. A frame uses MAC (hardware) addresses to send a packet on a LAN. The frame will take the packet to either a host on the LAN or a router's interface if the packet is destined for a remote network.

Remember the difference between static and dynamic routing. Static routing is where you, as the administrator, by hand, add every route into every routing table on every router on the network. This is as much work as it sounds like, which is why we use dynamic routing protocols that do the work for us. Of course, we'll discuss dynamic routing protocols more in the next chapter, but the main job of a routing protocol is to update routing tables.

Written Lab

You can find the answers to the written labs in Appendix A. Write the answers to the following questions:

1. True/False: RIPv2 is a hybrid routing protocol.

2. True/False: RIPv1 is a link state routing protocol.

3. True/False: EIGRP is a nonproprietary routing protocol.

4. An __________ is a collection of networks or subnets that are in the same administrative domain.

5. You need a routing protocol that can be run in a very large network with routers from multiple vendors. What routing protocol would be your best choice?

6. Which type of routing are you performing if you have to go to each router and type in each network and the path that IP will use to send packets?

7. You are trying to reach a server on another subnet. What will be the destination hardware address of a frame sent from your host?

8. You are trying to reach a server on another subnet. What will be the destination IP address of a packet sent from your host?

9. A server has received a frame from your remote host. What will be the source hardware address of the frame?

10. A server has received a packet from your remote host. What will be the destination IP address of the packet?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which is not a routing protocol?

   A. RIP

   B. RIPv2

   C. RIPv3

   D. EIGRP

2. Which of these best describes dynamic routing?

   A. All network addresses must be hand-typed into the routing table.

   B. Only a portion of the network address must be hand-typed into the routing table.

   C. Routing tables are updated automatically when changes occur in the network.

   D. A and B.

3. Which is true regarding dynamic routing?

   A. Static routes are best in large networks and thus better to use than dynamic routing protocols.

   B. Static routes are automatically added to the routing table but dynamic routes must be added by hand.

   C. You must use a DNS and WINS server when configuring dynamic routing.

   D. Dynamic routes are automatically added to the routing table.

4. Which of the following is true for MAC addresses?

   A. MAC addresses are never local on the LAN and always pass through a router.

   B. MAC addresses are always local on the LAN and never go through or past a router.

   C. MAC addresses will always be the IP address of Fa0/0 interface.

   D. None of the above.

5. What is it called when protocols update their forwarding tables after changes have occurred?

   A. Name resolution

   B. Routing

   C. Convergence

   D. ARP resolution

6. What command would be used to view the ARP cache on your host?

   A. `C:\  >show ip route`

   B. `C:\  >show ip arp`

C. `C:\  >show protocols`

D. `C:\  >arp -a`

7. What happens when a router receives a packet for a network that isn't listed in the routing table?

A. It forwards the packet to the next available router.

B. It holds the packet until the address is updated in the routing table.

C. The router will use RIP to inform the host that it can't send the packet.

D. None of the above.

8. Which of the following is not a distance vector protocol?

A. RIPv1

B. RIPv2

C. OSPF

D. IGRP

9. Which two of the following are link state protocols?

A. RIPv1

B. RIPv2

C. OSPF

D. IS-IS

E. IGRP

10. Which of the following is a hybrid routing protocol?

A. RIPv2

B. EIGRP

C. IS-IS

D. IGRP

11. What does the acronym IGRP stand for?

A. Interior Gateway Routing Protocol

B. Inside Gateway Redundancy Protocol

C. Interior Group Reliability Protocol

D. Interior Gateway Redundancy Protocol

12. What EGP protocol is used on the Internet?

A. GGP

B. EGP

C. BGP

D. IGP

13. What are the two categories of IGP protocols?

    A. Link state

    B. Static

    C. Distance vector

    D. EGP

14. What two pieces of information does a router require to make a routing decision? (Choose two.)

    A. Destination network (address)

    B. Destination MAC address

    C. Application layer protocol

    D. Neighbor router

15. Where does a frame have to carry a packet if it is destined for a remote network?

    A. Default gateway

    B. Neighbor host

    C. Switch

    D. Hub

16. Where along the IP routing process does a packet get changed?

    A. Router

    B. Host A

    C. Destination device

    D. Host B

17. When all routers in a network agree about the path from one point to another, the network is said to be what?

    A. Dynamic

    B. Static

    C. Secure

    D. Converged

18. What type of request must a client send if it does not know the destination MAC address?

    A. ARP broadcast

    B. Multicast

    C. ICMP redirect

    D. Reverse ARP

19. You need to perform maintenance on a router in your corporate office. It is important that the network does not go down. What can you do to accomplish your goal?

- **A.** Configure BGP on the router.
- **B.** Implement NAT on the router.
- **C.** Configure on the router a static route that temporarily reroutes traffic through another office.
- **D.** Implement convergence on the router.

20. When are you most likely to see a Request Timed Out message?

- **A.** When an unknown error has occurred
- **B.** When you have used the `arp -a` command incorrectly
- **C.** When a known error has occurred
- **D.** When you are using a hybrid routing protocol

Chapter 10

Routing Protocols

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Routing
  - Routing protocols (IPv4 and IPv6)
    - Distance-vector routing protocols
      - RIP
      - EIGRP
    - Link-state routing protocols
      - OSPF
    - Hybrid
      - BGP
- IPv6 concepts
  - Tunneling
  - Dual stack
  - Router advertisement
  - Neighbor discovery

✓ **2.2 Given a scenario, determine the appropriate placement of networking devices on a network and install/configure them**

- Router

Routing protocols are critical to a network's design. This chapter focuses on dynamic routing protocols. Dynamic routing protocols run only on routers that use them in order to discover networks and update their routing tables. Using dynamic routing is easier on you, the system administrator, than using the labor-intensive, manually achieved static routing method, but it'll cost you in terms of router CPU processes and bandwidth on the network links.

The source of the increased bandwidth usage and CPU cycles is the operation of the dynamic routing protocol itself. A router running a dynamic routing protocol shares routing information with its neighboring routers, and it requires additional CPU cycles and additional bandwidth to accomplish that.

In this chapter, I'll give you all the basic information you need to know about routing protocols so you can choose the correct one for each network you work on or design.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

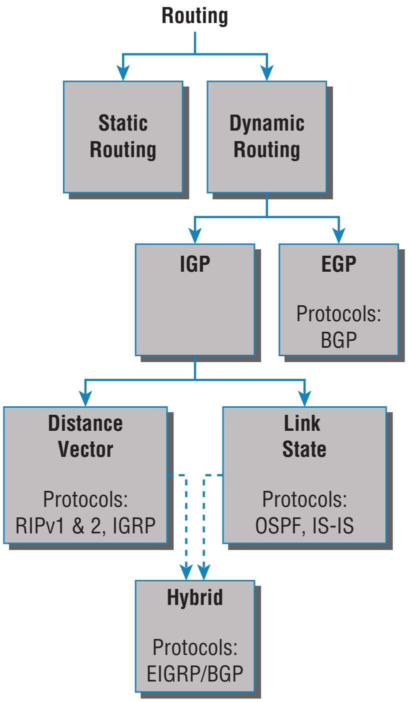
Routing Protocol Basics

Because getting a solid visual can really help people learn, I'll get you started by combining the last few figures used in Chapter 9, "Introduction to IP Routing." This way, you can get the big picture and really understand how routing works. Figure 10.1 shows the complete routing tree that I broke up piece by piece at the end of Chapter 9.

As I touched on in Chapter 9, two types of routing protocols are used in internetworks: interior gateway protocols (IGPs) and exterior gateway protocols (EGPs). IGPs are used to exchange routing information with routers in the same *autonomous system (AS)*. An AS is a collection of networks under a common administrative domain, which simply means that all routers sharing the same routing table information are in the same AS. EGPs are used to communicate between multiple ASs. A nice example of an EGP would be Border Gateway Protocol (BGP).

There are a few key points about routing protocols that I think it would be a good idea to talk over before getting deeper into the specifics of each one. First on the list is something known as an administrative distance.

FIGURE 10.1 Routing flow tree



Administrative Distances

The *administrative distance (AD)* is used to rate the trustworthiness of routing information received on one router from its neighboring router. An AD is represented as an integer from 0 to 255, where 0 equals the most trusted route and 255 the least. A value of 255 essentially means, "No traffic is allowed to be passed via this route."

If a router receives two updates listing the same remote network, the first thing the router checks is the AD. If one of the advertised routes has a lower AD than the other, the route with the lower AD is the one that will get placed in the routing table.

If both advertised routes to the same network have the same AD, then routing protocol metrics like *hop count* or the amount of bandwidth on the lines will be used to find the best path to the remote network. And as it was with the AD, the advertised route with the lowest metric will be placed in the routing table. But if both advertised routes have the same AD as well as the same metrics, then the routing protocol will *load-balance* to the remote network. To perform load balancing, a router will send packets down each link to test for the best one.

Real World Scenario

Why Not Just Turn On All Routing Protocols?

Many customers have hired me because all their employees were complaining about a slow, intermittent network that had a lot of latency. Many times, I have found that the administrators did not truly understand routing protocols and just enabled them all on every router.

This may sound laughable, but it is true. When an administrator tried to disable a routing protocol, such as the Routing Information Protocol (RIP), they would receive a call that part of the network was not working. First, understand that because of default ADs, although every routing protocol was enabled, only the Enhanced Interior Gateway Routing Protocol (EIGRP) would show up in most of the routing tables. This meant that Open Shortest Path First (OSPF), Intermediate System-to-Intermediate System (IS-IS), and RIP would be running in the background but just using up bandwidth and CPU processes, slowing the routers almost to a crawl.

Disabling all the routing protocols except EIGRP (this would only work on an all-Cisco router network) improved the network at least 30 percent. In addition, finding the routers that were configured only for RIP and enabling EIGRP solved the calls from users complaining that the network was down when RIP was disabled on the network. Last, I replaced the core routers with better routers with more memory, enabling faster, more efficient routing and raising the network response time to a total of 50 percent.

Table 10.1 shows the default ADs that a router uses to decide which route to take to a remote network.

TABLE 10.1 Default administrative distances

Route Source	Default AD
Connected interface	0
Static route	1
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110

Route Source	Default AD
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200
Unknown	255 (this route will never be used)

Understand that if a network is directly connected, the router will always use the interface connected to that network. Also good to know is that if you configure a static route, the router will believe that route to be the preferred one over any other routes it learns about dynamically. You can change the ADs of static routes, but by default, they have an AD of 1. That's only one place above zero, so you can see why a static route's default AD will always be considered the best by the router.

This means that if you have a static route, a RIP-advertised route, and an EIGRP-advertised route listing the same network, then by default, the router will always use the static route unless you change the AD of the static route.

Classes of Routing Protocols

The three classes of routing protocols introduced in Chapter 9, and shown in Figure 10.1, are as follows:

Distance Vector The *distance vector protocols* find the best path to a remote network by judging—you guessed it—distance. Each time a packet goes through a router, it equals something we call a *hop*, and the route with the fewest hops to the destination network will be chosen as the best path to it. The vector indicates the direction to the remote network. RIP, RIPv2, and Interior Gateway Routing Protocol (IGRP) are distance vector routing protocols. These protocols send the entire routing table to all directly connected neighbors.

Link State Using *link state protocols*, also called *shortest path first protocols*, the routers each create three separate tables. One of these tables keeps track of directly attached neighbors, one determines the topology of the entire internetwork, and one is used as the actual routing table. Link state routers know more about the internetwork than any distance vector routing protocol. OSPF and IS-IS are IP routing protocols that are completely link state. Link state protocols send updates containing the state of their own links to all other routers on the network.

Hybrid A *hybrid protocol* uses aspects of both distance vector and link state, and formerly, EIGRP was the only one you needed to understand to meet the Network+ objectives. But now, BGP is also listed as a hybrid routing protocol because of its capability to work as an EGP and be used in supersized internetworks internally. When deployed in this way, it's called internal BGP, or iBGP, but understand that it's still most commonly utilized as an EGP.

I also want you to understand that there's no one set way of configuring routing protocols for use in every situation because this really needs to be done on a case-by-case basis. Even though all of this might seem a little intimidating, if you understand how each of the different routing protocols works, I promise you'll be capable of making good, solid decisions that will truly meet the individual needs of any business!

Distance Vector Routing Protocols

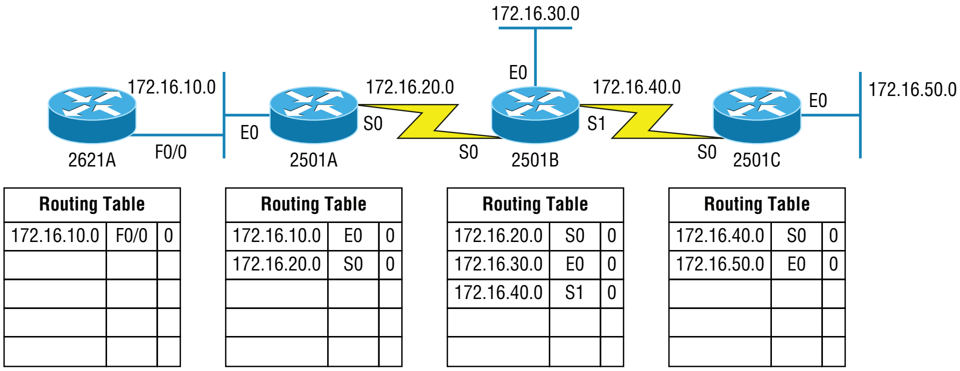
Okay, the distance vector routing algorithm passes its complete routing table contents to neighboring routers, which then combine the received routing table entries with their own routing tables to complete and update their individual routing tables. This is called *routing by rumor* because a router receiving an update from a neighbor router believes the information about remote networks without verifying for itself if the news is actually correct.

It's possible to have a network that has multiple links to the same remote network, and if that's the case, the AD of each received update is checked first. As I said, if the AD is the same, the protocol will then have to use other metrics to determine the best path to use to get to that remote network.

Distance vector uses only hop count to determine the best path to a network. If a router finds more than one link with the same hop count to the same remote network, it will automatically perform what's known as *round-robin load balancing*.

It's important to understand what a distance vector routing protocol does when it starts up. In Figure 10.2, the four routers start off with only their directly connected networks in their routing table. After a distance vector routing protocol is started on each router, the routing tables are then updated with all route information gathered from neighbor routers.

FIGURE 10.2 The internetwork with distance vector routing



Routing Table		
172.16.10.0	F0/0	0

Routing Table		
172.16.10.0	E0	0
172.16.20.0	S0	0

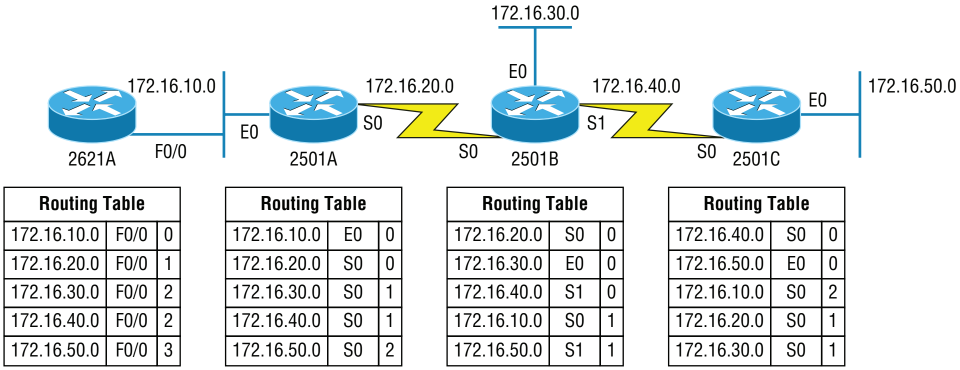
Routing Table		
172.16.20.0	S0	0
172.16.30.0	E0	0
172.16.40.0	S1	0

Routing Table		
172.16.40.0	S0	0
172.16.50.0	E0	0

As you can see in Figure 10.2, each router only has the directly connected networks in its routing table. Also notice that their hop count is zero in every case. Each router sends its complete routing table, which includes the network number, exit interface, and hop count to the network, out to each active interface.

Now, in Figure 10.3, the routing tables are complete because they include information about all the networks in the internetwork. They are considered *converged*. The hop count for every directly connected network remains zero, but notice that the hop count is incremented by one each time the path completely passes through a router. So, for router 2621A, the path to the 172.16.10.0 network still has a hop count of zero, but the hop count for the path to network 172.16.20.0 is one. The hop count to networks 172.16.30.0 and 172.16.40.0 increases to two, and so on. Usually, data transmission will cease while routers are converging—a good reason in favor of fast convergence time! In fact, one of the main problems with RIP is its slow convergence time.

FIGURE 10.3 Converged routing tables



Routing Table		
172.16.10.0	F0/0	0
172.16.20.0	F0/0	1
172.16.30.0	F0/0	2
172.16.40.0	F0/0	2
172.16.50.0	F0/0	3

Routing Table		
172.16.10.0	E0	0
172.16.20.0	S0	0
172.16.30.0	S0	1
172.16.40.0	S0	1
172.16.50.0	S0	2

Routing Table		
172.16.20.0	S0	0
172.16.30.0	E0	0
172.16.40.0	S1	0
172.16.10.0	S0	1
172.16.50.0	S1	1

Routing Table		
172.16.40.0	S0	0
172.16.50.0	E0	0
172.16.10.0	S0	2
172.16.20.0	S0	1
172.16.30.0	S0	1

As you can see in Figure 10.3, once all the routers have converged, the routing table in each router keeps information about three important things:

- The remote network number
- The interface that the router will use to send packets to reach that particular network
- The hop count, or metric, to the network

NOTE

Remember! Routing convergence time is the time required by protocols to update their forwarding tables after changes have occurred.

Let's start discussing dynamic routing protocols with one of the oldest routing protocols that is still in existence today.

Routing Information Protocol (RIP)

RIP is a true distance vector routing protocol. It sends the complete routing table out to all active interfaces every 30 seconds. RIP uses only one thing to determine the best way to a remote network—the hop count. And because it has a maximum allowable hop count of 15 by default, a hop count of 16 would be deemed unreachable. This means that although RIP works fairly well in small networks, it's pretty inefficient on large networks with slow WAN links or on networks populated with a large number of routers. Worse, this dinosaur of a protocol has a bad history of creating routing loops, which were somewhat kept in check by using things like maximum hop count. This is the reason why RIP only permits going through 15 routers before it will judge that route to be invalid. If all that isn't nasty enough for you, RIP also happens to be glacially slow at converging, which can easily cause latency in your network!

RIP version 1 uses only *classful routing*, which means that all devices in the network must use the same subnet mask for each specific address class. This is because RIP version 1 doesn't send updates with subnet mask information in tow. RIP version 2 provides something called *prefix routing* and does send subnet mask information with the route updates. Doing this is called *classless routing*.

RIP Version 2 (RIPv2)

Let's spend a couple of minutes discussing RIPv2 before we move into the advanced distance vector (also referred to as hybrid), Cisco-proprietary routing protocol EIGRP.

RIP version 2 is mostly the same as RIP version 1. Both RIPv1 and RIPv2 are distance vector protocols, which means that each router running RIP sends its complete routing tables out to all active interfaces at periodic time intervals. Also, the timers and loop-avoidance schemes are the same in both RIP versions. Both RIPv1 and RIPv2 are configured with classful addressing (but RIPv2 is considered classless because subnet information is sent with each route update), and both have the same AD (120).

But there are some important differences that make RIPv2 more scalable than RIPv1. And I've got to add a word of advice here before we move on: I'm definitely not advocating using RIP of either version in your network. But because RIP is an open standard, you can use RIP with any brand of router. You can also use OSPF because OSPF is an open standard as well.

Table 10.2 discusses the differences between RIPv1 and RIPv2.

TABLE 10.2 RIPv1 vs RIPv2

RIPv1	RIPv2
Distance vector	Distance vector
Maximum hop count of 15	Maximum hop count of 15
Classful	Classless

RIPv1	RIPv2
Broadcast based	Uses multicast 224.0.0.9
No support for VLSM	Supports VLSM networks
No authentication	Allows for MD5 authentication
No support for discontiguous networks	Supports discontiguous networks (covered in the next section, "VLSM and Discontiguous Networks")

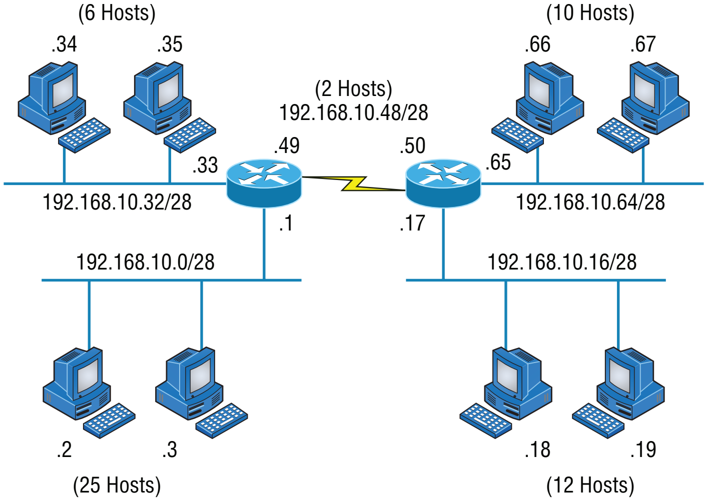
RIPv2, unlike RIPv1, is a classless routing protocol (even though it is configured as classful, like RIPv1), which means that it sends subnet mask information along with the route updates. By sending the subnet mask information with the updates, RIPv2 can support variable length subnet masks (VLSMs), which are described in the next section; in addition, network boundaries are summarized.

VLSM and Discontiguous Networks

VLSMs allow classless routing, meaning that the routing protocol sends subnet-mask information with the route updates. The reason it's good to do this is to save address space. If we didn't use a routing protocol that supports VLSMs, then every router interface, every node (PC, printer, server, and so on), would have to use the same subnet mask.

As the name suggests, with VLSMs we can have different subnet masks for different router interfaces. Check out Figure 10.4 to see an example of why classful network designs are inefficient.

FIGURE 10.4 Typical classful network



Looking at this figure, you'll notice that we have two routers, each with two LANs and connected together with a WAN serial link. In a typical classful network design example (RIP or RIPv2 routing protocol), you could subnet a network like this:

192.168.10.0 = Network

255.255.255.240 (/28) = Mask

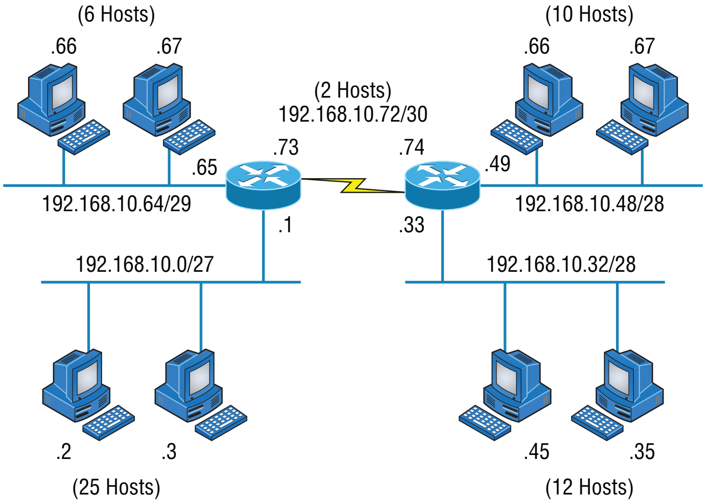
Our subnets would be (you know this part, right?) 0, 16, 32, 48, 64, 80, and so on. This allows us to assign 16 subnets to our internetwork. But how many hosts would be available on each network? Well, as you probably know by now, each subnet provides only 14 hosts. This means that with a /28 mask, each LAN can support 14 valid hosts—one LAN requires 25 addresses, so a /28 mask doesn't provide enough addresses for the hosts in that LAN! Moreover, the point-to-point WAN link also would consume 14 addresses when only 2 are required. It's too bad we can't just nick some valid hosts from that WAN link and give them to our LANs.

All hosts and router interfaces have the same subnet mask—again, this is called classful routing. And if we want this network to be more efficient, we definitely need to add different masks to each router interface.

But there's still another problem—the link between the two routers will never use more than two valid hosts! This wastes valuable IP address space, and it's the big reason I'm talking to you about VLSM networking.

Now let's take Figure 10.4 and use a classless design, which will become the new network shown in Figure 10.5. In the previous example, we wasted address space—one LAN didn't have enough addresses because every router interface and host used the same subnet mask. Not so good.

FIGURE 10.5 Classless network design



What would be good is to provide only the needed number of hosts on each router interface, meaning VLSMs. Remember that if a "classful routed network" requires that all subnet masks be the same length, then it follows that a "classless routed network" would allow us to use variable length subnet masks (VLSMs).

So, if we use a /30 on our WAN links and a /27, /28, and /29 on our LANs, we'll get 2 hosts per WAN interface and 30, 14, and 6 hosts per LAN interface—nice! This makes a huge difference—not only can we get just the right number of hosts on each LAN, we still have room to add more WANs and LANs using this same network.

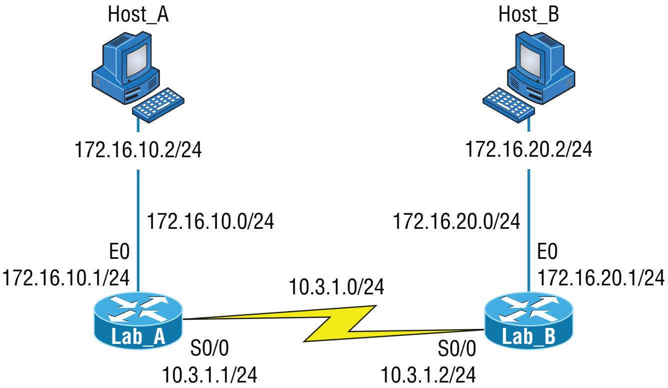
Remember, in order to implement a VLSM design on your network, you need to have a routing protocol that sends subnet-mask information with the route updates. This would be RIPv2, EIGRP, or OSPF. RIPv1 and IGRP will not work in classless networks and are considered classful routing protocols.

NOTE

By using a VLSM design, you do not necessarily make your network run better, but you can save a lot of IP addresses.

Now, what's a discontiguous network? It's one that has two or more subnetworks of a classful network connected together by different classful networks. Figure 10.6 displays a typical discontiguous network.

FIGURE 10.6 A discontiguous network



The subnets 172.16.10.0 and 172.16.20.0 are connected together with a 10.3.1.0 network. By default, each router thinks it has the only 172.16.0.0 classful network.

It's important to understand that discontiguous networks just won't work with RIPv1 at all. They don't work by default on RIPv2 or EIGRP either, but discontiguous networks do work on OSPF networks by default because OSPF does not auto-summarize like RIPv2 and EIGRP.

NOTE

Route aggregation is essentially combining multiple subnets into one larger subnet, and it's also known as supernetting. You would implement this type of route summarization if you required more efficient routing tables in large networks.

EIGRP

EIGRP is a classless, enhanced distance vector protocol that possesses a real edge over another older Cisco proprietary protocol, IGRP. That's basically why it's called Enhanced IGRP.

EIGRP uses the concept of an autonomous system to describe the set of contiguous routers that run the same routing protocol and share routing information. But unlike IGRP, EIGRP includes the subnet mask in its route updates. And as you now know, the advertisement of subnet information allows us to use VLSMs when designing our networks.

EIGRP is referred to as a *hybrid routing protocol* because it has characteristics of both distance vector and link state protocols. For example, EIGRP doesn't send link state packets as OSPF does; instead, it sends traditional distance vector updates containing information about networks, plus the cost of reaching them from the perspective of the advertising router. But EIGRP has link state characteristics as well—it synchronizes routing tables between neighbors at startup and then sends specific updates only when topology changes occur. This makes EIGRP suitable for very large networks.

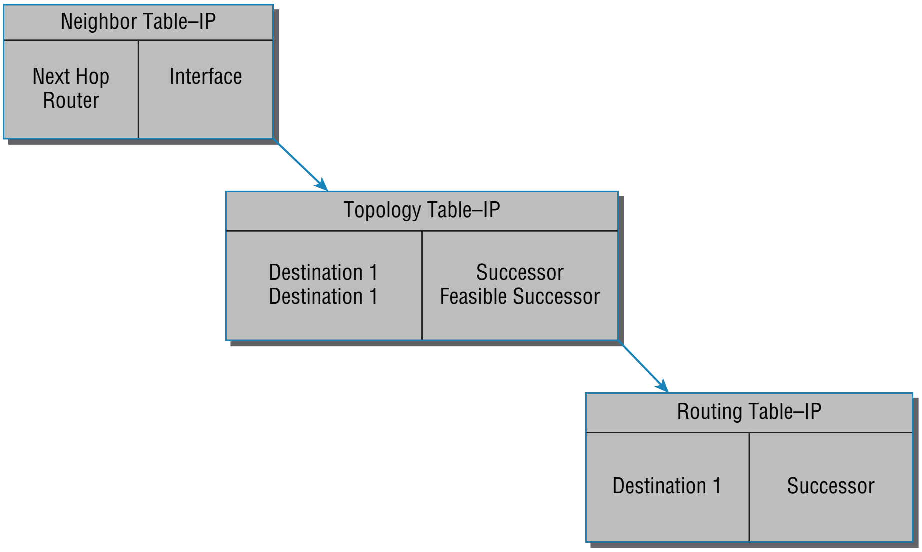
There are a number of powerful features that make EIGRP a real standout from RIP, RIPv2, and other protocols. The main ones are listed here:

- Support for IP and IPv6 (and some other useless routed protocols) via protocol-dependent modules
- Considered classless (same as RIPv2 and OSPF)
- Support for VLSM/Classless Inter-Domain Routing (CIDR)
- Support for summaries and discontiguous networks
- Efficient neighbor discovery
- Communication via Reliable Transport Protocol (RTP)
- Best path selection via Diffusing Update Algorithm (DUAL)

Another great feature of EIGRP is that it's simple to configure and turn on like a distance vector protocol, but it keeps track of more information than a distance vector does. It creates and maintains additional tables instead of just one table as distance vector routing protocols do. To determine the best path to each network, EIGRP uses bandwidth and delay of the line as well as sending reliability, load, and the MTU information between routers, but it only uses bandwidth and delay by default.

These tables are called the neighbor table, *topology table*, and routing table, as shown in Figure 10.7.

FIGURE 10.7 EIGRP tables



Neighbor Table Each router keeps state information about adjacent neighbors. When a newly discovered neighbor is learned on a router interface, the address and interface of that neighbor are recorded, and the information is held in the neighbor table and stored in RAM. Sequence numbers are used to match acknowledgments with update packets. The last sequence number received from the neighbor is recorded so that out-of-order packets can be detected.

Topology Table The topology table is populated by the neighbor table, and the best path to each remote network is found by running Diffusing Update Algorithm (DUAL). The topology table contains all destinations advertised by neighboring routers, holding each destination address and a list of neighbors that have advertised the destination. For each neighbor, the advertised metric, which comes only from the neighbor's routing table, is recorded. If the neighbor is advertising this destination, it must be using the route to forward packets.

Successor (Routes in a Routing Table) A successor route (think successful!) is the best route to a remote network. A successor route is used by EIGRP to forward traffic to a destination and is stored in the routing table. It is backed up by a feasible successor route that is stored in the topology table—if one is available.

Feasible Successor (Backup Routes) A *feasible successor* is a path considered a backup route. EIGRP will keep up to six feasible successors in the topology table. Only the one with the best metric (the successor) is copied and placed in the routing table.

By using the feasible distance and having feasible successors in the topology table as backup links, EIGRP allows the network to converge instantly and updates to any neighbor only consist of traffic sent from EIGRP. All of these things make for a very fast, scalable, fault-tolerant routing protocol.

NOTE

Route redistribution is the term used for translating from one routing protocol into another. An example would be where you have an old router running RIP but you have an EIGRP network. You can run route redistribution on one router to translate the RIP routes into EIGRP.

Border Gateway Protocol (BGP)

In a way, you can think of Border Gateway Protocol (BGP) as the heavyweight of routing protocols. This is an external routing protocol (used between autonomous systems, unlike RIP or OSPF, which are internal routing protocols) that uses a sophisticated algorithm to determine the best route.

NOTE

Even though BGP is an EGP by default, it can be used within an AS, which is one of the reasons the objectives are calling this a hybrid routing protocol. Another reason they call it a hybrid is because it's often known as a path vector protocol instead of a distance vector like RIP.

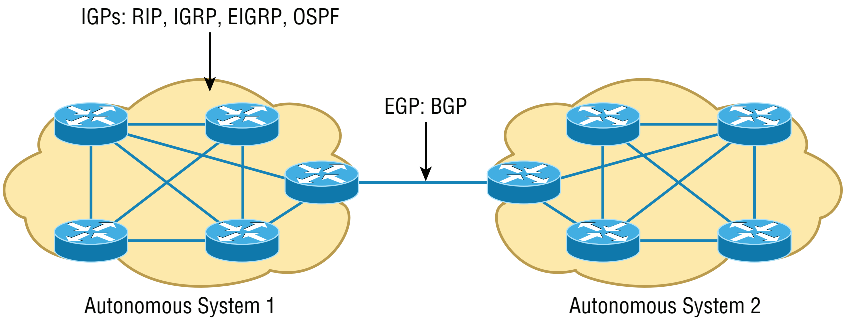
In fact, it just happens to be the core routing protocol of the Internet. And it's not exactly breaking news that the Internet has become a vital resource in so many organizations, is it? No—but this growing dependence has resulted in redundant connections to many different ISPs.

This is where BGP comes in. The sheer onslaught of multiple connections would totally overwhelm other routing protocols like OSPF, which I am going to talk about shortly. BGP is essentially an alternative to using default routes for controlling path selections. *Default routes* are configured on routers to control packets that have a destination IP address that is not found in the routing table. Please see *CCNA Routing and Switching Complete Study Guide: Exam 100-105, Exam 200-105, Exam 200-125, 2nd Edition* for more information on static and default routing.

Because the Internet's growth rate shows no signs of slowing, ISPs use BGP for its ability to make classless routing and summarization possible. These capabilities help to keep routing tables smaller and more efficient at the ISP core.

BGP is used for IGPs to connect ASs together in larger networks, if needed, as shown in Figure 10.8.

FIGURE 10.8 Border Gateway Protocol (BGP)



NOTE An autonomous system is a collection of networks under a common administrative domain. IGPs operate within an autonomous system, and EGPs connect different autonomous systems together.

So yes, very large private IP networks can make use of BGP. Let's say you wanted to join a number of large OSPF networks together. Because OSPF just couldn't scale up enough to handle such a huge load, you would go with BGP instead to connect the ASs together. Another situation in which BGP would come in really handy would be if you wanted to multi-home a network for better redundancy, either to a multiple access point of a single ISP or to multiple ISPs.

Internal routing protocols are employed to advertise all available networks, including the metric necessary to get to each of them. BGP is a personal favorite of mine because its routers exchange path vectors that give you detailed information on the BGP AS numbers, hop by hop (called an AS path), required to reach a specific destination network. Also good to know is that BGP doesn't broadcast its entire routing table like RIP does; it updates a lot more like OSPF, which is a huge advantage. Also, the routing table with BGP is called a Routing Information Base (RIB).

And BGP also tells you about any/all networks reachable at the end of the path. These factors are the biggest differences you need to remember about BGP. Unlike IGPs that simply tell you how to get to a specific network, BGP gives you the big picture on exactly what's involved in getting to an AS, including the networks located in that AS itself.

And there's more to that "BGP big picture"—this protocol carries information like the network prefixes found in the AS and includes the IP address needed to get to the next AS (the next-hop attribute). It even gives you the history on how the networks at the end of the path were introduced into BGP in the first place, known as the origin code attribute.

All of these traits are what makes BGP so useful for constructing a graph of loop-free autonomous systems, for identifying routing policies, and for enabling us to create and enforce restrictions on routing behavior based upon the AS path—sweet!

Link State Routing Protocols

Link state protocols also fall into the classless category of routing protocols, and they work within packet-switched networks. OSPF and IS-IS are two examples of link state routing protocols.

Remember, for a protocol to be a classless routing protocol, the subnet-mask information must be carried with the routing update. This enables every router to identify the best route to each and every network, even those that don't use class-defined default subnet masks (i.e., 8, 16, or 24 bits), such as VLSM networks. All neighbor routers know the cost of the network route that's being advertised. One of the biggest differences between link state and distance vector protocols is that link state protocols learn and maintain much more information about the internetwork than distance vector routing protocols do. Distance vector routing protocols only maintain routing tables with the destination routes and vector costs (like hop counts) in them. Link state routing protocols maintain two additional tables with more detailed information, with the first of these being the neighbor table. The neighbor table is maintained through the use of *hello packets* that are exchanged by all routers to determine which other routers are available to exchange routing data with. All routers that can share routing data are stored in the neighbor table.

The second table maintained is the topology table, which is built and sustained through the use of link state advertisements or packets (LSAs or LSPs). In the topology table, you'll find a listing for every destination network plus every neighbor (route) through which it can be reached. Essentially, it's a map of the entire internetwork.

Once all of that raw data is shared and each one of the routers has the data in its topology table, the routing protocol runs the Shortest Path First (SPF) algorithm to compare it all and determine the best paths to each of the destination networks.

Open Shortest Path First (OSPF)

Open Shortest Path First (OSPF) is an open-standard routing protocol that's been implemented by a wide variety of network vendors, including Cisco. OSPF works by using the *Dijkstra algorithm*. First, a shortest-path tree is constructed, and then the routing table is populated with the resulting best paths. OSPF converges quickly (although not as fast as EIGRP), and it supports multiple, equal-cost routes to the same destination. Like EIGRP, it supports both IP and IPv6 routed protocols, but OSPF must maintain a separate database and routing table for each, meaning you're basically running two routing protocols if you are using IP and IPv6 with OSPF.

OSPF provides the following features:

- Consists of areas and autonomous systems
- Minimizes routing update traffic
- Allows scalability
- Supports VLSM/CIDR
- Has unlimited hop count
- Allows multivendor deployment (open standard)
- Uses a loopback (logical) interface to keep the network stable

OSPF is the first link state routing protocol that most people are introduced to, so it's good to see how it compares to more traditional distance vector protocols like RIPv2 and RIPv1. Table 10.3 gives you a comparison of these three protocols.

TABLE 10.3 OSPF and RIP comparison

Characteristic	OSPF	RIPv2	RIPv1
Type of protocol	Link state	Distance vector	Distance vector
Classless support	Yes	Yes	No

Characteristic	OSPF	RIPv2	RIPv1
VLSM support	Yes	Yes	No
Auto-summarization	No	Yes	Yes
Manual summarization	Yes	No	No
Discontiguous support	Yes	Yes	No
Route propagation	Multicast on change	Periodic multicast	Periodic broadcast
Path metric	Bandwidth	Hops	Hops
Hop-count limit	None	15	15
Convergence	Fast	Slow	Slow
Peer authentication	Yes	Yes	No
Hierarchical network	Yes (using areas)	No (flat only)	No (flat only)
Updates	Event triggered	Route table updates time intervals	Route table updates
Route computation	Dijkstra	Bellman-Ford	Bellman-Ford

OSPF has many features beyond the few I've listed in Table 10.3, and all of them contribute to a fast, scalable, and robust protocol that can be actively deployed in thousands of production networks. One of OSPF's most noteworthy features is that after a network change, such as when a link changes to up or down, OSPF converges with serious speed! In fact, it's the fastest of any of the interior routing protocols we'll be covering. Just to make sure you're clear, convergence refers to when all routers have been successfully updated with the change.

OSPF is supposed to be designed in a hierarchical fashion, which basically means that you can separate the larger internetwork into smaller internetworks called *areas*. This is definitely the best design for OSPF.

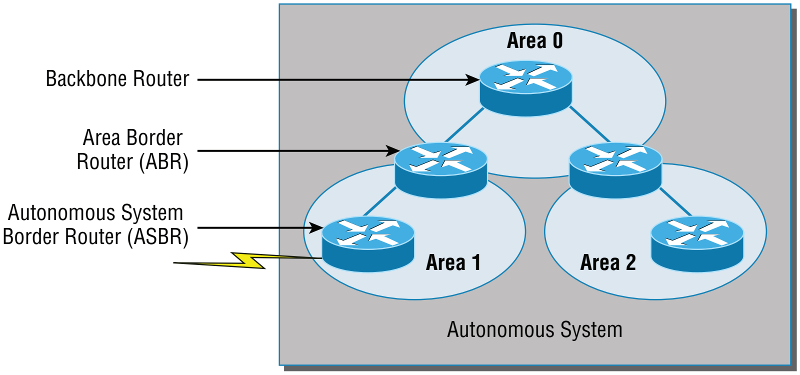
The following are reasons you really want to create OSPF in a hierarchical design:

- To decrease routing overhead
- To speed up convergence
- To confine network instability to single areas of the network

Pretty sweet benefits! But you have to earn them—OSPF is more elaborate and difficult to configure in this manner.

Figure 10.9 shows a typical OSPF simple design. Notice how each router connects to the backbone—called area 0, or the backbone area. OSPF must have an area 0, and all other areas should connect to this area. Routers that connect other areas to the backbone area within an AS are called area border routers (ABRs). Still, at least one interface of the ABR must be in area 0.

FIGURE 10.9 OSPF design example



OSPF runs inside an autonomous system, but it can also connect multiple autonomous systems together. The router that connects these ASs is called an *autonomous system border router (ASBR)*. Typically, in today's networks, BGP is used to connect between ASs, not OSPF.

Ideally, you would create other areas of networks to help keep route updates to a minimum and to keep problems from propagating throughout the network. But that's beyond the scope of this chapter. Just make note of it for your future networking studies.

Intermediate System-to-Intermediate System (IS-IS)

IS-IS is an IGP, meaning that it's intended for use within an administrative domain or network, not for routing between ASs. That would be a job that an EGP (such as BGP, which we just covered) would handle instead.

IS-IS is a link state routing protocol, meaning it operates by reliably flooding topology information throughout a network of routers. Each router then independently builds a picture of the network's topology, just as they do with OSPF. Packets or datagrams are forwarded based on the best topological path through the network to the destination.

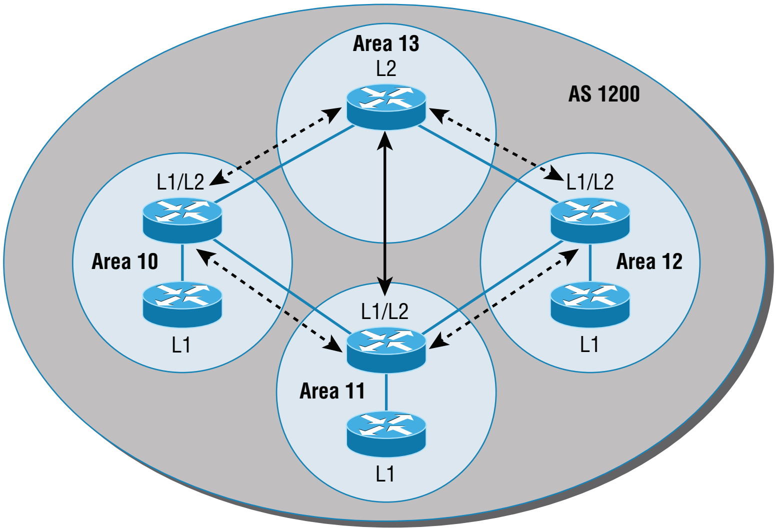
Figure 10.10 shows an IS-IS network and the terminology used with IS-IS.

Here are the definitions for the terms used in the IS-IS network shown in Figure 10.10:

L1 Level 1 intermediate systems route within an area. When the destination is outside an area, they route toward a Level 2 system.

L2 Level 2 intermediate systems route between areas and toward other ASs.

FIGURE 10.10 IS-IS network terminology



The similarity between IS-IS and OSPF is that both employ the Dijkstra algorithm to discover the shortest path through the network to a destination network. The difference between IS-IS and OSPF is that IS-IS uses Connectionless Network Service (CLNS) to provide connectionless delivery of data packets between routers, and it also doesn't require an area 0 like OSPF does. OSPF uses IP to communicate between routers instead.

An advantage to having CLNS around is that it can easily send information about multiple routed protocols (IP and IPv6), and as I already mentioned, OSPF must maintain a completely different routing database for IP and IPv6, respectively, for it to be able to send updates for both protocols.

IS-IS supports the most important characteristics of OSPF and EIGRP because it supports VLSM and also because it converges quickly. Each of these three protocols has advantages and disadvantages, but it's these two shared features that make any of them scalable and appropriate for supporting the large-scale networks of today.

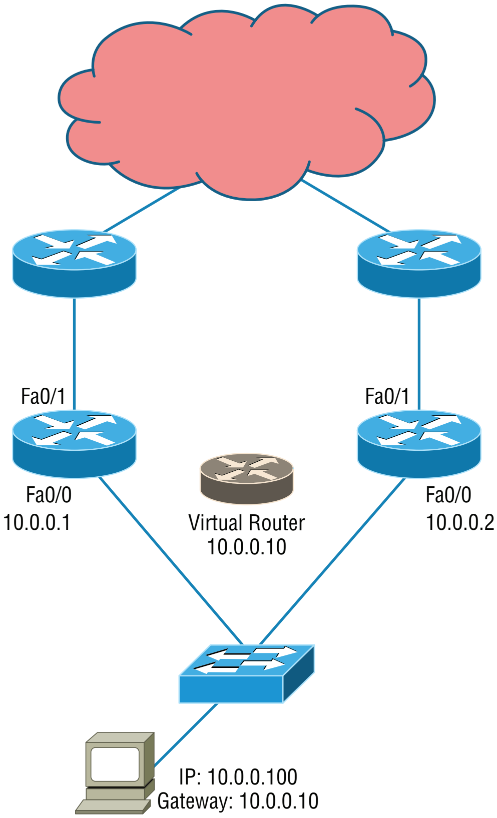
One last thing—even though it's not as common, IS-IS, although comparable to OSPF, is actually preferred by ISPs because of its ability to run IP and IPv6 without creating a separate database for each protocol as OSPF does. That single feature makes it more efficient in very large networks.

High Availability

First hop redundancy protocols (FHRPs) work by giving you a way to configure more than one physical router to appear as if they were only a single logical one. This makes client configuration and communication easier because you can simply configure a single default gateway and the host machine can use its standard protocols to communicate. *First hop* is a reference to the default router being the first router, or first router hop, through which a packet must pass.

So how does a redundancy protocol accomplish this? The protocols I'm going to describe to you do this basically by presenting a virtual router to all of the clients. The virtual router has its own IP and MAC addresses. The virtual IP address is the address that's configured on each of the host machines as the default gateway. The virtual MAC address is the address that will be returned when an ARP request is sent by a host. The hosts don't know or care which physical router is actually forwarding the traffic, as you can see in Figure 10.11.

FIGURE 10.11 FHRPs use a virtual router with a virtual IP address and virtual MAC address.



It's the responsibility of the redundancy protocol to decide which physical router will actively forward traffic and which one will be placed in standby in case the active router fails. Even if the active router fails, the transition to the standby router will be transparent to the hosts because the virtual router, identified by the virtual IP and MAC addresses, is now used by the standby router. The hosts never change default gateway information, so traffic keeps flowing.

NOTE

Fault-tolerant solutions provide continued operation in the event of a device failure, and load-balancing solutions distribute the workload over multiple devices.

Next we'll explore these two important redundancy protocols:

Hot Standby Router Protocol (HSRP) This is by far Cisco's favorite protocol ever! Don't buy just one router; buy up to eight routers to provide the same service, and keep seven as backup in case of failure! HSRP is a Cisco proprietary protocol that provides a redundant gateway for hosts on a local subnet, but this isn't a load-balanced solution. HSRP allows you to configure two or more routers into a standby group that shares an IP address and MAC address and provides a default gateway. When the IP and MAC addresses are independent from the routers' physical addresses (on a virtual interface, not tied to a specific interface), they can swap control of an address if the current forwarding and active router fails. But there is actually a way you can sort of achieve load balancing with HSRP—by using multiple VLANs and designating a specific router for one VLAN, then an alternate router as active for VLAN via trunking.

Virtual Router Redundancy Protocol (VRRP) This also provides a redundant—but again, not load-balanced—gateway for hosts on a local subnet. It's an open standard protocol that functions almost identically to HSRP. I'll comb through the fine differences that exist between these protocols.

Hot Standby Router Protocol (HSRP)

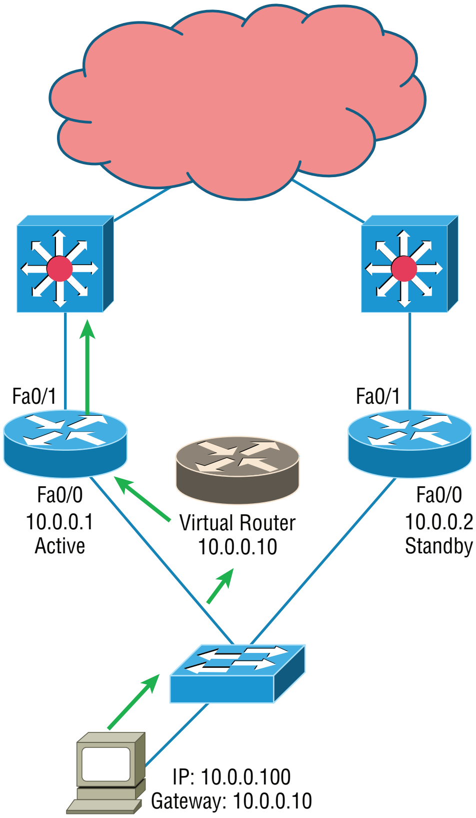
Again, HSRP is a Cisco proprietary protocol that can be run on most, but not all, of Cisco's router and multilayer switch models. It defines a standby group, and each standby group that you define includes the following routers:

- Active router
- Standby router
- Virtual router
- Any other routers that may be attached to the subnet

The problem with HSRP is that with it, only one router is active and two or more routers just sit there in standby mode and won't be used unless a failure occurs—not very cost effective or efficient! Figure 10.12 shows how only one router is used at a time in an HSRP group.

The standby group will always have at least two routers participating in it. The primary players in the group are the one active router and one standby router that communicate to each other using multicast Hello messages. The Hello messages provide all of the required communication for the routers. The Hellos contain the information required to accomplish the election that determines the active and standby router positions. They also hold the key to the failover process. If the standby router stops receiving hello packets from the active router, it then takes over the active router role, as shown in Figure 10.13.

FIGURE 10.12 HSRP active and standby routers



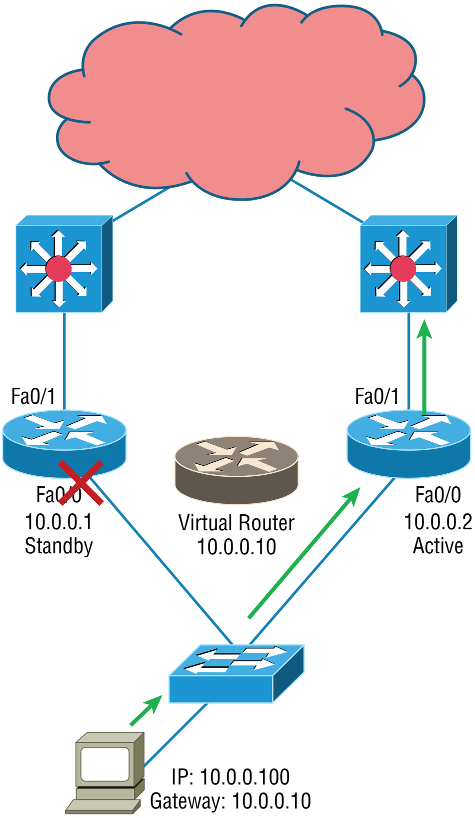
As soon as the active router stops responding to Hellos, the standby router automatically becomes the active router and starts responding to host requests.

Virtual MAC Address

A virtual router in an HSRP group has a virtual IP address and a virtual MAC address. So where does that virtual MAC come from? The virtual IP address isn't that hard to figure out; it just has to be a unique IP address on the same subnet as the hosts defined in the configuration. But MAC addresses are a little different, right? Or are they? The answer is yes—sort of. With HSRP, you create a totally new, made-up MAC address in addition to the IP address.

The HSRP MAC address has only one variable piece in it. The first 24 bits still identify the vendor who manufactured the device (the organizationally unique identifier, or OUI). The next 16 bits in the address tells us that the MAC address is a well-known HSRP MAC address. Finally, the last 8 bits of the address are the hexadecimal representation of the HSRP group number.

FIGURE 10.13 Example of HSRP active and standby routers swapping interfaces



Let me clarify all this with an example of what an HSRP MAC address would look like:

```
0000.0c07.ac0a
```

- The first 24 bits (0000.0c) are the vendor ID of the address; in the case of HSRP being a Cisco protocol, the ID is assigned to Cisco.
- The next 16 bits (07.ac) are the well-known HSRP ID. This part of the address was assigned by Cisco in the protocol, so it's always easy to recognize that this address is for use with HSRP.
- The last 8 bits (0a) are the only variable bits and represent the HSRP group number that you assign. In this case, the group number is 10 and converted to hexadecimal when placed in the MAC address, where it becomes the 0a that you see.

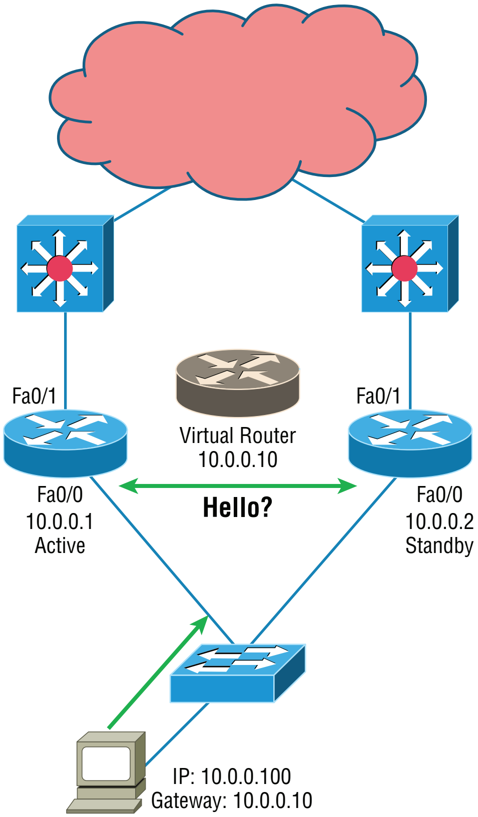
You can see this MAC address added to the ARP cache of every router in the HSRP group. There will be the translation from the IP address to the MAC address as well as the interface on which it's located.

HSRP Timers

Before we get deeper into the roles that each of the routers can have in an HSRP group, I want to define the HSRP timers. The timers are very important to HSRP function because they ensure communication between the routers, and if something goes wrong, they allow the standby router to take over. The HSRP timers include *hello*, *hold*, *active*, and *standby*.

Hello Timer The hello timer is the defined interval during which each of the routers send out Hello messages. Their default interval is 3 seconds, and they identify the state that each router is in. This is important because the particular state determines the specific role of each router and, as a result, the actions each will take within the group. Figure 10.14 shows the Hello messages being sent, and the router uses the hello timer to keep network traffic flowing in case of a failure.

FIGURE 10.14 HSRP Hellos



This timer can be changed, and people used to avoid doing so because it was thought that lowering the hello value would place an unnecessary load on the routers. That isn't true with most of the routers today; in fact, you can configure the timers in milliseconds, meaning the failover time can be in milliseconds! Still, keep in mind that increasing the value will make the standby router wait longer before taking over for the active router when it fails or can't communicate.

Hold Timer The hold timer specifies the interval the standby router uses to determine whether the active router is offline or out of communication. By default, the hold timer is 10 seconds, roughly three times the default for the hello timer. If one timer is changed for some reason, I recommend using this multiplier to adjust the other timers too. By setting the hold timer at three times the hello timer, you ensure that the standby router doesn't take over the active role every time there's a short break in communication.

Active Timer The active timer monitors the state of the active router. The timer resets each time a router in the standby group receives a hello packet from the active router. This timer expires based on the hold time value that's set in the corresponding field of the HSRP Hello message.

Standby Timer The standby timer is used to monitor the state of the standby router. The timer resets anytime a router in the standby group receives a hello packet from the standby router and expires based on the hold time value that's set in the respective hello packet.

Real World Scenario

Large Enterprise Network Outages with FHRPs

Years ago when HSRP was all the rage, and before VRRP, enterprises used hundreds of HSRP groups. With the hello timer set to 3 seconds and a hold time of 10 seconds, these timers worked just fine and we had great redundancy with our core routers.

However, as we've seen in the last few years, and will certainly see in the future, 10 seconds is now a lifetime! Some of my customers have been complaining with the failover time and loss of connectivity to their virtual server farms.

So lately I've been changing the timers to well below the defaults. Cisco had changed the timers so you could use sub-second times for failover. Because these are multicast packets, the overhead that is seen on a current high-speed network is almost nothing.

The hello timer is typically set to 200 msec and the hold time is 700 msec. The command is as follows:

```
(config-if)#Standby 1 timers msec 200 msec 700
```

This almost ensures that not even a single packet is lost when there is an outage.

Virtual Router Redundancy Protocol

Like HSRP, Virtual Router Redundancy Protocol (VRRP) allows a group of routers to form a single virtual router. In an HSRP or VRRP group, one router is elected to handle all requests sent to the virtual IP address. With HSRP, this is the active router. An HSRP group has only one active router, at least one standby router, and many listening routers. A VRRP group has one master router and one or more backup routers and is the open standard implementation of HSRP.

Comparing VRRP and HSRP

The LAN workstations are configured with the address of the virtual router as their default gateway, just as they are with HSRP, but VRRP differs from HSRP in these important ways:

- VRRP is an IEEE standard (RFC 2338) for router redundancy; HSRP is a Cisco proprietary protocol.
- The virtual router that represents a group of routers is known as a VRRP group.
- The active router is referred to as the master virtual router.
- The master virtual router may have the same IP address as the virtual router group.
- Multiple routers can function as backup routers.
- VRRP is supported on Ethernet, Fast Ethernet, and Gigabit Ethernet interfaces as well as on Multiprotocol Label Switching (MPLS), virtual private networks (VPNs), and VLANs.

VRRP Redundancy Characteristics

VRRP has some unique features:

- VRRP provides redundancy for the real IP address of a router or for a virtual IP address shared among the VRRP group members.
- If a real IP address is used, the router with that address becomes the master.
- If a virtual IP address is used, the master is the router with the highest priority.
- A VRRP group has one master router and one or more backup routers.
- The master router uses VRRP messages to inform group members of its status.
- VRRP allows load sharing across more than one virtual router.

Advanced IPv6 Concepts

Before we jump into the coverage of IPv6 routing protocols, we need to discuss some of the operations that are performed differently in IPv6 than in IPv4 and that includes several operations that are radically different. We'll also discuss in the following sections some of the methods that have been developed over the past few years to ease the pain of transitioning to an IPv6 environment from one that is IPv4.

Router Advertisement

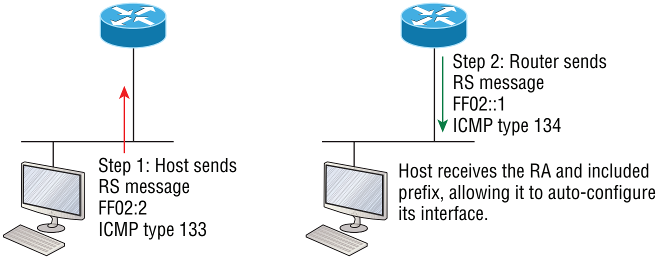
A router advertisement is part of a new system configuration option in IPv6. This a packet sent by routers to give the host a network ID (called a prefix in IPv6) so that the host can generate its own IPv6 address derived from its MAC address.

To perform auto-configuration, a host goes through a basic three-step process:

1. First, the host needs the prefix information, similar to the network portion of an IPv4 address, to configure its interface, so it sends a router solicitation (RS) request for it. This RS is then sent out as a multicast to all routers (FF02::2). The actual information being sent is a type of ICMP message, and like everything in networking, this ICMP message has a number that identifies it. The RS message is ICMP type 133.
2. The router answers back with the required prefix information via a router advertisement (RA). An RA message also happens to be a multicast packet that's sent to the all-nodes multicast address (FF02::1) and is ICMP type 134. RA messages are sent on a periodic basis, but the host sends the RS for an immediate response so it doesn't have to wait until the next scheduled RA to get what it needs.
3. Upon receipt, the host will generate an IPv6 address. The exact process used (stateless or stateful auto-configuration or by DHCPv6) is determined by instructions within the RA.

The first two steps are shown in Figure 10.15.

FIGURE 10.15 First two steps to IPv6 auto-configuration

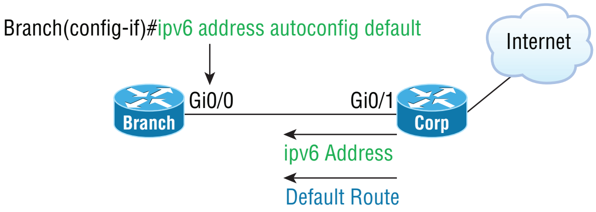


By the way, when the host generates an IPV6 address using the prefix and its MAC address the process is called stateless auto-configuration because it doesn't contact or connect to and receive any further information from the other device.

Take a look at Figure 10.16. In this figure, the Branch router needs to be configured, but I just don't feel like typing in an IPv6 address on the interface connecting to the Corp router. I also don't feel like typing in any routing commands, but I need more than a link-local address on that interface, so I'm going to have to do something! So basically, I want to have the Branch router work with IPv6 on the internetwork with the least amount of effort from me. Let's see if I can get away with that.

Aha—there is an easy way! I love IPv6 because it allows me to be relatively lazy when dealing with some parts of my network, yet it still works really well. When I use the command `ipv6 address autoconfig`, the interface will listen for RAs and then, via the EUI-64 format, it will assign itself a global address—sweet!

FIGURE 10.16 IPv6 auto-configuration example



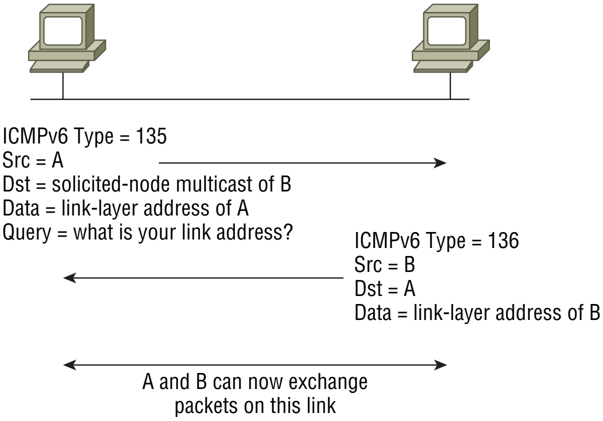
Neighbor Discovery

One of the big changes in IPv6 is the discontinuation of the use of all broadcasts, including the ARP broadcast. Devices use a new process to send to one another within a subnet. They send to one another's *link-local address* rather than the MAC addresses. Even devices that have been assigned an IPv6 address manually will still generate a link-local address. These addresses are generated using the MAC address as is done in stateless auto-configuration; the prefix is *not* learned from the router. A link-local address always adopts a prefix of FE80::/64.

That means that rather than needing to learn a MAC address to send locally, the host needs to learn the link-local addresses of all of the other hosts in its subnet. This is done using a process called neighbor discovery. This is done using neighbor solicitation messages and neighbor advertisement messages. These are both sent to IPv6 multicast addresses that have been standardized for this process.

Neighbor solicitation messages are sent on the local link when a host needs the link-layer address of another node (see Figure 10.17). The source address in a neighbor solicitation message is the IPv6 address of the node sending the neighbor solicitation message. The destination address in the neighbor solicitation message is the solicited-node multicast address that corresponds to the IPv6 address of the destination node. The neighbor solicitation message also includes the link-layer address of the source node.

FIGURE 10.17 IPv6 neighbor discovery: neighbor solicitation message


ICMPv6 Type = 135
Src = A
Dst = solicited-node multicast of B
Data = link-layer address of A
Query = what is your link address?
ICMPv6 Type = 136
Src = B
Dst = A
Data = link-layer address of B
A and B can now exchange
packets on this link

The destination node replies by sending a neighbor advertisement message, which has a value of 136 in the Type field of the ICMP packet header, on the local link. The data portion of the neighbor advertisement message includes the link-layer address of the node sending the neighbor advertisement message. After the source node receives the neighbor advertisement, the source node and destination node can communicate.

Tunneling

When tunneling is used as a transition mechanism to IPv6, it involves encapsulating one type of protocol in another type of protocol for the purpose of transmitting it across a network that supports the packet type or protocol. At the tunnel endpoint, the packet is deencapsulated and the contents are then processed in its native form.

Overlay tunneling encapsulates IPv6 packets in IPv4 packets for delivery across an IPv4 network. Overlay tunnels can be configured between border routers or between a border router and a host capable of supporting both IPv6 and IPv4. Cisco IOS supports the following tunnel types:

- Manual
- Routing encapsulation (GRE)
- 6to4
- ISATAP

Some of the more significant methods are covered in the following sections.

GRE Tunnels

Although not used as an IPv6 transition mechanism, Generic Routing Encapsulation (GRE) tunnels are worth discussing while talking about tunneling. GRE is a general-purpose encapsulation that allows for transporting packets from one network through another network through a VPN. One of its benefits is its ability to use a routing protocol. It also can carry non-IP traffic, and when implemented as a GRE over IPsec tunnel, it supports encryption. When this type of tunnel is built, the GRE encapsulation will occur before the IPSec encryption process. One key thing to keep in mind is that the tunnel interfaces on either end must be in the same subnet.

6to4 Tunneling

6to4 tunneling is super useful for carrying IPv6 data over a network that is still IPv4. In some cases, you will have IPv6 subnets or portions of your network that are all IPv6, and those networks will have to communicate with each other. This could happen over a WAN or some other network that you do not control. So how do we fix this problem? By creating a tunnel that will carry the IPv6 traffic for you across the IPv4 network. Now having a tunnel is not that hard, and it isn't difficult to understand. It is really taking the IPv6 packet that would normally be traveling across the network, grabbing it up, and placing an IPv4 header on the front of it that specifies an IPv4 protocol type of 41.

When you're configuring either a manual or automatic tunnel (covered in the next two sections), three key pieces must be configured:

- The tunnel mode
- The IPv4 tunnel source
- A 6to4 IPv6 address that lies within 2002 ::/16

Manual IPv6 Tunneling

In order to make this happen we are going to have a couple of dual-stacked routers. We just have to add a little configuration to place a tunnel between the routers. Tunnels are very simple. We just have to tell each router where the tunnel is starting and where it has to end up. Let's take a look. The following configuration creates what is known as a manual IPv6 tunnel.

```
Router1(config)#int tunnel 0
Router1(config-if)#ipv6 address 2001:db8:1:1::1/64
Router1(config-if)#tunnel source 192.168.30.1
Router1(config-if)#tunnel destination 192.168.40.1
Router1(config-if)#tunnel mode ipv6ip
```

```
Router2(config)#int tunnel 0
Router2(config-if)#ipv6 address 2001:db8:2:2::1/64
Router2(config-if)#tunnel source 192.168.40.1
Router2(config-if)#tunnel destination 192.168.30.1
Router2(config-if)#tunnel mode ipv6ip
```

This will allow our IPv6 networks to communicate over the IPv4 network. Now this is not meant to be a permanent configuration. The end goal should be to have an all-IPv6 network end to end.

6to4 (Automatic)

The following configuration uses what is known as automatic 6to4 tunneling. This allows for the endpoints to auto-configure an IPv6 address where a site-specific /48 bit prefix is dynamically constructed by prepending the prefix 2002 to an IPv4 address assigned to the site. This means the first 2 bytes of the IPv6 address will be 0x2002 and the next 4 bytes will be the hexadecimal equivalent of the IPv4 address. Therefore, in this case 192.168.99.1 translates to 2002:c0a8:6301:: /48. Tunnel interface 0 is configured without an IPv4 or IPv6 address because the IPv4 or IPv6 addresses on Ethernet interface 0 are used to construct a tunnel source address. A tunnel destination address is not specified because the destination address is automatically constructed. It is also possible for each tunnel to have multiple destinations, which is not possible when creating a manual IPv6 tunnel.

```
Router(config)# interface ethernet 0
Router(config-if)# ip address 192.168.99.1 255.255.255.0
Router(config-if)# ipv6 address 2002:c0a8:6301::/48 eui-64
Router(config-if)# exit
Router(config)# interface tunnel 0
Router(config-if)# no ip address
Router(config-if)# ipv6 unnumbered ethernet 0
Router(config-if)# tunnel source ethernet 0
Router(config-if)# tunnel mode ipv6ip 6to4
Router(config-if)# exit
```

When using automatic 6to4 tunnels, in many cases you will need to reference the tunnel endpoint when creating the neighbor statement (for example, in BGP). When doing so, you can refer to the auto-configured address in the preceding example in three ways in the neighbor command.

```
:: c0a8:6301
:: 192.168.99.1
0:0:0:0:0:0:192.168.99.1
```

To configure a static route to a network that needs to cross a 6to4 tunnel, use the `ipv6 route` command. When you do so, the least significant 32 bits of the address referenced by the command will correspond to the IPv4 address assigned to the tunnel source. For example, in the following command, the final 32 bits will be the IPv4 address of the tunnel 0 interface.

```
Ipv6 route 2002::/16 tunnel 0
```

ISATAP Tunneling

Intra-Site Automatic Tunnel Addressing Protocol is another mechanism for transmitting IPv6 packets over an IPv4 network. The word *automatic* means that once an ISATAP server/router has been set up, only the clients must be configured to connect to it. A sample configuration is shown here.

```
R1(config)#ipv6 unicast-routing
R1(config)#interface tunnel 1
R1(config-if)# tunnel source ethernet 0
R1(config-if)# tunnel mode ipv6ip isatap
R1(config-if)#  ipv6 address 2001:DB8::/64 eui-64
```

One other thing that maybe noteworthy: if the IPv4 network that you are traversing in this situation has a NAT translation point, it will break the tunnel encapsulation that we have created. In the following section, a solution is discussed.

Teredo

Teredo gives full IPv6 connectivity for IPv6 hosts that are on an IPv4 network but have no direct native connection to an IPv6 network. Its distinguishing feature is that it is able to perform its function even from behind Network Address Translation (NAT) devices such as home routers.

The Teredo protocol performs several functions:

- Diagnoses UDP over IPv4 (UDPv4) connectivity and discovers the kind of NAT present (using a simplified replacement to the STUN protocol)
- Assigns a globally routable unique IPv6 address to each host
- Encapsulates IPv6 packets inside UDPv4 datagrams for transmission over an IPv4 network (this includes NAT traversal)
- Routes traffic between Teredo hosts and native (or otherwise non-Teredo) IPv6 hosts

There are several components that can make up the Teredo infrastructure:

Teredo Client A host that has IPv4 connectivity to the Internet from behind a NAT device and uses the Teredo tunneling protocol to access the IPv6 Internet.

Teredo Server A well-known host that is used for initial configuration of a Teredo.

Teredo Relay The remote end of a Teredo tunnel. A Teredo relay must forward all of the data on behalf of the Teredo clients it serves, with the exception of direct Teredo client to Teredo client exchanges.

Teredo Host-Specific Relay A Teredo relay whose range of service is limited to the very host it runs on.

Dual Stack

This is the most common type of migration strategy. It allows the devices to communicate using either IPv4 or IPv6. This technique allows for one-by-one upgrade of applications and devices on the network. As more and more things on the network are upgraded, more of your communication will occur over IPv6. Eventually all devices and software will be upgraded and the IPv4 protocol stacks can be removed. The configuration of dual stacking on a Cisco router is very easy. It requires nothing more than enabling IPv6 forwarding and applying an address to the interfaces that are already configured with IPv4. It will look something like this.

```
Corp(config)#ipv6 unicast-routing
Corp(config)#interface fastethernet 0/0
Corp(config-if)#ipv6 address 2001:db8:3c4d:1::/64 eui-64
Corp(config-if)#ip address 192.168.255.1 255.255.255.0
```

IPv6 Routing Protocols

Most of the routing protocols we’ve already discussed have been upgraded for use in IPv6 networks. Also, many of the functions and configurations that we’ve already learned will be used in almost the same way as they’re used now. Knowing that broadcasts have been eliminated in IPv6, it follows that any protocols that use entirely broadcast traffic will go the way of the dodo—but unlike the dodo, it'll be good to say good-bye to these bandwidth-hogging, performance-annihilating little gremlins!

The routing protocols that we'll still use in version 6 got a new name and a facelift. Let's talk about a few of them now.

First on the list is RIPng (next generation). Those of you who have been in IT for a while know that RIP has worked very well for us on smaller networks, which happens to be the reason it didn't get whacked and will still be around in IPv6. And we still have EIGRPv6 because it already had protocol-dependent modules and all we had to do was add a new one to it for the IPv6 protocol. Rounding out our group of protocol survivors is OSPFv3—that's not a typo; it really is version 3. OSPF for IPv4 was actually version 2, so when it got its upgrade to IPv6, it became OSPFv3.

RIPng

To be honest, the primary features of RIPng are the same as they were with RIPv2. It is still a distance vector protocol, has a max hop count of 15, and still has the same loop avoidance mechanisms as well as using UDP port 521.

And it still uses multicast to send its updates, too, but in IPv6, it uses FF02::9 for the transport address. This is actually kind of cool because in RIPv2, the multicast address was 224.0.0.9, so the address still has a 9 at the end in the new IPv6 multicast range. In fact, most routing protocols got to keep a little bit of their IPv4 identities like that.

But of course there are differences in the new version or it wouldn't be a new version, would it? We know that routers keep the next-hop addresses of their neighbor routers for every destination network in their routing table. The difference is that with RIPng, the router keeps track of this next-hop address using the link-local address, not a global address. So just remember that RIPng will pretty much work the same way as with IPv4.

EIGRPv6

As with RIPng, EIGRPv6 works much the same as its IPv4 predecessor does—most of the features that EIGRP provided before EIGRPv6 will still be available.

EIGRPv6 is still an advanced distance vector protocol that has some link state features. The neighbor-discovery process using Hellos still happens, and it still provides reliable communication with a reliable transport protocol that gives us loop-free fast convergence using DUAL.

Hello packets and updates are sent using multicast transmission, and as with RIPng, EIGRPv6's multicast address stayed almost the same. In IPv4 it was 224.0.0.10; in IPv6, it's FF02::A (A = 10 in hexadecimal notation).

Last to check out in our group is what OSPF looks like in the IPv6 routing protocol.

OSPFv3

The new version of OSPF continues the trend of the routing protocols having many similarities with their IPv4 versions.

The foundation of OSPF remains the same—it is still a link state routing protocol that divides an entire internetwork or autonomous system into areas, making a hierarchy.

Adjacencies (neighbor routers running OSPF) and next-hop attributes now use link-local addresses, and OSPFv3 still uses multicast traffic to send its updates and acknowledgments, with the addresses FF02::5 for OSPF routers and FF02::6 for OSPF-designated routers, which provide topological updates (route information) to other routers. These new addresses are the replacements for 224.0.0.5 and 224.0.0.6, respectively, which were used in OSPFv2.

With all this routing information behind you, it's time to go through some review questions and then move on to learning all about switching in the next chapter.

NOTE

Shortest Path Bridging (SPB), specified in the IEEE 802.1aq standard, is a computer networking technology intended to simplify the creation and configuration of networks and replace the older 802.1d/802.1w protocols while enabling multipath routing

Summary

This chapter covered the basic routing protocols that you may find on a network today. Probably the most common routing protocols you'll run into are RIP, OSPF, and EIGRP.

I covered RIP, RIPv2, and the differences between the two RIP protocols as well as EIGRP, and BGP in the section on distance vector protocols. We also covered IPv6 routing protocols and some advanced IPv6 operations, including transitional mechanisms such as dual stacking and tunneling.

I finished by discussing OSPF and IS-IS and when you would possibly see each one in a network.

Exam Essentials

Remember the differences between RIPv1 and RIPv2. RIPv1 sends broadcasts every 30 seconds and has an AD of 120. RIPv2 sends multicasts (224.0.0.9) every 30 seconds and also has an AD of 120. RIPv2 sends subnet mask information with the route updates, which allows it to support classless networks and discontiguous networks. RIPv2 also supports authentication between routers, and RIPv1 does not.

Compare OSPF and RIPv1. OSPF is a link state protocol that supports VLSM and classless routing; RIPv1 is a distance vector protocol that does not support VLSM and supports only classful routing.

Written Lab

You can find the answers to the written labs in Appendix A.

1. The default administrative distance of RIP is ____________.
2. The default administrative distance of EIGRP is ____________.
3. The default administrative distance of RIPv2 is ____________.
4. What is the default administrative distance of a static route?
5. What is the version or name of RIP that is used with IPv6?
6. What is the version or name of OSPF that is used with IPv6?
7. What is the version or name of EIGRP that is used with IPv6?
8. When would you use BGP?
9. When could you use EIGRP?
10. Is BGP considered link state or distance vector routing protocol?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following protocols support VLSM, summarization, and discontiguous networking? (Choose three.)
   - **A.** RIPv1
   - **B.** IGRP
   - **C.** EIGRP
   - **D.** OSPF
   - **E.** BGP
   - **F.** RIPv2
2. Which of the following are considered distance vector routing protocols? (Choose two.)
   - **A.** OSPF
   - **B.** RIP
   - **C.** RIPv2
   - **D.** IS-IS
3. Which of the following are considered link state routing protocols? (Choose two.)
   - **A.** OSPF
   - **B.** RIP
   - **C.** RIPv2
   - **D.** IS-IS
4. Which of the following is considered a hybrid routing protocol? (Choose two.)
   - **A.** OSPF
   - **B.** BGP
   - **C.** RIPv2
   - **D.** IS-IS
   - **E.** EIGRP
5. Why would you want to use a dynamic routing protocol instead of using static routes?
   - **A.** There is less overhead on the router.
   - **B.** Dynamic routing is more secure.
   - **C.** Dynamic routing scales to larger networks.
   - **D.** The network runs faster.

6. Which of the following is a vendor-specific FHRP protocol?

   A. STP

   B. OSPF

   C. RIPv1

   D. EIGRP

   E. IS-IS

   F. HSRP

7. RIP has a long convergence time and users have been complaining of response time when a router goes down and RIP has to reconverge. Which can you implement to improve convergence time on the network?

   A. Replace RIP with static routes.

   B. Update RIP to RIPv2.

   C. Update RIP to OSPF using link state.

   D. Replace RIP with BGP as an exterior gateway protocol.

8. What is the administrative distance of OSPF?

   A. 90

   B. 100

   C. 110

   D. 120

9. Which of the following protocols will advertise routed IPv6 networks?

   A. RIP

   B. RIPng

   C. OSPFv2

   D. EIGRPv3

10. What is the difference between static and dynamic routing?

    A. You use static routing in large, scalable networks.

    B. Dynamic routing is used by a DNS server.

    C. Dynamic routes are added automatically.

    D. Static routes are added automatically.

11. Which routing protocol has a maximum hop count of 15?

    A. RIPv1

    B. IGRP

    C. EIGRP

    D. OSPF

12. Which of the following describes routing convergence time?

A. The time it takes for your VPN to connect

B. The time required by protocols to update their forwarding tables after changes have occurred

C. The time required for IDS to detect an attack

D. The time required by switches to update their link status and go into forwarding state

13. What routing protocol is typically used to connect ASs on the Internet?

A. IGRP

B. RIPv2

C. BGP

D. OSPF

14. RIPv2 sends out its routing table every 30 seconds just like RIPv1, but it does so more efficiently. What type of transmission does RIPv2 use to accomplish this task?

A. Broadcasts

B. Multicasts

C. Telecast

D. None of the above

15. Which routing protocols have an administrative distance of 120? (Choose two.)

A. RIPv1

B. RIPv2

C. EIGRP

D. OSPF

16. Which of the following routing protocols uses AS-Path as one of the methods to build the routing tables?

A. OSPF

B. IS-IS

C. BGP

D. RIP

E. EIGRP

17. Which IPv6 routing protocol uses UDP port 521?

A. RIPng

B. EIGRPv6

C. OSPFv3

D. IS-IS

18. What EIGRP information is held in RAM and maintained through the usage of hello and update packets? (Select all that apply.)

A. DUAL table

B. Neighbor table

C. Topology table

D. Successor route

19. Which is true regarding EIGRP successor routes?

A. Successor routes are saved in the neighbor table.

B. Successor routes are stored in the DUAL table.

C. Successor routes are used only if the primary route fails.

D. A successor route is used by EIGRP to forward traffic to a destination.

20. Which of the following uses only hop count as a metric to find the best path to a remote network?

A. RIP

B. EIGRP

C. OSPF

D. BGP

Switching and Virtual LANs

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Properties of network traffic
  - Broadcast domains
  - Collision domains
- Segmentation and interface properties
  - VLANs
  - Trunking (802.1Q)
  - Tagging and untagging ports
  - Port mirroring
  - Switching loops/spanning tree
  - PoE and PoE+ (802.3af, 802.3at)
  - MAC address table
- Distributed switching

✓ **2.2 Given a scenario, determine the appropriate placement of networking devices on a network and install/configure them**

- Switch
- Bridge

✓ **3.2 Compare and contrast business continuity and disaster recovery concepts.**

- Port aggregation

✓ **4.2 Explain authentication and access controls**

- Port security
- MAC filtering

✓ **4.6 Explain common mitigation techniques and their purposes**

- Change native VLAN
- Switch port protection
  - Spanning tree
  - Flood guard
  - BPDU guard
  - Root guard
  - DHCP snooping
- Network segmentation
  - VLAN

✓ **5.3 Given a scenario, troubleshoot common wired connectivity and performance issues**

- Duplex/speed mismatch
- VLAN mismatch

Layer 2 switching is the process of using the hardware addresses of devices on a LAN to segment a network. Because you've got the basic ideas down, I'm now going to focus on the more in-depth particulars of Layer 2 switching and how it works.

You already know that switching breaks up large collision domains into smaller ones and that a collision domain is a network segment with two or more devices sharing the same bandwidth. A hub network is a typical example of this type of technology. But because each port on a switch is actually its own collision domain, you can create a much better Ethernet LAN by simply replacing your hubs with switches!

Switches truly have changed the way networks are designed and implemented. If a pure switched design is properly implemented, it will result in a clean, cost-effective, and resilient internetwork. In this chapter, we'll survey and compare how networks were designed before and after switching technologies were introduced.

Routing protocols like RIP, which you learned about in Chapter 10, employ processes for preventing network loops from occurring at the Network layer. This is all good, but if you have redundant physical links between your switches, routing protocols won't do a thing to stop loops from occurring at the Data Link layer. That's exactly the reason Spanning Tree Protocol was developed—to put a stop to loops taking place within a Layer 2 switched network. The essentials of this vital protocol, as well as how it works within a switched network, are some of the important subjects that we'll cover thoroughly in this chapter.

And to finish up this chapter, you're going to learn exactly what a VLAN is and how VLAN memberships are used in a switched network as well as how trunking is used to send information from all VLANs across a single link. Good stuff!

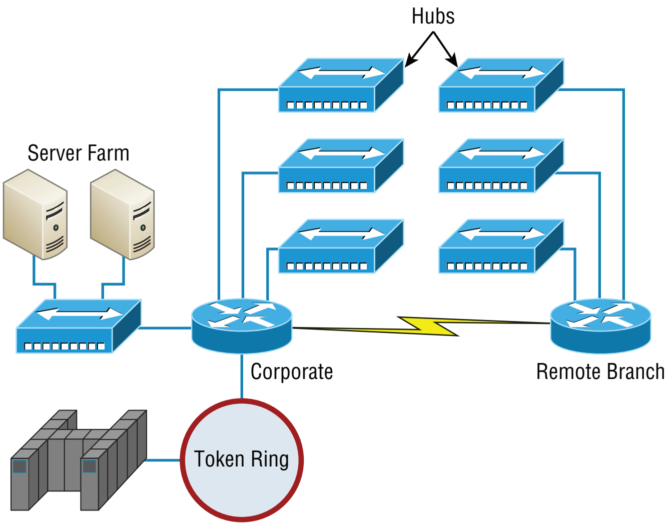
NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Networking Before Layer 2 Switching

Because knowing the history of something really helps with understanding why things are the way they are today, I'm going to go back in time a bit and talk about the condition of networks before switches and the part switches have played in the evolution of corporate

LANs by helping to segment them. For a visual of how a typical network design looked before LAN switching, check out the network in Figure 11.1.

FIGURE 11.1 A network before switching



The design in Figure 11.1 was called a *collapsed backbone* because all the hosts involved had to go to the corporate backbone in order to reach any network services—both LAN and mainframe.

Going back even further, before networks like the one shown in Figure 11.1 had physical segmentation devices such as routers and hubs, there was the mainframe network. This type of network comprised mainframe controllers made by IBM, Honeywell, Sperry, DEC, and so on and dumb terminals that connected into the controller(s). Any remote sites were connected to the mainframe with bridges.

And then the PC began its rise to stardom, and the mainframe was connected to an Ethernet or Token Ring LAN where the servers were installed. These servers were usually OS/2 or LAN Manager because this was "pre-NT." Each floor of a building ran either coax or twisted-pair wiring to the corporate backbone, which was then connected to a router. PCs ran an emulating software program that allowed them to connect to mainframe services, giving those PCs the ability to access services from the mainframe and LAN simultaneously. Eventually, the PC became robust enough to allow application developers to port applications more effectively than they ever could before—an advance that markedly reduced networking prices and enabled businesses to grow at a much faster rate.

Moving forward to when Novell rose to popularity in the late 1980s and early 1990s, OS/2 and LAN Manager servers were by and large replaced with NetWare servers. This made the Ethernet network even more popular because that's what Novell 3.*x* servers used to communicate with client-server software.

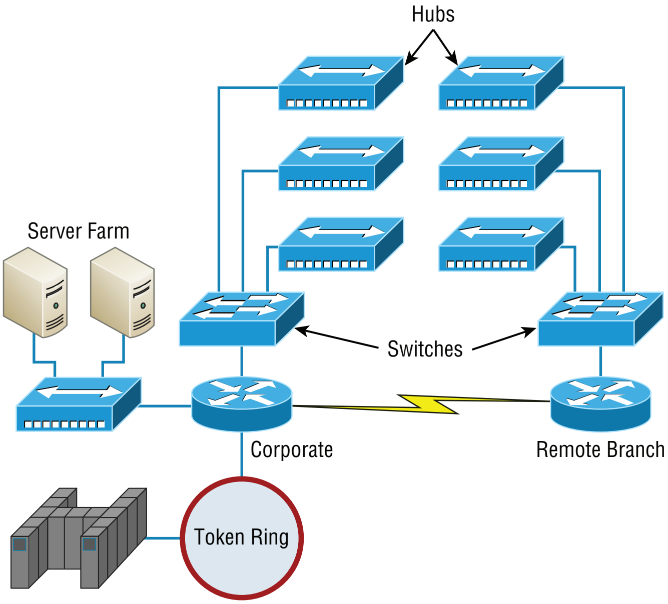
So basically, that's the story about how the network in Figure 11.1 came into being. But soon a big problem arose with this configuration. As the corporate backbone grew and grew, network services became slower and slower. A big reason for this was that at the same time this huge burst in growth was taking place, LAN services began to require even faster response times. This resulted in networks becoming totally saturated and overwhelmed. Everyone was dumping the dumb terminals used to access mainframe services in favor of those slick new PCs so they could more easily connect to the corporate backbone and network services.

And all this was taking place before the Internet's momentous popularity, so everyone in the company needed to access the corporate network's own, internal services. Without the Internet, all network services were internal, meaning that they were exclusive to the company network. As you can imagine, this situation created a screaming need to segment that single, humongous, and now plodding corporate network, which was connected together with sluggish old routers.

How was this issue addressed? Well, at first, Cisco responded by simply creating faster routers (no doubt about that), but still more segmentation was needed, especially on the Ethernet LANs. The invention of Fast Ethernet was a very good and helpful thing, yet it too fell short of solving that network segmentation need. But devices called *bridges* did provide relief, and they were first used in the networking environment to break up collision domains.

Sounds good, but only so much—bridges were sorely limited by the number of ports and other network services they could provide, and that's when Layer 2 switches came to the rescue. These switches saved the day by breaking up collision domains on each and every port—like a bridge—but switches could provide hundreds of ports! This early, switched LAN looked like the network pictured in Figure 11.2.

FIGURE 11.2 The first switched LAN

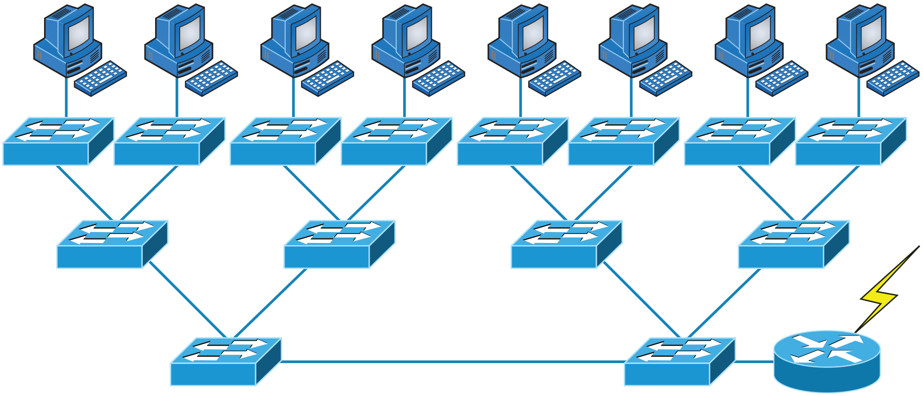


As you can see here, each hub was placed into a switch port—an innovation that vastly improved the network. So now, instead of each building being crammed into the same collision domain, each hub became its own separate collision domain. Yet still, as is too often the case, there was a catch—switch ports were still very new and, therefore, super expensive. Because switches were so cost prohibitive, simply adding a switch into each floor of the building just wasn't going to happen—at least, not yet. But thanks to whomever you choose to thank for these things, the switch price tag has dropped dramatically; now, having every one of your users plugged into a switch port is a really good solution, and cost effective too!

So there it is—if you're going to create a network design and implement it, including switching services is a must.

A typical, contemporary, and complete switched network design/implementation would look something like Figure 11.3.

FIGURE 11.3 The typical switched network design



"But wait—there's still a router in there!" you say. Yes, it's not a mirage—there *is* a router in there. But its job has changed quite a bit. Instead of performing physical segmentation, it now creates and handles logical segmentation. Those logical segments are called VLANs, and no worries, I promise to explain them thoroughly throughout the rest of this chapter.

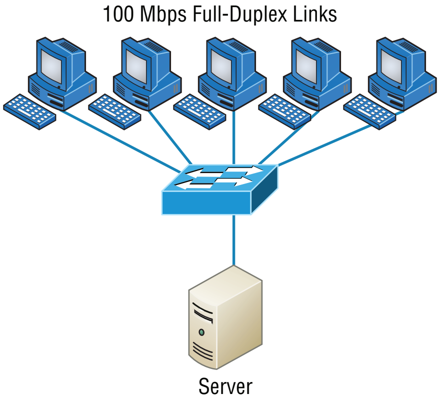
Switching Services

Bridges use software to create and manage a filter table, but switches use *application-specific integrated circuits (ASICs)* to accomplish this. Even so, it's still okay to think of a Layer 2 switch as a multiport bridge because their basic reason for being is the same: to break up collision domains.

Layer 2 switches and bridges are faster than routers because they don't take up time looking at the Network layer header information. Instead, they look at the frame's hardware addresses before deciding to forward, flood, or drop the frame.

Switches create private, dedicated collision domains and provide independent bandwidth on each port, unlike hubs. Figure 11.4 shows five hosts connected to a switch—all running 100 Mbps full duplex to the server. Unlike with a hub, each host has full-duplex, 100 Mbps of dedicated communication to the server.

FIGURE 11.4 Switches create private domains.



Layer 2 switching provides the following benefits:

- Hardware-based bridging (ASIC)
- Wire speed
- Low latency
- Low cost

What makes Layer 2 switching so efficient is that no modification to the data packet takes place. The device reads only the frame encapsulating the packet, which makes the switching process considerably faster and less error prone than routing processes.

And if you use Layer 2 switching for both workgroup connectivity and network segmentation (breaking up collision domains), you can create a flatter network design with more network segments than you can with traditional routed networks.

Plus, Layer 2 switching increases bandwidth for each user because, again, each connection (interface) into the switch is its own collision domain. This feature makes it possible for you to connect multiple devices to each interface—very cool.

Coming up, we'll dive deeper into the Layer 2 switching technology.

Limitations of Layer 2 Switching

Because people usually toss Layer 2 switching into the same category as bridged networks, we also tend to think it has the same hang-ups and issues that bridged networks do. Keep in mind that bridges are good and helpful things if we design the network correctly, keeping our devices' features as well as their limitations in mind. To end up with a solid design that includes bridges, there are two really important things to consider:

- You absolutely have to break up the collision domains properly.
- A well-oiled, functional bridged network is one whose users spend 80 percent of their time on the local segment.

So, bridged networks break up collision domains, but remember, that network is really still just one big broadcast domain. Neither Layer 2 switches nor bridges break up broadcast domains by default—something that not only limits your network's size and growth potential but can also reduce its overall performance!

Broadcasts and multicasts, along with the slow convergence time of spanning trees, can give you some major grief as your network grows. These are the big reasons Layer 2 switches and bridges just can't completely replace routers (Layer 3 devices) in the internetwork.

Bridging vs. LAN Switching

It's true—Layer 2 switches really are pretty much just bridges that give us a lot more ports. But the comparison doesn't end there. Here's a list of some significant differences and similarities between bridges and switches that you need to keep in mind:

- Bridges are software based, whereas switches are hardware based because they use ASIC chips to help make filtering decisions.
- A switch can be viewed as a multiport bridge.
- There can be only one spanning-tree instance per bridge, whereas switches can have many. (I'm going to tell you all about spanning trees in a bit.)
- Switches have a higher number of ports than most bridges.
- Both bridges and switches forward Layer 2 broadcasts.
- Bridges and switches learn MAC addresses by examining the source address of each frame received.
- Both bridges and switches make forwarding decisions based on Layer 2 addresses.

Three Switch Functions at Layer 2

There are three distinct functions of Layer 2 switching—you need to know these! They are as follows:

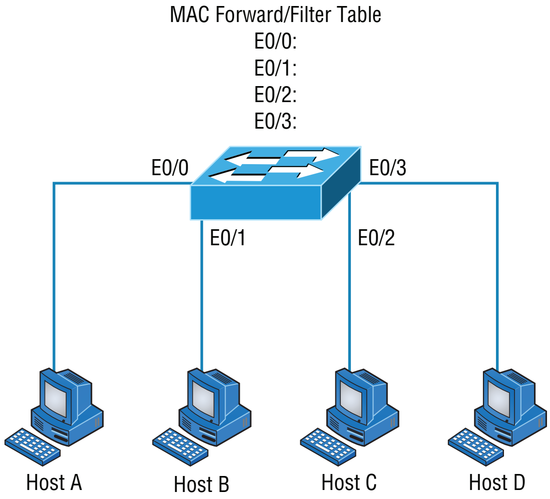
- Address learning
- Forward/filter decisions
- Loop avoidance

The next three sections cover these functions in detail.

Address Learning

Layer 2 switches and bridges are capable of *address learning*; that is, they remember the source hardware address of each frame received on an interface and enter this information into a MAC database known as a *forward/filter table*. But first things first—when a switch is initially powered on, the MAC forward/filter table is empty, as shown in Figure 11.5.

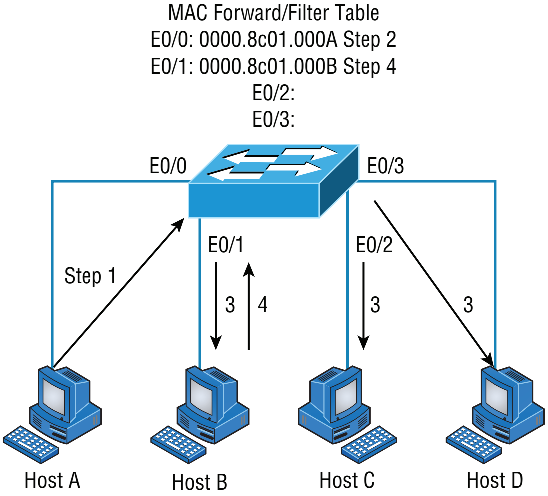
FIGURE 11.5 Empty forward/filter table on a switch



When a device transmits and an interface receives a frame, the switch places the frame's source address in the MAC forward/filter table, which allows it to remember the interface on which the sending device is located. The switch then has no choice but to flood the network with this frame out of every port except the source port because it has no idea where the destination device is actually located.

If a device answers this flooded frame and sends a frame back, then the switch will take the source address from that frame and place that MAC address in its database as well, thereby associating the newly discovered address with the interface that received the frame. Because the switch now has both of the relevant MAC addresses in its filtering table, the two devices can make a point-to-point connection. The switch doesn't need to flood the frame as it did the first time because now the frames can and will be forwarded only between the two devices recorded in the table. This is exactly the thing that makes Layer 2 switches better than hubs, because in a hub network, all frames are forwarded out all ports every time—no matter what. This is because hubs just aren't equipped to collect, store, and draw upon data in a table as a switch is. Figure 11.6 shows the processes involved in building a MAC database.

FIGURE 11.6 How switches learn hosts' locations



In this figure, you can see four hosts attached to a switch. When the switch is powered on, it has nothing in its MAC address forward/filter table (just as in Figure 11.5). But when the hosts start communicating, the switch places the source hardware address of each frame in the table along with the port that the frame's address corresponds to.

Let me give you a step-by-step example of how a forward/filter table becomes populated:

1. Host A sends a frame to Host B. Host A's MAC address is 0000.8c01.000A, and Host B's MAC address is 0000.8c01.000B.
2. The switch receives the frame on the E0/0 interface and places the source address in the MAC address table, associating it with the port it came in on.
3. Because the destination address is not in the MAC database, the frame is forwarded (*flooded*) out all interfaces—except the source port.
4. Host B receives the frame and responds to Host A. The switch receives this frame on interface E0/1 and places the source hardware address in the MAC database, associating it with the port it came in on.
5. Host A and Host B can now make a point-to-point connection, and only the two devices will receive the frames. Hosts C and D will not see the frames, nor are their MAC addresses found in the database, because they haven't yet sent a frame to the switch.

Oh, by the way, it's important to know that if Host A and Host B don't communicate to the switch again within a certain amount of time, the switch will flush their entries from the database to keep it as current as possible.

Forward/Filter Decisions

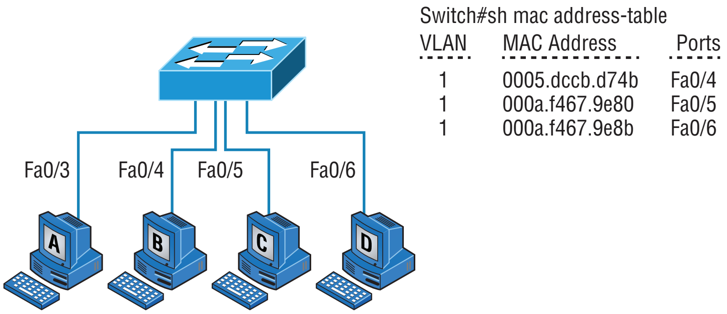
When a frame arrives at a switch interface, the destination hardware address is compared to the forward/filter MAC database and the switch makes a *forward/filter decision*. In other words, if the destination hardware address is known (listed in the database), the frame is only sent out the specified exit interface. The switch will not transmit the frame out any interface except the destination interface. Not transmitting the frame preserves bandwidth on the other network segments and is called *frame filtering*.

But as I mentioned earlier, if the destination hardware address isn't listed in the MAC database, then the frame is flooded out all active interfaces except the interface on which the frame was received. If a device answers the flooded frame, the MAC database is updated with the device's location—its particular interface.

So by default, if a host or server sends a broadcast on the LAN, the switch will flood the frame out all active ports except the source port. Remember, the switch creates smaller collision domains, but it's still one large broadcast domain by default.

In Figure 11.7, you can see Host A sending a data frame to Host D. What will the switch do when it receives the frame from Host A?

FIGURE 11.7 Forward/filter table



```
Switch#sh mac address-table
VLAN   MAC Address      Ports
------ ---------------- ------
  1    0005.dccb.d74b   Fa0/4
  1    000a.f467.9e80   Fa0/5
  1    000a.f467.9e8b   Fa0/6
```

If you answered that because Host A's MAC address is not in the forward/filter table, the switch will add the source address and port to the MAC address table and then forward the frame to Host D, you're halfway there. If you also came back with, "If Host D's MAC address was not in the forward/filter table, the switch would have flooded the frame out all ports except for port Fa0/3," then congratulations—you nailed it!

Let's take a look at the output of a `show mac address-table` command as seen from a Cisco Catalyst switch (the MAC address table works pretty much exactly the same on all brands of switches):

```
Switch#sh mac address-table
Vlan    Mac Address       Type        Ports
----    --------------    -------     -----
   1    0005.dccb.d74b    DYNAMIC     Fa0/1
   1    000a.f467.9e80    DYNAMIC     Fa0/3
   1    000a.f467.9e8b    DYNAMIC     Fa0/4
```

```
1    000a.f467.9e8c    DYNAMIC     Fa0/3
1    0010.7b7f.c2b0    DYNAMIC     Fa0/3
1    0030.80dc.460b    DYNAMIC     Fa0/3
1    0030.9492.a5dd    DYNAMIC     Fa0/1
1    00d0.58ad.05f4    DYNAMIC     Fa0/1
```

Now suppose the preceding switch received a frame with the following MAC addresses:

Source MAC: **0005.dccb.d74b**

Destination MAC: **000a.f467.9e8c**

How will the switch handle this frame? The right answer is that the destination MAC address will be found in the MAC address table and the frame will be forwarded out Fa0/3 only. Remember that if the destination MAC address is not found in the forward/filter table, it will forward the frame out all ports of the switch looking for the destination device.

Now that you can see the MAC address table and how switches add hosts' addresses to the forward filter table, how do you stop switching loops if you have multiple links between switches? Let's talk about this possible problem in more detail.

Loop Avoidance

Redundant links between switches can be a wise thing to implement because they help prevent complete network failures in the event that one link stops working.

But it seems like there's always a downside—even though redundant links can be extremely helpful, they often cause more problems than they solve. This is because frames can be flooded down all redundant links simultaneously, creating network loops as well as other evils. Here are a few of the problems you can be faced with:

- If no loop avoidance schemes are put in place, the switches will flood broadcasts endlessly throughout the internetwork. This is sometimes referred to as a broadcast storm. (In real life, it's often referred to in less-polite ways that we're not permitted to repeat in print!) Figure 11.8 illustrates how a broadcast can be propagated throughout the network. Pay special attention to how a frame is continually being flooded through the internetwork's physical network media. One way to test the loop avoidance operations of your switch network is to plug one end of a cable into one port and the other end of the same cable into another port. If loop avoidance is not operational, this should cause a big broadcast storm!
- What you see in Figure 11.8 is that a device can receive multiple copies of the same frame because that frame can arrive from different segments at the same time. Figure 11.9 demonstrates how a whole bunch of frames can arrive from multiple segments simultaneously. The server in the figure sends a unicast frame to another device connected to Segment 1. Because it's a unicast frame, Switch A receives and forwards the frame, and Switch B provides the same service—it forwards the unicast. This is bad because it means that the destination device on Segment 1 receives that unicast frame twice, causing additional overhead on the network.

FIGURE 11.8 Broadcast storm

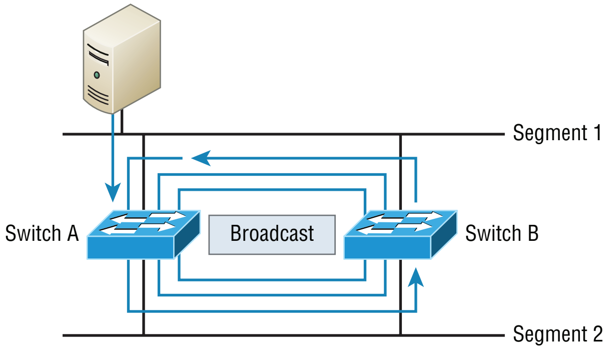
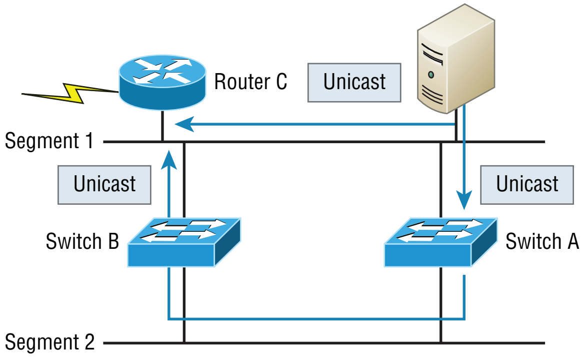


FIGURE 11.9 Multiple frame copies



- You may have thought of this one: The MAC address filter table could be totally confused about the device's location because the switch can receive the frame from more than one link. Worse, the bewildered switch could get so caught up in constantly updating the MAC filter table with source hardware address locations that it might fail to forward a frame! This is called *thrashing* the MAC table.
- One of the nastiest things that can happen is having multiple loops propagating throughout a network. This means you end up with loops occurring within other loops, and if a broadcast storm happened at the same time, the network wouldn't be able to perform frame switching at all—it's toast!

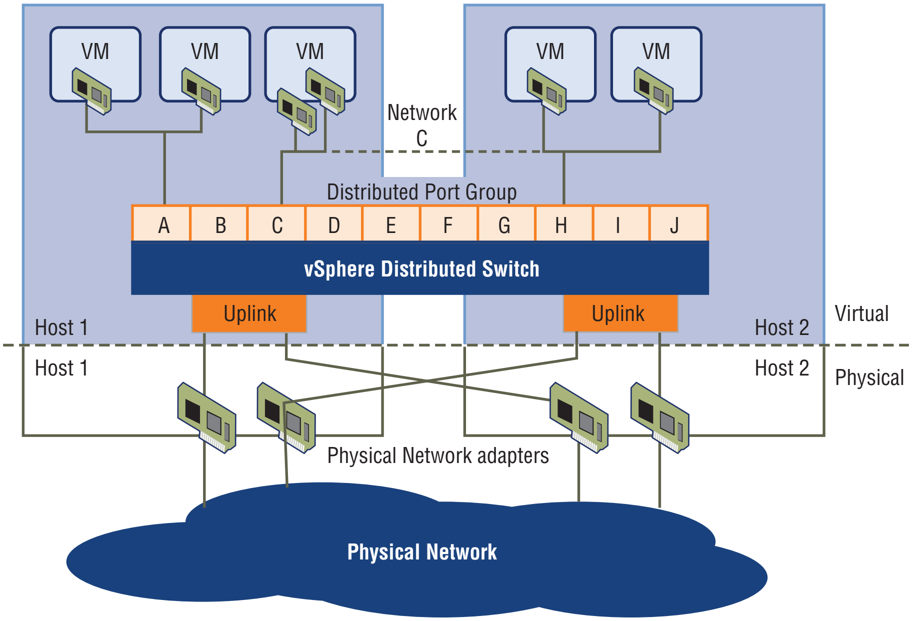
All of these problems spell disaster (or something like it) and are decidedly ugly situations that just must be avoided or at least fixed somehow. That's where the Spanning Tree Protocol comes into the game. It was developed to solve each and every one of the problems I just told you about.

Distributed Switching

In a virtual environment such as you might find in many of today's data centers, not only are virtual servers used in the place of physical servers, but virtual switches (software based) are used to provide connectivity between the virtual systems. These virtual servers reside on physical devices that are called hosts. The virtual switches can be connected to a physical switch to enable access to the virtual servers from the outside world.

One of the unique features of these virtual switches is the ability of the switches to span multiple physical hosts. When this is done, the switch is called a distributed switch. This provides connectivity between virtual servers that are located on different hosts, as shown in Figure 11.10.

FIGURE 11.10 Distributed switching



Spanning Tree Protocol

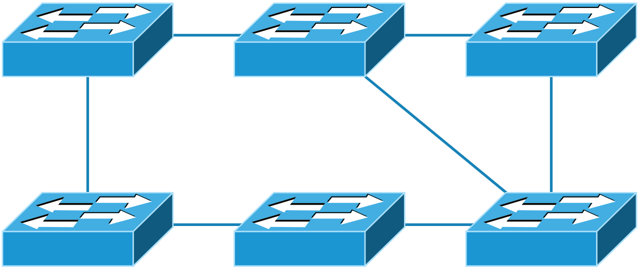
Once upon a time, a company called Digital Equipment Corporation (DEC) was purchased and renamed Compaq. But before that happened, DEC created the original version of *Spanning Tree Protocol (STP)*. The IEEE later created its own version of STP called 802.1D. Yet again, it's not all clear skies—by default, most switches run the IEEE 802.1D version of STP, which isn't compatible with the DEC version. The good news is that there is a new industry standard called 802.1w, which is faster but not enabled by default on any switches.

To begin with, STP's main task is to stop network loops from occurring on your Layer 2 network (bridges or switches). It achieves this feat by vigilantly monitoring the network to find all links and making sure that no loops occur by shutting down any redundant ones. STP uses the *spanning-tree algorithm (STA)* to first create a topology database and then search out and destroy redundant links. With STP running, frames will be forwarded only on the premium, STP-picked links. Switches transmit Bridge Protocol Data Units (BPDUs) out all ports so that all links between switches can be found.

NOTE STP is a Layer 2 protocol that is used to maintain a loop-free switched network.

STP is necessary in networks such as the one shown in Figure 11.11.

FIGURE 11.11 A switched network with switching loops



In Figure 11.11, you see a switched network with a redundant topology (switching loops). Without some type of Layer 2 mechanism to stop network loops, we would fall victim to the problems I discussed previously: broadcast storms and multiple frame copies.

NOTE Understand that the network in Figure 11.11 would actually sort of work, albeit extremely slowly. This clearly demonstrates the danger of switching loops. And to make matters worse, it can be super hard to find this problem once it starts!

Spanning Tree Port States

The ports on a bridge or switch running STP can transition through five different states:

Blocking A blocked port won't forward frames; it just listens to BPDUs and will drop all other frames. The purpose of the blocking state is to prevent the use of looped paths. All ports are in a blocking state by default when the switch is powered up.

Listening The port listens to BPDUs to make sure no loops occur on the network before passing data frames. A port in listening state prepares to forward data frames without populating the MAC address table.

Learning The switch port listens to BPDUs and learns all the paths in the switched network. A port in learning state populates the MAC address table but doesn't forward data frames. Forward delay is the time it takes to transition a port from listening to learning mode. It's set to 15 seconds by default.

Forwarding The port sends and receives all data frames on the bridged port. If the port is still a designated or root port at the end of the learning state, it enters the forwarding state.

Disabled A port in the disabled state (administratively) does not participate in the frame forwarding or STP. A port in the disabled state is virtually nonoperational.

NOTE Switches populate the MAC address table in learning and forwarding modes only.

Switch ports are usually in either the blocking or forwarding state. A forwarding port is one that has been determined to have the lowest (best) cost to the root bridge. But when and if the network experiences a topology change because of a failed link or when someone adds a new switch into the mix, you'll find the ports on a switch in the listening and learning states.

As I mentioned, blocking ports is a strategy for preventing network loops. Once a switch determines the best path to the root bridge, all other redundant ports will be in blocking mode. Blocked ports can still receive BPDUs—they just don't send out any frames.

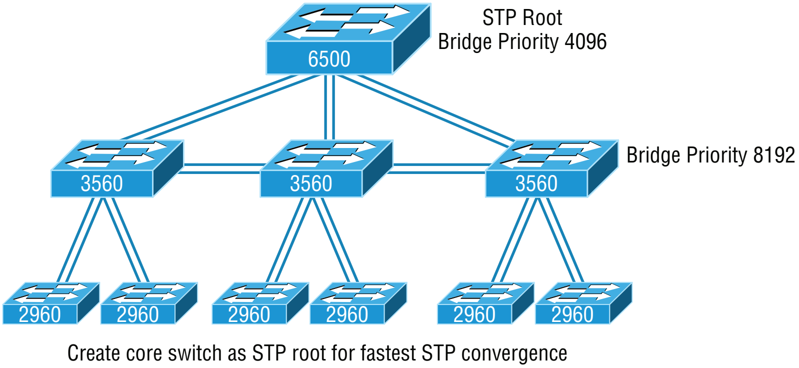
If a switch determines that a blocked port should now be the designated, or root, port, say because of a topology change, the port will respond by going into listening mode and check all the BPDUs it receives to ensure that it won't create a loop once the port goes back into forwarding mode.

STP Convergence

Convergence is what happens when all the ports on bridges and switches have transitioned to either forwarding or blocking modes. During this phase, no data will be forwarded until the convergence event is complete. Plus, before data can begin being forwarded again, all devices must be updated. Yes—you read that right: When STP is converging, all host data stops transmitting! So if you want to remain on speaking terms with your network's users (or remain employed for any length of time), you positively must make sure that your switched network is physically designed really well so that STP can converge quickly and painlessly.

Figure 11.12 demonstrates a really great way to design and implement your switched network so that STP converges efficiently.

FIGURE 11.12 An optimal hierarchical switch design



Convergence is truly important because it ensures that all devices are in either the forwarding mode or the blocking mode. But as I've drilled into you, it does cost you some time. It usually takes 50 seconds to go from blocking to forwarding mode, and I don't recommend changing the default STP timers. (You can adjust those timers if you really have to.) By creating your physical switch design in a hierarchical manner, as shown in Figure 11.12, you can make your core switch the STP root. This makes everyone happy because it makes STP convergence happen fast.

Because the typical spanning-tree topology's time to convergence from blocking to forwarding on a switch port is 50 seconds, it can create time-out problems on your servers or hosts—like when you reboot them. To address this hitch, you can disable spanning tree on individual ports.

Rapid Spanning Tree Protocol 802.1w

How would you like to have a good STP configuration running on your switched network (regardless of the brand of switches) but instead of taking 50 seconds to converge, the switched network can converge in about 5 seconds, or maybe even less. How does that sound? Absolutely—yes, we want this! Well then, welcome to the world of *Rapid Spanning Tree Protocol (RSTP)*.

RSTP was not designed to be a "brand-new" protocol but more of an evolution of the 802.1D standard, with faster convergence time when a topology change occurs. Backward compatibility was a must when 802.1w was created.

The 802.1w is defined in these different port states (compared to 802.1D):

- Disabled = discarding
- Blocking = discarding
- Listening = discarding
- Learning = learning
- Forwarding = forwarding

To verify the spanning-tree type running on your Cisco switch, use the following command:

```
S1#sh spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     000d.29bd.4b80
             Cost        3012
             Port        56 (Port-channel1)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    49153  (priority 49152 sys-id-ext 1)
             Address     001b.2b55.7500
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 15
  Uplinkfast enabled
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------
Fa0/3            Desg FWD 3100      128.3    Edge Shr
Fa0/4            Desg FWD 3019      128.4    Edge P2p
Fa0/8            Desg FWD 3019      128.8    P2p
Po1              Root FWD 3012      128.56   P2p
```

Since the type output shows `Spanning tree enabled protocol ieee`, we know we are running the 802.1D protocol. If the output shows RSTP, then you know your switch is running the 802.1w protocol.

Virtual LANs

I know I keep telling you this, but I've got to be sure you never forget it, so here I go one last time: By default, switches break up collision domains and routers break up broadcast domains. Okay, I feel better! Now we can move on.

In contrast to the networks of yesterday, which were based on collapsed backbones, today's network design is characterized by a flatter architecture—thanks to switches. So now what? How do we break up broadcast domains in a pure switched internetwork? By creating a virtual local area network (VLAN), that's how!

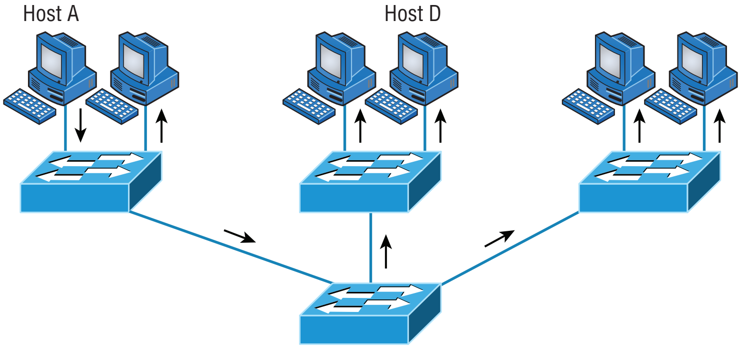
A VLAN is a logical grouping of network users and resources connected to administratively defined ports on a switch. When you create VLANs, you gain the ability to create smaller broadcast domains within a Layer 2 switched internetwork by assigning the various ports on the switch to different subnetworks. A VLAN is treated like its own subnet or broadcast domain, meaning that frames broadcasted onto the network are only switched between the ports logically grouped within the same VLAN.

So, does this mean we no longer need routers? Maybe yes, maybe no—it really depends on what your specific goals and needs are. By default, hosts in a specific VLAN can't communicate with hosts that are members of another VLAN, so if you want inter-VLAN communication, the answer is yes, you still need a router.

VLAN Basics

Figure 11.13 shows how Layer 2 switched networks are typically designed—as flat networks. With this configuration, every broadcast packet transmitted is seen by every device on the network regardless of whether the device needs to receive that data or not.

FIGURE 11.13 Flat network structure

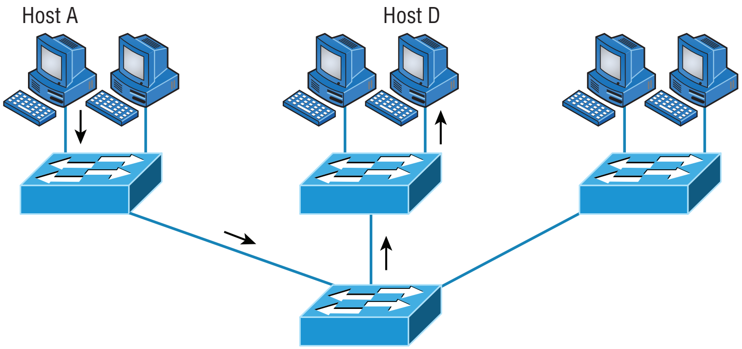


By default, routers allow broadcasts to occur only within the originating network, whereas switches forward broadcasts to all segments. Oh, and by the way, the reason it's called a *flat network* is because it's one *broadcast domain*, not because the actual design is physically flat. In Figure 11.13, you can see Host A sending out a broadcast and all ports on all switches forwarding it—all except each port that receives it.

Now check out Figure 11.14. It pictures a switched network and shows Host A sending a frame with Host D as its destination. What's important to get out of this figure is that the frame is forwarded only out of the port where Host D is located. This is a huge improvement over the old hub networks, unless having one collision domain by default is what you really want. (I'm guessing not!)

Okay, you already know that the coolest benefit you gain by having a Layer 2 switched network is that it creates an individual collision domain segment for each device plugged into each port on the switch. But as is often the case, new advances bring new challenges with them. One of the biggest is that the greater the number of users and devices, the more broadcasts and packets each switch must handle.

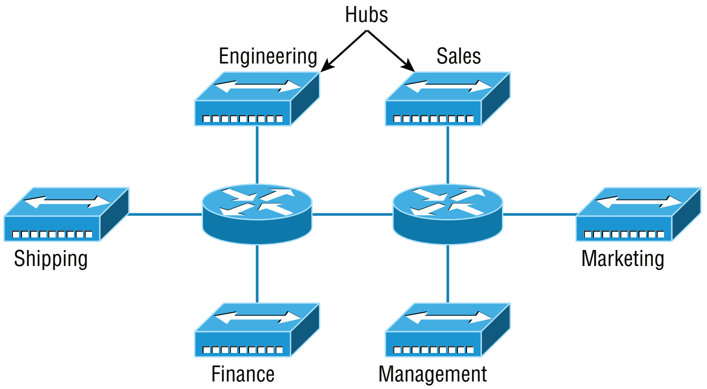
FIGURE 11.14 The benefit of a switched network



And of course, the all-important issue of security and its demands also must be considered—while simultaneously becoming more complicated! VLANs present a security challenge because by default, within the typical Layer 2 switched internetwork, all users can see all devices. And you can't stop devices from broadcasting, plus you can't stop users from trying to respond to broadcasts. This means your security options are dismally limited to placing passwords on your servers and other devices.

To understand how a VLAN looks to a switch, it's helpful to begin by first looking at a traditional network. Figure 11.15 shows how a network used to be created using hubs to connect physical LANs to a router.

FIGURE 11.15 Physical LANs connected to a router



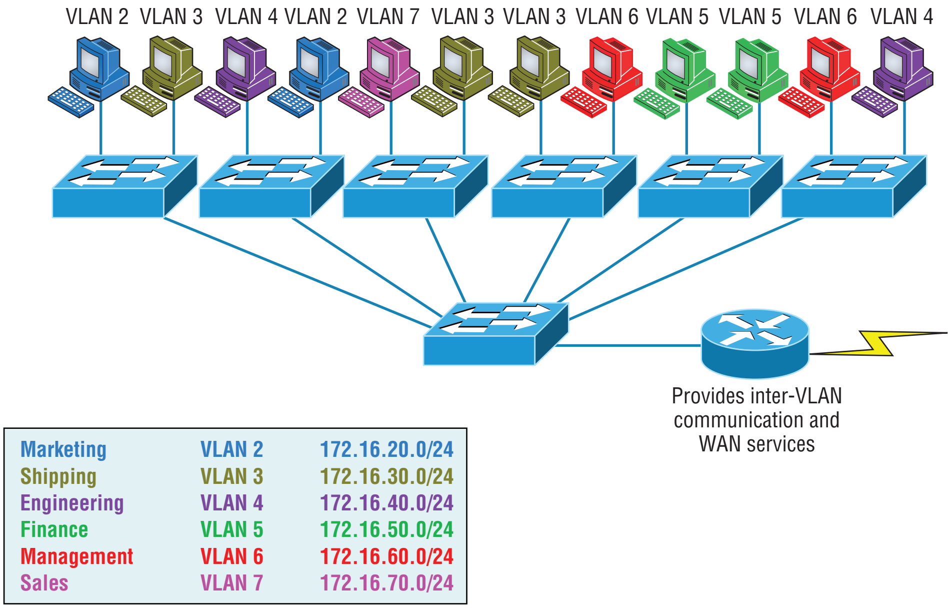
Here you can see that each network is attached with a hub port to the router (each segment also has its own logical network number, even though this isn't obvious looking at the figure). Each host attached to a particular physical network has to match that network's logical network number in order to be able to communicate on the internetwork. Notice that each department has its own LAN, so if we needed to add new users to, let's say, Sales, we would just plug them into the Sales LAN and they would automatically be part of the Sales collision and broadcast domain. This design actually did work well for many years.

But there was one major flaw: What happens if the hub for Sales is full and we need to add another user to the Sales LAN? Or, what do we do if there's no more physical space for a new employee where the Sales team is located? Hmmm, well, let's say there just happens to be plenty of room over in the Finance section of the building. That new Sales team member will just have to sit on the same side of the building as the Finance people, and we'll just plug the poor soul into the hub for Finance. Simple, right?

So wrong! Doing this obviously makes the new user part of the Finance LAN, which is very bad for many reasons. First and foremost, we now have a major security issue. Because the new Sales employee is a member of the Finance broadcast domain, the newbie can see all the same servers and access all network services that the Finance folks can. Second, for this user to access the Sales network services they need to get their job done, they would have to go through the router to log in to the Sales server—not exactly efficient.

Now, let's look at what a switch accomplishes for us. Figure 11.16 demonstrates how switches come to the rescue by removing the physical boundary to solve our problem. It also shows how six VLANs (numbered 2 through 7) are used to create a broadcast domain for each department. Each switch port is then administratively assigned a VLAN membership, depending on the host and which broadcast domain it's placed in.

FIGURE 11.16 Switches removing the physical boundary



Marketing	VLAN 2	172.16.20.0/24
Shipping	VLAN 3	172.16.30.0/24
Engineering	VLAN 4	172.16.40.0/24
Finance	VLAN 5	172.16.50.0/24
Management	VLAN 6	172.16.60.0/24
Sales	VLAN 7	172.16.70.0/24

So now if we needed to add another user to the Sales VLAN (VLAN 7), we could just assign the port to VLAN 7 regardless of where the new Sales team member is physically located—nice! This illustrates one of the sweetest advantages to designing your network with VLANs over the old collapsed backbone design. Now, cleanly and simply, each host that needs to be in the Sales VLAN is merely assigned to VLAN 7.

Notice that I started assigning VLANs with VLAN number 2. The number is irrelevant, but you might be wondering what happened to VLAN 1. Well, that VLAN is an administrative VLAN, and even though it can be used for a workgroup, Cisco recommends that you use it for administrative purposes only. You can't delete or change the name of VLAN 1, and by default, all ports on a switch are members of VLAN 1 until you actually do change them.

Now, because each VLAN is considered a broadcast domain, it's got to also have its own subnet number (refer again to Figure 11.16). And if you're also using IPv6, then each VLAN must also be assigned its own IPv6 network number. So you don't get confused, just keep thinking of VLANs as separate subnets or networks.

Let's get back to that "because of switches, we don't need routers anymore" misconception. When looking at Figure 11.16, you can see that there are seven VLANs, or broadcast domains, counting VLAN 1 (not shown in the figure). The hosts within each VLAN can communicate with each other but not with anything in a different VLAN because the hosts in any given VLAN "think" that they're actually in a collapsed backbone, illustrated in Figure 11.15.

So what handy little device do you think we need to enable the hosts in Figure 11.16 to communicate to a host or hosts on a different VLAN? You guessed it—a router! Those hosts absolutely need to go through a router, or some other Layer 3 device, just as they do when they're configured for internetwork communication (as shown in Figure 11.15). It works the same way it would if we were trying to connect different physical networks. Communication between VLANs must go through a Layer 3 device. So don't expect mass router extinction anytime soon!

Quality of Service

Before we dive in further into VLANs, I want to make sure that you have a fundamental understanding of QoS and why it is important. Chapter 20, "Management, Monitoring, and Optimization," will provide more detail on QoS.

Quality of Service (QoS) refers to the way the resources are controlled so that the quality of services is maintained. It's basically the ability to provide a different priority for one or more types of traffic over other levels; priority is applied to different applications, data flows, or users so that they can be guaranteed a certain performance level.

QoS methods focus on one of five problems that can affect data as it traverses network cable:

- Delay
- Dropped packets
- Error
- Jitter
- Out-of-order delivery

QoS can ensure that applications with a required bit rate receive the necessary bandwidth to work properly. Clearly, on networks with excess bandwidth, this is not a factor, but the more limited your bandwidth is, the more important a concept like this becomes.

NOTE To provide inter-VLAN communication (communication between VLANs), you need to use a router or a Layer 3 switch.

VLAN Memberships

Most of the time, VLANs are created by a system administrator who proceeds to assign switch ports to each one. VLANs of this type are known as *static VLANs*. If you don't mind doing a little more work when you begin this process, assign all the host devices' hardware addresses into a database so your switches can be configured to assign VLANs dynamically anytime you plug a host into a switch. I hate saying things like "obviously," but obviously, this type of VLAN is known as a *dynamic VLAN*. I'll be covering both static and dynamic VLANs next.

Static VLANs

Creating static VLANs is the most common way to create a VLAN, and one of the reasons for that is because static VLANs are the most secure. This security stems from the fact that any switch port you've assigned a VLAN association to will always maintain it unless you change the port assignment manually.

Static VLAN configuration is pretty easy to set up and supervise, and it works really well in a networking environment where any user movement within the network needs to be controlled. It can be helpful to use network management software to configure the ports, but you don't have to use it if you don't want to.

In Figure 11.16, each switch port was configured manually with a VLAN membership based on which VLAN the host needed to be a member of—remember, the device's actual physical location doesn't matter one bit as long as the VLAN assignments are correctly configured. Which broadcast domain your hosts become members of is purely up to you. And again, remember that each host also has to have the correct IP address information. For instance, you must configure each host in VLAN 2 into the 172.16.20.0/24 network for it to become a member of that VLAN. It's also a good idea to keep in mind that if you plug a host into a switch, you have to verify the VLAN membership of that port. If the membership is different than what's needed for that host, the host won't be able to gain access to the network services that it needs, such as a workgroup server.

NOTE Static access ports are either manually assigned to a VLAN or assigned through a RADIUS server for use with IEEE 802.1X.

Dynamic VLANs

On the other hand, a dynamic VLAN determines a host's VLAN assignment automatically. Using intelligent management software, you can base VLAN assignments on hardware (MAC) addresses, protocols, or even applications that work to create dynamic VLANs.

For example, let's say MAC addresses have been entered into a centralized VLAN management application and you hook up a new host. If you attach it to an unassigned switch port, the VLAN management database can look up the hardware address and both assign and configure the switch port into the correct VLAN. Needless to say, this makes management and configuration much easier because if a user moves, the switch will simply assign them to the correct VLAN automatically. But here again, there's a catch—initially, you've got to do a lot more work setting up the database. It can be very worthwhile, though!

And here's some more good news: You can use the VLAN Management Policy Server (VMPS) service to set up a database of MAC addresses to be used for the dynamic addressing of your VLANs. The VMPS database automatically maps MAC addresses to VLANs.

Identifying VLANs

Know that switch ports are Layer 2–only interfaces that are associated with a physical port. A switch port can belong to only one VLAN if it is an access port or all VLANs if it is a trunk port, as I'll explain in a minute. You can manually configure a port as an access or trunk port, or you can let the Dynamic Trunking Protocol (DTP) operate on a per-port basis to set the switch port mode. DTP does this by negotiating with the port on the other end of the link.

Switches are definitely pretty busy devices. As frames are switched throughout the network, they've got to be able to keep track of all the different port types plus understand what to do with them depending on the hardware address. And remember—frames are handled differently according to the type of link they're traversing.

There are two different types of links in a switched environment: access ports and trunk ports.

Access Ports

An access port belongs to and carries the traffic of only one VLAN. Anything arriving on an access port is simply assumed to belong to the VLAN assigned to the port. Any device attached to an *access link* is unaware of a VLAN membership—the device just assumes it's part of the same broadcast domain, but it doesn't have the big picture, so it doesn't understand the physical network topology at all.

Another good thing to know is that switches remove any VLAN information from the frame before it's forwarded out to an access-link device. Remember that access-link devices can't communicate with devices outside their VLAN unless the packet is routed. And you can only create a switch port to be either an access port or a trunk port—not both. So you've got to choose one or the other, and know that if you make it an access port, that port can be assigned to one VLAN only.

Voice Access Ports

Not to confuse you, but all that I just said about the fact that an access port can be assigned to only one VLAN is really only sort of true. Nowadays, most switches will allow you to add a second VLAN to an access port on a switch port for your voice traffic; it's called the voice VLAN. The voice VLAN used to be called the auxiliary VLAN, which allowed it to be overlaid on top of the data VLAN, enabling both types of traffic through the same port. Even though this is technically considered to be a different type of link, it's still just an access port that can be configured for both data and voice VLANs. This allows you to connect both a phone and a PC device to one switch port but still have each device in a separate VLAN. If you are configuring voice VLANs, you'll want to configure Quality of Service (QoS) on the switch ports to provide a higher precedence to voice traffic over data traffic to improve sound quality.

NOTE

Suppose you plug a host into a switch port and users are unable to access any server resources. The two typical reasons this happens is because the port is configured in the wrong VLAN membership or STP has shut down the port because STP thought there was possibly a loop.

Trunk Ports

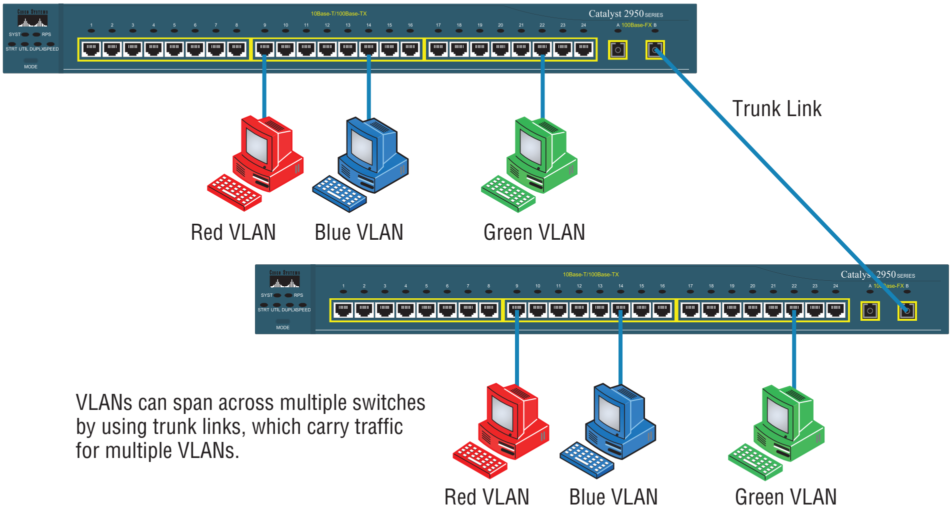
Believe it or not, the term *trunk port* was inspired by the telephone system trunks that carry multiple telephone conversations at a time. So it follows that trunk ports can similarly carry multiple VLANs at a time.

A *trunk link* is a 100 Mbps or 1000 Mbps point-to-point link between two switches, between a switch and router, or even between a switch and server, and it carries the traffic of multiple VLANs—from 1 to 4,094 VLANs at a time.

Trunking can be a real advantage because with it, you get to make a single port part of a whole bunch of different VLANs at the same time. This is a great feature because you can actually set ports up to have a server in two separate broadcast domains simultaneously so your users won't have to cross a Layer 3 device (router) to log in and access it. Another benefit of trunking comes into play when you're connecting switches. Information from multiple VLANs can be carried across trunk links, but by default, if the links between your switches aren't trunked, only information from the configured VLAN will be switched across that link.

Check out Figure 11.17. It shows how the different links are used in a switched network. All hosts connected to the switches can communicate to all ports in their VLAN because of the trunk link between them. Remember, if we used an access link between the switches, this would allow only one VLAN to communicate between switches. As you can see, these hosts are using access links to connect to the switch, so they're communicating in one VLAN only. That means that without a router, no host can communicate outside its own VLAN, but the hosts can send data over trunked links to hosts on another switch configured in their same VLAN.

FIGURE 11.17 Access and trunk links in a switched network



VLANs can span across multiple switches by using trunk links, which carry traffic for multiple VLANs.

It's finally time to tell you about the VLAN identification methods.

VLAN Identification Methods

VLAN identification is what switches use to keep track of all those frames as they're traversing a switch fabric. All of our hosts connect together via a switch fabric in our switched network topology. It's how switches identify which frames belong to which VLANs, and there's more than one trunking method: ISL and 802.1Q.

Inter-Switch Link (ISL)

Inter-Switch Link (ISL) is a way of explicitly tagging VLAN information onto an Ethernet frame. This tagging information allows VLANs to be multiplexed over a trunk link through an external encapsulation method (ISL), which allows the switch to identify the VLAN membership of a frame over the trunked link.

By running ISL, you can interconnect multiple switches and still maintain VLAN information as traffic travels between switches on trunk links. ISL functions at Layer 2 by encapsulating a data frame with a new header and cyclic redundancy check (CRC).

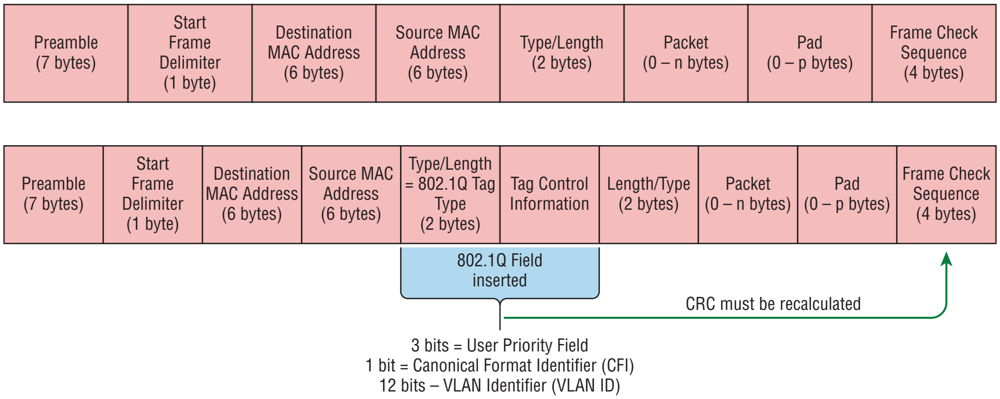
Of note is that this is proprietary to Cisco switches, and it's used for Fast Ethernet and Gigabit Ethernet links only. *ISL routing* is pretty versatile and can be used on a switch port, on router interfaces, and on server interface cards to trunk a server.

IEEE 802.1Q

Created by the IEEE as a standard method of frame tagging, IEEE 802.1Q works by inserting a field into the frame to identify the VLAN. This is one of the aspects of 802.1Q that makes it your only option if you want to trunk between a Cisco switched link and another brand of switch. In a mixed environment, you've just got to use 802.1Q for the trunk to work!

Unlike ISL, which encapsulates the frame with control information, 802.1Q inserts an 802.1Q field along with tag control information, as shown in Figure 11.18.

FIGURE 11.18 IEEE 802.1Q encapsulation with and without the 802.1Q tag


Preamble (7 bytes)
Start Frame Delimiter (1 byte)
Destination MAC Address (6 bytes)
Source MAC Address (6 bytes)
Type/Length (2 bytes)
Packet (0 – n bytes)
Pad (0 – p bytes)
Frame Check Sequence (4 bytes)
Preamble (7 bytes)
Start Frame Delimiter (1 byte)
Destination MAC Address (6 bytes)
Source MAC Address (6 bytes)
Type/Length = 802.1Q Tag Type (2 bytes)
Tag Control Information
Length/Type (2 bytes)
Packet (0 – n bytes)
Pad (0 – p bytes)
Frame Check Sequence (4 bytes)
802.1Q Field inserted
CRC must be recalculated
3 bits = User Priority Field
1 bit = Canonical Format Identifier (CFI)
12 bits – VLAN Identifier (VLAN ID)

To meet the exam objectives, it's really the 12-bit VLAN ID that matters, so keep your focus on it. This field identifies the VLAN and can be 2^12 minus 2 for the 0 and 4,095 reserved VLANs, which means an 802.1Q tagged frame can carry information for 4,094 VLANs.

It works like this: You first designate each port that's going to be a trunk with 802.1Q encapsulation. The other ports must be assigned a specific VLAN ID in order for them to communicate. VLAN 1 is the default native VLAN, and when using 802.1Q, all traffic for a native VLAN is *untagged*. The ports that populate the same trunk create a group with this native VLAN, and each port gets tagged with an identification number reflecting that membership. Again the default is VLAN 1. The native VLAN allows the trunks to accept information that was received without any VLAN identification or frame tag.

NOTE

The basic purpose of ISL and 802.1Q frame-tagging methods is to provide inter-switch VLAN communication. Remember that any ISL or 802.1Q frame tagging is removed if a frame is forwarded out an access link—tagging is used internally and across trunk links only!

VLAN Trunking Protocol

The basic goals of *VLAN Trunking Protocol (VTP)* are to manage all configured VLANs across a switched internetwork and to maintain consistency throughout that network. VTP allows you to add, delete, and rename VLANs—and information about those actions is then propagated to all other switches in the VTP domain.

Here's a list of some of the cool features VTP has to offer:

- Consistent VLAN configuration across all switches in the network
- Accurate tracking and monitoring of VLANs
- Dynamic reporting of added VLANs to all switches in the VTP domain
- Adding VLANs using plug-and-play

Very nice, but before you can get VTP to manage your VLANs across the network, you have to create a VTP server (really, you don't need to even do that since all switches default to VTP server mode, but just make sure you have a server). All servers that need to share VLAN information must use the same domain name, and a switch can be in only one domain at a time. So basically, this means that a switch can share VTP domain information with other switches only if they're configured into the same VTP domain. You can use a VTP domain if you have more than one switch connected in a network, but if you've got all your switches in only one VLAN, you just don't need to use VTP. Do keep in mind that VTP information is sent between switches only via a trunk port.

Switches advertise VTP management domain information as well as a configuration revision number and all known VLANs with any specific parameters. But there's also something called *VTP transparent mode*. In it, you can configure switches to forward VTP information through trunk ports but not to accept information updates or update their VTP databases.

If you've got sneaky users adding switches to your VTP domain behind your back, you can include passwords, but don't forget—every switch must be set up with the same password. And as you can imagine, this little snag can be a real hassle administratively!

Switches detect any added VLANs within a VTP advertisement and then prepare to send information on their trunk ports with the newly defined VLAN in tow. Updates are sent out as revision numbers that consist of summary advertisements. Anytime a switch sees a higher revision number, it knows the information it's getting is more current, so it will overwrite the existing VLAN database with the latest information.

You should know these requirements for VTP to communicate VLAN information between switches:

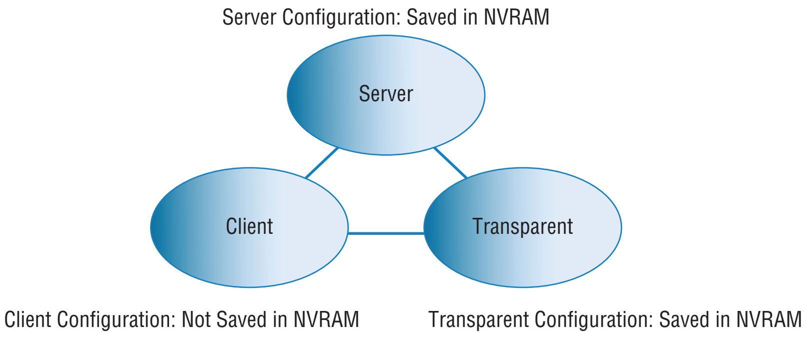
- The VTP management domain name of both switches must be set the same.
- One of the switches has to be configured as a VTP server.
- Set a VTP password if used.
- No router is necessary and a router is not a requirement.

Now that you've got that down, we're going to delve deeper into the world of VTP with VTP modes.

VTP Modes of Operation

Figure 11.19 shows you all three different modes of operation within a VTP domain:

FIGURE 11.19 VTP modes


Server Configuration: Saved in NVRAM
Server
Client
Transparent
Client Configuration: Not Saved in NVRAM
Transparent Configuration: Saved in NVRAM

Server This is the default mode for all Catalyst switches. You need at least one server in your VTP domain to propagate VLAN information throughout that domain. Also important is that the switch must be in server mode for you to be able to create, add, and delete VLANs in a VTP domain. VLAN information has to be changed in server mode, and any change made to VLANs on a switch in server mode will be advertised to the entire VTP domain. In VTP server mode, VLAN configurations are saved in NVRAM on the switch.

Client In client mode, switches receive information from VTP servers, but they also receive and forward updates, so in this way they behave like VTP servers. The difference is that they can't create, change, or delete VLANs. Plus, none of the ports on a client switch can be added to a new VLAN before the VTP server notifies the client switch of the new VLAN and the VLAN exists in the client's VLAN database. Also good to know is that VLAN information sent from a VTP server isn't stored in NVRAM, which is important because it means that if the switch is reset or reloaded, the VLAN information will be deleted. Here's a hint: If you want a switch to become a server, first make it a client so it receives all the correct VLAN information, then change it to a server—so much easier!

Transparent Switches in transparent mode don't participate in the VTP domain or share its VLAN database, but they'll still forward VTP advertisements through any configured trunk links. An admin on a transparent switch can create, modify, and delete VLANs because they keep their own database—one they keep secret from the other switches. Despite being kept in NVRAM memory, the VLAN database in transparent mode is actually only locally significant. The whole purpose of transparent mode is to allow remote switches to receive the VLAN database from a VTP-server-configured switch through a switch that is not participating in the same VLAN assignments.

Do We Really Need to Put an IP Address on a Switch?

The answer is absolutely not! Switches have all ports enabled and ready to rock. Take the switch out of the box, plug it in, and the switch starts learning MAC addresses in the CAM. But since the switches are providing Layer 2 services, why do we need an IP address? Because you still need an IP address for *in-band* management, which is used with your *virtual terminals*, that's why. Telnet, SSH, SNMP, and so on all require IP addresses to communicate with the switch, in-band, through the network. And remember, since all ports are enabled by default, you need to shut down unused ports or assign them to an unused VLAN. Configuring a switch *out-of-band* means you're not going through the network to configure the device; you're actually using a port, such as a console port, to configure the switch instead. Most of the time, you'll use the console port upon starting up the switch. After that, all the management will be completed in-band.

So now you know that the switch needs a management IP address for in-band management purposes, but exactly where do you want to place it? Conveniently, there's something predictably called the management VLAN interface, and that's clearly your target. It's a routed interface found on every switch, and it's referred to as interface VLAN 1. Good to know that this management interface can be changed, and all manufacturers recommend changing it to a different management interface for security purposes.

Yes, you can buy switches that are *unmanaged*, but you would never ever want to do that for an enterprise network! The only environment in which doing that would make sense is in a home network, but that's about it. Anything you get for an office or larger network absolutely must be a *managed* switch!

With all that in mind, let's get down to configuring a switch now.

We'll begin our configuration by connecting into the switch via the console and setting the administrative functions. At this point, we'll also assign an IP address to each switch, but as I said, doing that isn't really necessary to make our network function. The only reason we're going to do that is so we can manage/administer it remotely—in-band—via a protocol like Telnet. Let's use a simple IP scheme like 192.168.10.16/28. And by the way, this mask should be familiar to you. Let's check out the following output:

```
Switch>enable
Switch#config t
Switch(config)#hostname S1
S1(config)#enable secret todd
S1(config)#int f0/15
S1(config-if)#description 1st connection to S3
S1(config-if)#int f0/16
S1(config-if)#description 2nd connection to S3
S1(config-if)#speed 1000
S1(config-if)#duplex full
S1(config-if)#line console 0
S1(config-line)#password console
S1(config-line)#login
S1(config-line)#line vty 0 15
S1(config-line)#password telnet
S1(config-line)#login
S1(config-line)#int vlan 1
```

```
S1(config-if)#ip address 192.168.10.17 255.255.255.240
S1(config-if)#no shut
S1(config-if)#exit
S1(config)#ip default-gateway 192.168.10.30
S1(config)#banner motd #this is my S1 switch#
S1(config)#exit
S1#copy run start
Destination filename [startup-config]? [enter]
Building configuration...
[OK]
S1#
```

In this output, the first thing to notice is that there aren't any IP addresses configured on the switch's physical interfaces. Since all ports on a switch are enabled by default, there's not really a whole lot to configure. But look again—I configured the speed and duplex of the switch to gigabit, full-on port 16. Most of the time you would just leave these as auto-detect, and I actually recommend doing that. My next step is to set the console password for out-of-band management and then the VTY (Telnet) password for in-band management. The next task is to set the default gateway of the switch and banner. So you don't get confused, I want to clarify that the *default gateway* is used to send management (in-band) traffic to a remote network so you can manage the switch remotely. Understand this is not the default gateway for the hosts—the default gateway would be the router interface address assigned to each VLAN.

The IP address is configured under a logical interface, called a management domain or VLAN. You can use default VLAN 1 to manage a switched network just as we're doing here, or you can be smart and opt to use a different VLAN for management.

The preceding configuration demonstrates how to configure the switch for local management, meaning that the passwords to log in to the switch are right there in the switch's configuration. You can also configure switches and routers to store their usernames and passwords remotely for ease of configuration using a AAA server. Doing this allows you to change the passwords at one device without having to telnet into each device separately to change passwords.

To get this done, use the following command:

```
S1(config)#aaa authentication login default
```

This tells the switch to use AAA when Telnet or SSH is used for in-band management. This next command tells the switch to use the AAA server if someone is trying to access the console of the switch:

```
S1(config)#aaa authentication login console
```

So remember, no IP addresses on physical switch interfaces, no routing protocols there either, and so on. We're performing Layer 2 switching at this point, not routing!

Switch Port Protection

There are many features that are available to mitigate switch attacks. In this section we'll examine some of these protections.

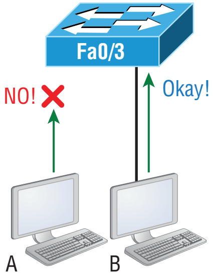
Port Security

Clearly, it's a bad idea to have your switches available for anyone to just plug into and play around with. Security is a big deal—even more of a concern regarding wireless security, so why wouldn't we demand switch security as much, if not more?

But just how do we actually prevent someone from simply plugging a host into one of our switch ports—or worse, adding a hub, switch, or access point into the Ethernet jack in their office? By default, MAC addresses dynamically appear in your MAC forward/filter database, but the good news is that you can stop bad guys in their tracks by using port security!

Figure 11.20 pictures two hosts connected to the single switch port Fa0/3 via either a hub or access point (AP).

FIGURE 11.20 Port security on a switch port restricts port access by MAC address.



Port Fa0/3 is configured to observe and allow only certain MAC addresses to associate with the specific port, so in this example, Host A is denied access, but Host B is allowed to associate with the port.

By using port security, you can limit the number of MAC addresses that can be assigned dynamically to a port, set static MAC addresses, and—here's my favorite part—set penalties for users who abuse your policy! Personally, I like to have the port shut down when the security policy is violated. Making abusers bring me a memo from their boss explaining why they violated the security policy brings with it a certain poetic justice, which is nice. And I'll also require something like that before I'll enable their port again. Things like this really seem to help people remember to behave!

DHCP Snooping

A rogue DHCP server (one not under your control that is giving out incompatible IP addresses) can be an annoyance that causes users to be unable to connect to network resources, or it may play a part in several types of attacks. In either case, DHCP snooping is a switch feature that can help to prevent your devices from communicating with illegitimate DHCP servers.

When enabled, DHCP snooping allows responses to client requests from only DHCP servers located on trusted switch ports (which you define). When only ports where company DHCP servers are located are configured to be trusted, rogue DHCP servers will be unable to respond to client requests.

The protection doesn't stop there, however. The switch will also, over time, develop an IP address to MAC address table called the bindings table, derived from "snooping " on DHCP traffic to and from the legitimate DHCP server. The bindings table will alert the switch to any packets that have mappings that do not match the table. These frames will be dropped. The bindings table is also used with ARP inspection, which makes the configuration of DHCP snooping a prerequisite of ARP inspection.

ARP Inspection

Many man-in-the-middle attacks are made possible by the attacker polluting the ARP cache of the two victims such that their cache maps each other's IP addresses to the MAC address of the attacker, thus allowing the attacker to receive all traffic in the conversation.

Dynamic ARP inspection (DAI) is a feature that, when configured, uses the DHCP snooping database of IP address to MAC address mappings to verify the MAC address mappings of each frame going through the switch. In this way, any frames with incorrect or altered mappings are dropped by the switch, thus breaking any attacks depending on these bogus mappings. Because it uses the DHCP snooping database, the configuration of DHCP snooping is a prerequisite to enabling DAI.

Flood Guard

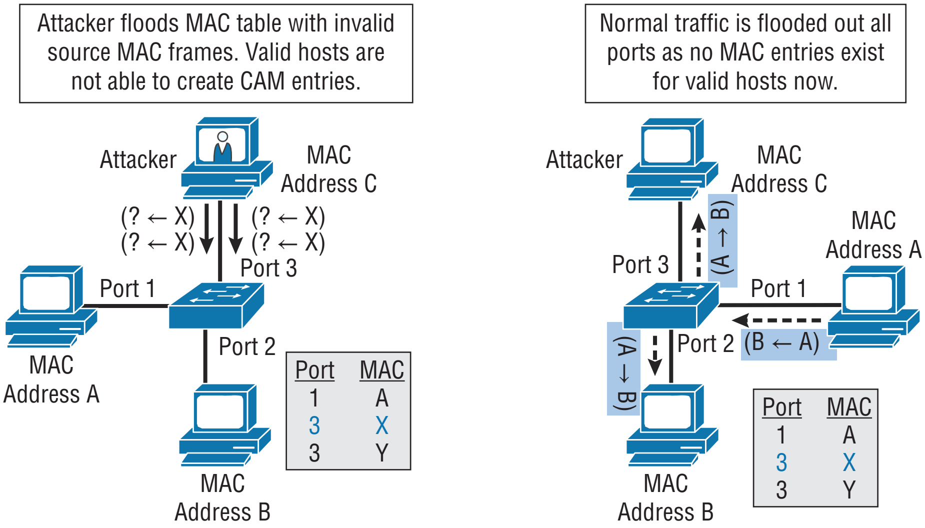
Switches can undergo an attack where some malicious individual floods the switch with unknown MAC addresses. Since switches record all MAC addresses of received frames, the switch will continue to update its MAC table with these MAC addresses until it pushes all legitimate MAC addresses out of the limited space provided for the MAC table in memory. Once this occurs, all traffic received by the switch will be unknown to the switch and it will flood this traffic out of all ports, basically turning the switch into a hub. Now the attacker can connect a sniffer to his port and receive all traffic rather than only the traffic destined for that port as would normally be the case. This attack is shown in Figure 11.21.

Flood guard is a feature that can be implemented to prevent this attack. It uses two mechanisms to accomplish this; unknown unicast flood blocking (UUFB) and unknown unicast flood rate-limiting (UUFRL).

The UUFB feature blocks unknown unicast and multicast traffic flooding at a specific port, only permitting egress traffic with MAC addresses that are known to exist on the port. The UUFRL feature applies a rate limit globally to unknown unicast traffic on all VLANs.

When these two features are combined, flooding attacks can be prevented in switches that support the features.

FIGURE 11.21 MAC flooding attack



Attacker floods MAC table with invalid source MAC frames. Valid hosts are not able to create CAM entries.

Normal traffic is flooded out all ports as no MAC entries exist for valid hosts now.

Port	MAC
1	A
3	X
3	Y

Port	MAC
1	A
3	X
3	Y

BPDU Guard

When a switch that is unknown to you and not under your control is connected to one of your switches, it can play havoc with your STP topology and may even allow the rogue switch to become the root bridge! As you know, when a switch starts receiving STP BPDUs from a new switch, the information in the BPDU (specifically the switch priority) is used to determine if the switch might be a new root bridge (causing a new election) or if the STP topology should be changed.

To prevent this from occurring, a feature called BPDU Guard can be implemented. This feature should be enabled on all switch ports that do not connect to known switches. Since most connections between switches and from the switch to a router are trunk ports, then it is typically enabled on all access ports or ports that connect to end devices.

The effect of enabling this feature is simple but effective. The ports on which it is enabled will be shut down when a BPDU is received. While reenabling the port can be done manually, you can also configure the port to wait a period and then reenable itself automatically as well.

Root Guard

Another feature that can be used to maintain the desired STP topology is called Root Guard. This feature is like BPDU Guard in that it also prevents a new switch from altering the topology. It is applied to all interfaces on the current root bridge and prevents these ports from becoming root ports. Despite the name, root ports are only present on non-root switches and represent the best path back to the root bridge.

The feature prevents this by disabling a port if a BPDU is received that, because of its superior priority number, would cause a new root bridge election. It differs from BPDU

Guard in that BPDU Guard disables a port where it is configured when *any* BPDU is received. This would be undesirable behavior on the root bridge as it needs to receive those BPDUs to maintain the topology. So, in summary, it helps to maintain the current root bridge's role as the root bridge.

Port Bonding

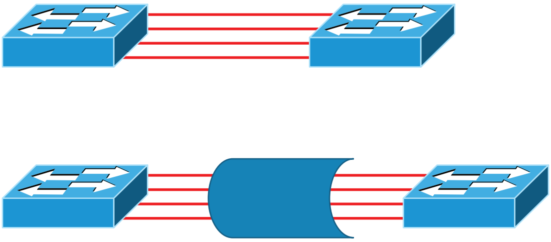
Know that almost all Ethernet networks today will typically have multiple links between switches because this kind of design provides redundancy and resiliency. On a physical design that includes multiple links between switches, STP will do its job and put a port or ports into blocking mode. In addition to that, routing protocols like OSPF and EIGRP could see all these redundant links as individual ones, depending on the configuration, which can mean an increase in routing overhead.

We can gain the benefits from multiple links between switches by using port channeling. EtherChannel is a port channel technology that was originally developed by Cisco as a switch-to-switch technique for grouping several Fast Ethernet or Gigabit Ethernet ports into one logical channel.

Also important to note is that once your port channel is up and working, Layer 2 STP and Layer 3 routing protocols will treat those bundled links as a single one, which would stop STP from performing blocking. An additional nice result is that because the routing protocols now only see this as a single link, a single adjacency across the link can be formed—elegant!

Figure 11.22 shows how a network would look if we had four connections between switches, before and after configuring port channels.

FIGURE 11.22 Before and after port channels



Now as usual, there's the Cisco version and the IEEE version of port channel negotiation protocols to choose from, and you can take your pick. Cisco's version is called Port Aggregation Protocol (PAgP), and the IEEE 802.3ad standard is called Link Aggregation Control Protocol (LACP). Both versions work equally well, but the way you configure each is slightly different. Keep in mind that both PAgP and LACP are negotiation protocols and that EtherChannel can actually be statically configured without PAgP or LACP. Still, it's better to use one of these protocols to help with compatibility issues as well as to manage link additions and failures between two switches.

Cisco EtherChannel allows us to bundle up to eight active ports between switches. The links must have the same speed, duplex setting, and VLAN configuration—in other words, you can't mix interface types and configurations into the same bundle.

Here are a few things to remember:

Port Channeling/Bonding Refers to combining two to eight Fast Ethernet or Gigabit Ethernet ports together between two switches into one aggregated logical link to achieve more bandwidth and resiliency.

EtherChannel Cisco's proprietary term for port channeling.

PAgP This is a Cisco proprietary port channel negotiation protocol that aids in the automatic creation of EtherChannel links. All links in the bundle must match the same parameters (speed, duplex, VLAN info), and when PAgP identifies matched links, it groups the links into an EtherChannel. This is then added to STP as a single bridge port. At this point, PAgP's job is to send packets every 30 seconds to manage the link for consistency, any link additions and modifications, and failures.

LACP (802.3ad) This has the exact same purpose as PAgP, but it's nonproprietary, so it can work between multi-vendor networks.

Device Hardening

A discussion of switch security would be incomplete without discussing device hardening. Actually, this entire section is applicable to not only the routers and switches in your network but of all devices including endpoints such as laptops, mobile devices and desktops.

One of the ongoing goals of operations security is to ensure that all systems have been hardened to the extent that is possible and still provide functionality. The hardening can be accomplished both on a physical and logical basis. From a logical perspective

- Remove unnecessary applications.
- Disable unnecessary services.
- Block unrequired ports.
- Tightly control the connecting of external storage devices and media if it's allowed at all.

Two Additional Advanced Features of Switches

Switches really expand our flexibility when we're designing our networks. The features that we need to cover for the CompTIA Network+ objectives are as follows:

- Power over Ethernet (PoE)
- Port mirroring/spanning (local vs remote)

Power over Ethernet (802.3af, 802.3at)

Power over Ethernet (PoE and PoE+) technology describes a system for transmitting electrical power, along with data, to remote devices over standard twisted-pair cable in an Ethernet network. This technology is useful for powering IP telephones (Voice over IP, or VoIP), wireless LAN access points, network cameras, remote network switches, embedded computers, and other appliances—situations where it would be inconvenient, expensive, and possibly not even feasible to supply power separately. One reason for this is that the main wiring usually must be done by qualified and/or licensed electricians for legal and/or insurance mandates.

The IEEE has created a standard for PoE called 802.3af, and for PoE+ it's referred to as 802.3at. This standard describes precisely how a powered device is detected and also defines two methods of delivering Power over Ethernet to a given powered device. Keep in mind that the PoE+ standard, 802.3at, delivers more power than 802.3af, which is compatible with Gigabit Ethernet with four-wire pairs at 30watts.

This process happens one of two ways: either by receiving the power from an Ethernet port on a switch (or other capable device) or via a power injector. And you can't use both approaches to get the job done. And this can lead to serious trouble, so be sure before connecting!

Real World Scenario

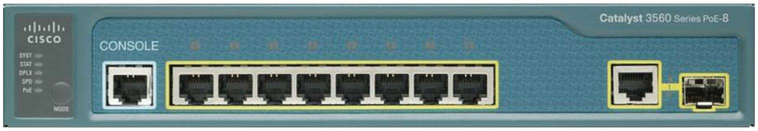
PoE

It would be rare for me not to design a network around PoE. Most of my consulting work is wireless networking, including large outdoor wireless networks. When I design the network, I order equipment based on the amount of power needed to run it, knowing I'll have only a few electrical outlets, or even no outlets if all my equipment is outside. This means that all my switches must run PoE to my access points and wireless bridges and must do this for long distances.

For me to accomplish this, I need to order the more expensive, large-scale enterprise switches. If you have devices that need PoE but do not have long-distance connections, you can use lower-end switches, but you must verify that they provide the right amount of power. There was a customer who called me because their network access points were going up and down. The bottom line is that they had purchased less-expensive switches and there was not enough power to run the equipment. They ended up buying all new switches. So, before you buy a PoE switch, verify that the switch provides the right power for your environment.

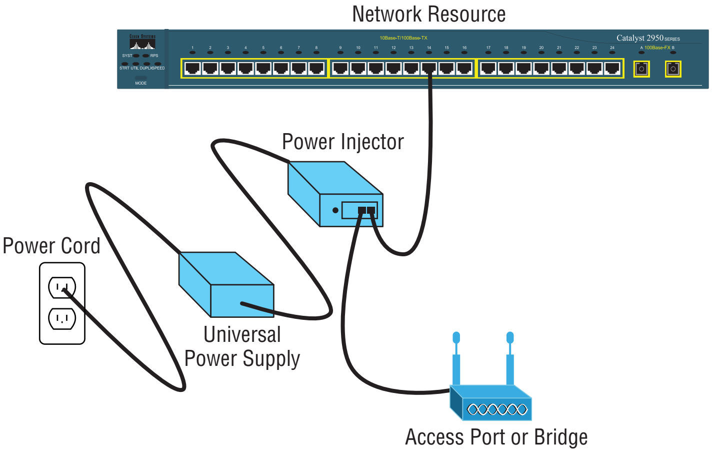
Figure 11.23 shows an example of a switch that provides PoE to any PoE-capable device.

FIGURE 11.23 Switched Ethernet ports can provide power to devices.



As I just said, if you don't have a switch with PoE, then you can use a power injector. Figure 11.24 shows a picture of a typical power injector physically installed in a network.

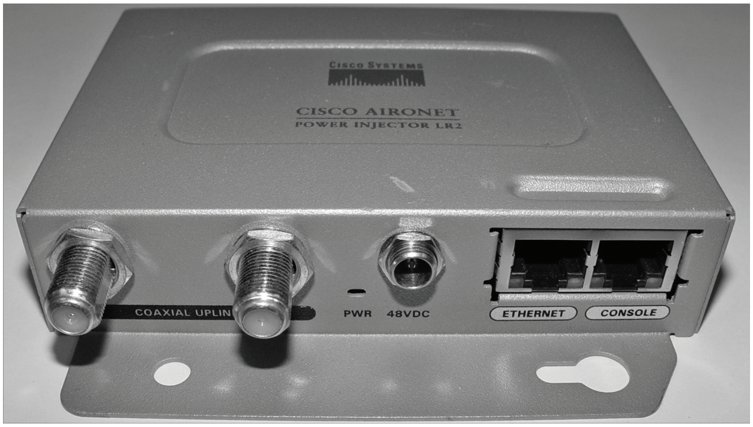
FIGURE 11.24 An external power injector used for PoE



NOTE Use caution when using an external power injector! Take the time to make sure the power injector provides the voltage level for which your device was manufactured.

Because most higher-end switches provide PoE, we don't need to worry about injectors, but if you are adding a wireless bridge into an existing network that has switches without PoE, you need to add a power injector. Figure 11.25 shows a power injector used for a wireless bridge.

FIGURE 11.25 Wireless bridge power injector

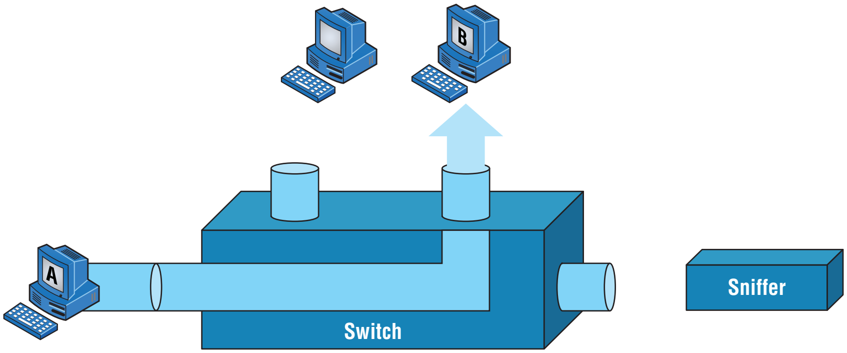


Now, let's discuss how we would troubleshoot a network that has a switch in the LAN instead of a hub.

Port Mirroring/Spanning (SPAN/RSPAN)

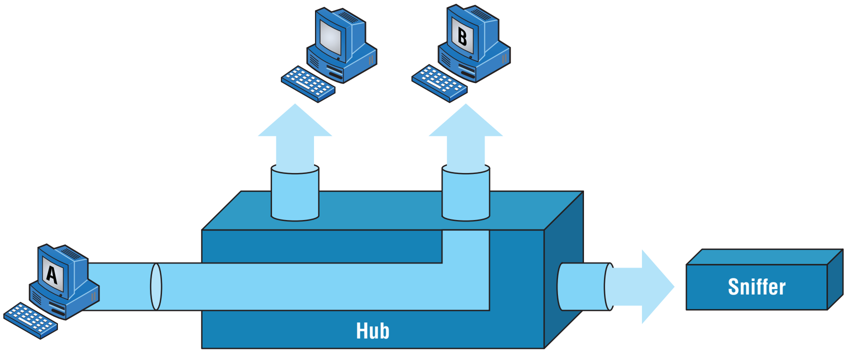
Port mirroring, also called *Switch Port Analyzer (SPAN) and Remote SPAN*, allows you to sniff traffic on a network when using a switch. In Figure 11.26, you can see how a typical switch will read the forward/filter table and only send traffic out the destination port (this is the whole idea of using a switch, so this is good!).

FIGURE 11.26 Switches send frames out the destination port only.



All good, but a problem with this arises when you need to sniff traffic on the network. Figure 11.26 illustrates this issue; the sniffer isn't seeing data coming from Host A to Host B. To solve this little snag, you can temporarily place a hub between Host A and Host B, as demonstrated in Figure 11.27.

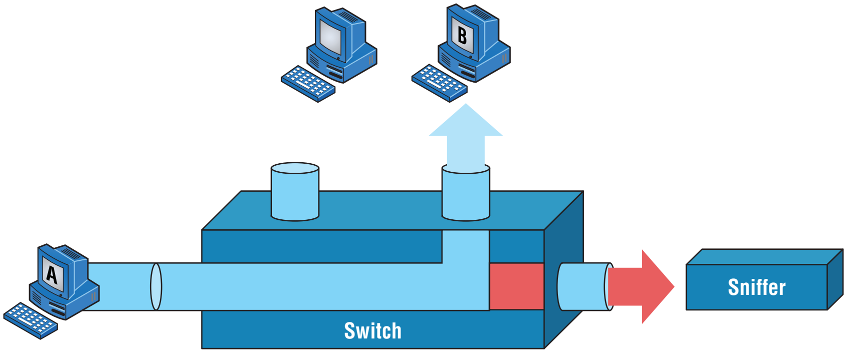
FIGURE 11.27 Place a hub between two hosts to troubleshoot.



This method will allow you to see the frames sent from Host A to Host B. The bad news, however, is that by doing this, you'll bring down the network temporarily.

The port-mirroring option allows you to place a port in span mode so that every frame from Host A is captured by both Host B and the sniffer, as shown in Figure 11.28. This would also be a helpful option to take advantage of if you were connecting an IDS or IPS to the switch as well.

FIGURE 11.28 Port spanning/mirroring



Be careful when using port mirroring because it can cause a lot of overhead on the switch and possibly crash your network. Because of this, it's a really good idea to use this feature at strategic times, and only for short periods if possible.

NOTE

The last thing I want you to bear in mind is that RSPAN extends SPAN by enabling remote monitoring of multiple switches across your network. The traffic for each RSPAN session is carried over a user-specified RSPAN VLAN, which is dedicated for a specific RSPAN session in all participating switches.

Summary

In this chapter, I talked about the differences between switches and bridges and how they both work at Layer 2 and create a MAC address forward/filter table in order to make decisions about whether to forward or flood a frame.

I also discussed problems that can occur if you have multiple links between bridges (switches) and how to solve these problems by using the Spanning Tree Protocol (STP).

This chapter also introduced you to the world of virtual LANs and described how switches can use them. We talked about how VLANs break up broadcast domains in a switched internetwork—a very important, necessary thing because Layer 2 switches only break up collision domains and, by default, all switches make up one large broadcast domain. I also described access links and went over how trunked VLANs work across a Fast Ethernet link.

Trunking is a crucial technology to understand well when you're dealing with a network populated by multiple switches that are running several VLANs.

Exam Essentials

Remember the three switch functions. Address learning, forward/filter decisions, and loop avoidance are the functions of a switch.

Understand the main purpose of the Spanning Tree Protocol in a switched LAN. The main purpose of STP is to prevent switching loops in a network with redundant switched paths.

Remember the states of STP. The purpose of the blocking state is to prevent the use of looped paths. A port in the listening state prepares to forward data frames without populating the MAC address table. A port in the learning state populates the MAC address table but doesn't forward data frames. A port in the forwarding state sends and receives all data frames on the bridged port. Last, a port in the disabled state is virtually nonoperational.

Remember to check a switch port's VLAN assignment when plugging in a new host. If you plug a new host into a switch, then you must verify the VLAN membership of that port. If the membership is different than what is needed for that host, the host will not be able to reach the needed network services, such as a workgroup server.

Understand what PoE provides. Power over Ethernet was created to provide power to devices that are connected to a switch port but that are not in a place that has a power outlet—for example, an access point in a ceiling.

List features that can be used to maintain the STP topology. These include BPDU Guard, Root Guard, and flood guards.

Written Lab

You can find the answers to the written labs in Appendix A. Write the answers to the following questions:

1. VLANs break up ________ domains in a Layer 2 switched network.
2. Switches, by default, only break up ________ domains.
3. What does trunking provide?
4. You need to power a device such as an access point or IP phone. What protocol can provide power to these devices over an Ethernet cable?

5. You plug a host into a switch port and the host receives an IP address but the user can't get to the services it needs. What is probably the problem?

6. If a destination MAC address is not in the forward/filter table, what will the switch do with the frame?

7. What are the three switch functions at Layer 2?

8. If a frame is received on a switch port and the source MAC address is not in the forward/filter table, what will the switch do?

9. What is used at Layer 2 to prevent switching loops?

10. You need to implement a separate network for contractors and guests working at your office. Which technology should you implement?

Review Questions

You can find the answers to the review questions in Appendix B.

1. You want to improve network performance by increasing the bandwidth available to hosts and limiting the size of the broadcast domains. Which of the following options will achieve this goal?

A. Managed hubs

B. Bridges

C. Switches

D. Switches configured with VLANs

2. The types of ports that can be found on a switch are ______________________ and ______________________. (Choose two.)

A. VLAN Trunk Protocol

B. Access

C. 802.1Q

D. Trunk

3. Which switching technology reduces the size of a broadcast domain?

A. ISL

B. 802.1Q

C. VLANs

D. STP

4. Which of the following are IEEE versions of STP? (Choose two.)

A. 802.1X

B. VLANs

C. 802.1D

D. 802.11

E. 802.1w

5. You connect a host to a switch port, but the new host cannot log into the server that is plugged into the same switch. What could the problem be? (Choose two.)

A. The router is not configured for the new host.

B. The STP configuration on the switch is not updated for the new host.

C. The host has an invalid MAC address.

D. The switch port the host is connected to is not configured to the correct VLAN membership.

E. STP shut down the port.

6. Which of the following are benefits of VLANs? (Choose three.)

A. They increase the size of collision domains.

B. They allow logical grouping of users by function.

C. They can enhance network security.

D. They increase the size of broadcast domains while decreasing the number of collision domains.

E. They simplify switch administration.

F. They increase the number of broadcast domains while decreasing the size of the broadcast domains.

7. Which of the following is a Layer 2 protocol used to maintain a loop-free network?

A. VTP

B. STP

C. RIP

D. CDP

8. What is the result of segmenting a network with a bridge (switch)? (Choose two.)

A. It increases the number of collision domains.

B. It decreases the number of collision domains.

C. It increases the number of broadcast domains.

D. It decreases the number of broadcast domains.

E. It makes smaller collision domains.

F. It makes larger collision domains.

9. You connect your host to a switch that is running network analysis software. However, you are not seeing any packets from the server. What do you need to implement on the switch to see all the packet information?

A. VLANs

B. STP

C. Port mirroring

D. Authentication

10. Which of the following features of a switch will allow two switches to pass VLAN network information?

A. PoE

B. VLANs

C. Trunking

D. STP

11. What are the distinct functions of Layer 2 switching that increase available bandwidth on the network? (Choose three.)

    A. Address learning

    B. Routing

    C. Forwarding and filtering

    D. Creating network loops

    E. Loop avoidance

    F. IP addressing

12. Which of the following statements is true?

    A. A switch creates a single collision domain and a single broadcast domain. A router creates a single collision domain.

    B. A switch creates separate collision domains but one broadcast domain. A router provides a separate broadcast domain.

    C. A switch creates a single collision domain and separate broadcast domains. A router provides a separate broadcast domain as well.

    D. A switch creates separate collision domains and separate broadcast domains. A router provides separate collision domains.

13. What does a switch do when a frame is received on an interface and the destination hardware address is unknown or not in the filter table?

    A. Forwards the switch to the first available link

    B. Drops the frame

    C. With the exception of the source port, floods the network with the frame looking for the device

    D. Sends back a message to the originating station asking for a name resolution

14. If a switch receives a frame and the source MAC address is not in the MAC address table but the destination address is, what will the switch do with the frame?

    A. Discard it and send an error message back to the originating host

    B. Flood the network with the frame

    C. Add the source address and port to the MAC address table and forward the frame out the destination port

    D. Add the destination to the MAC address table and then forward the frame

15. When would you configure VTP on a switch?

    A. When you have hubs connected in your network

    B. When you have redundant links between switches

    C. When you have multiple hosts in multiple VLANs and you want to share all the data between hosts without a router

    D. When you have multiple switches with multiple VLANs and you want to share the VLAN database from one switch to all the others

16. When is STP said to be converged on the root bridge? (Choose two.)

A. When all ports are in the forwarding state

B. When all ports are in the blocking state

C. When all ports are in the listening state

D. When all ports are in the learning state

17. In which two states is the MAC address table populated with addresses? (Choose two.)

A. Blocking

B. Listening

C. Learning

D. Forwarding

18. You have multiple departments all connected to switches, with crossover cables connecting the switches together. However, response time on the network is still very slow even though you have upgraded from hubs to switches. What technology should you implement to improve response time on the networks?

A. STP

B. VLANs

C. Convergence

D. OSPF

19. If you are configuring voice VLANs, which of the following should you configure on the switch ports to provide a higher precedence to voice traffic over data traffic to improve sound quality?

A. Access VLANs

B. VTP

C. QoS

D. STP

20. What is a disadvantage of using port spanning?

A. It breaks up broadcast domains on all ports.

B. It can create overhead on the switch.

C. It makes the switch one large collision domain.

D. It makes the switch fast between only two ports instead of all ports.

Wireless Networking

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Properties of network traffic
  - CSMA/CA

✓ **1.5 Compare and contrast the characteristics of network topologies, types, and technologies**

- Wireless topologies
  - Mesh
  - Ad hoc
  - Infrastructure
- Types
  - WLAN
  - PAN
- Technologies that facilitate the Internet of Things (IoT)
  - Z-Wave
  - Ant+
  - Bluetooth
  - NFC
  - IR
  - RFID
  - 802.11

✓ **1.6 Given a scenario, implement the appropriate wireless technologies and configurations**

- 802.11 standards
  - a
  - b

    - g
    - n
    - ac
- Cellular
    - GSM
    - TDMA
    - CDMA
- Frequencies
    - 2.4 GHz
    - 5.0 GHz
- Speed and distance requirements
- Channel bandwidth
- Channel bonding
- MIMO/MU-MIMO
- Unidirectional/omnidirectional
- Site surveys

✓ **2.2 Given a scenario, determine the appropriate placement of networking devices on a network and install/configure them**

- Wireless access point

✓ **2.3 Explain the purposes and use cases for advanced networking devices**

- Wireless controller

✓ **4.3 Given a scenario, secure a basic wireless network**

- WPA
- WPA2
- TKIP-RC4
- CCMP-AES
- Authentication and authorization
    - EAP
    - PEAP

  - EAP-FAST
  - EAP-TLS
  - Shared or open
  - Pre-shared key
  - MAC filtering
- Geofencing

✓ **4.4 Summarize common networking attacks**

- Rogue access point
- Evil twin
- War-driving

✓ **5.4 Given a scenario, troubleshoot common wireless connectivity and performance issues**

- Reflection
- Refraction
- Absorption
- Latency
- Jitter
- Attenuation
- Incorrect antenna type
- Interference
- Incorrect antenna placement
- Channel overlap
- Overcapacity
- Distance limitations
- Frequency mismatch
- Wrong SSID
- Wrong passphrase
- Security type mismatch
- Power levels
- Signal-to-noise ratio

While you're sipping coffee at a café or hanging out in an airport until they finally fix the plane you're waiting to board, you are no longer limited to just reading actual papers and magazines. Now, you have the option to connect to the local wireless network and catch up on your emails, blog, do a little gaming—maybe even get some work done! It's come to the point that many of us wouldn't even think of checking into a hotel that doesn't offer this important little amenity. So clearly, those of us already in or wishing to enter the IT field better have our chops down regarding wireless network components and their associated installation factors, right? (Answer: a resounding YES!)

With that established, here's a great starting point. If you want to understand the basic wireless LANs (WLANs) most commonly used today, just think 10BaseT Ethernet with hubs. What this means is that our WLANs typically run half-duplex communication—everyone is sharing the same bandwidth, and only one user is communicating at a time.

This isn't necessarily bad; it's just not good enough. Because most people rely on wireless networks today, it's critical that they evolve faster than greased lightning to keep up with our rapidly escalating needs. The good news is that this is actually happening—and it even works securely!

The goal in this chapter is to introduce you to wireless networks and the technologies in use today. I'll also cover the various components used, the IEEE 802.11 standards, wireless installation, and of course, wireless security.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Introduction to Wireless Technology

Transmitting a signal using the typical 802.11 specifications works a lot like it does with a basic Ethernet hub: They're both two-way forms of communication, and they both use the same frequency to both transmit and receive, often referred to as *half-duplex* as mentioned in the chapter introduction. Wireless LANs (WLANs) use radio frequencies (RFs) that are radiated into the air from an antenna that creates radio waves. These waves can be absorbed, refracted, or reflected by walls, water, and metal surfaces, resulting in low signal strength. So because of this innate vulnerability to surrounding environmental factors, it's pretty apparent that wireless will never offer us the same robustness as a wired network can, but that still doesn't mean we're not going to run wireless. Believe me, we definitely will!

We can increase the transmitting power and we'd be able to gain a greater transmitting distance, but doing so can create some nasty distortion, so it has to be done carefully. By using higher frequencies, we can attain higher data rates, but this is, unfortunately, at the cost of decreased transmitting distances. And if we use lower frequencies, we get to transmit greater distances but at lower data rates. This should make it pretty clear to you that understanding all the various types of WLANs you can implement is imperative to creating the LAN solution that best meets the specific requirements of the unique situation you're dealing with.

Also important to note is the fact that the 802.11 specifications were developed so that there would be no licensing required in most countries—to ensure that the user has the freedom to install and operate without any licensing or operating fees. This means that any manufacturer can create wireless networking products and sell them at a local computer store or wherever. It also means that all our computers should be able to communicate wirelessly without configuring much, if anything at all.

Various agencies have been around for a very long time to help govern the use of wireless devices, frequencies, standards, and how the frequency spectrums are used. Table 12.1 shows the current agencies that help create, maintain, and even enforce wireless standards worldwide.

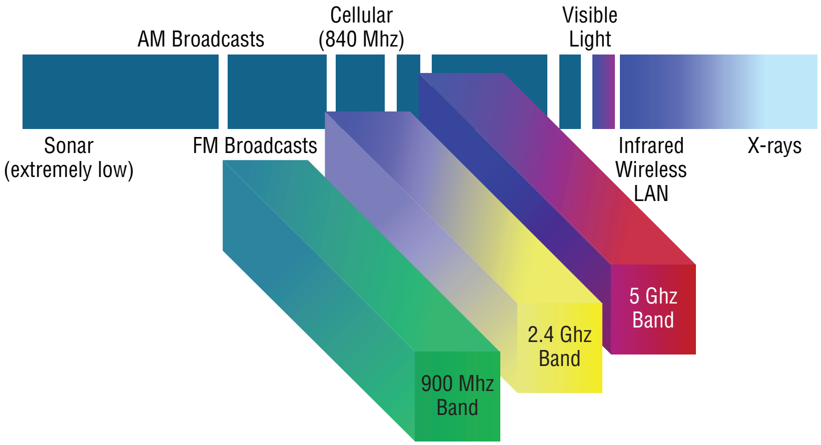
TABLE 12.1 Wireless agencies and standards

Agency	Purpose	Website
Institute of Electrical and Electronics Engineers (IEEE)	Creates and maintains operational standards	`www.ieee.org`
Federal Communications Commission (FCC)	Regulates the use of wireless devices in the U.S.	`www.fcc.gov`
European Telecommunications Standards Institute (ETSi)	Chartered to produce common standards in Europe	`www.etsi.org`
Wi-Fi Alliance	Promotes and tests for WLAN interoperability	`www.wi-fi.com`
WLAN Association (WLANA)	Educates and raises consumer awareness regarding WLANs	`www.wlana.org`

Because WLANs transmit over radio frequencies, they're regulated by the same types of laws used to govern things like AM/FM radios. In the United States, it's the Federal Communications Commission (FCC) that regulates the use of wireless LAN devices, and the Institute of Electrical and Electronics Engineers (IEEE) takes it from there and creates standards based on what frequencies the FCC releases for public use.

The FCC has released three unlicensed bands for public use: 900 MHz, 2.4 GHz, and 5 GHz. The 900 MHz and 2.4 GHz bands are referred to as the Industrial, Scientific, and Medical (ISM) bands, and the 5 GHz band is known as the Unlicensed National Information Infrastructure (U-NII) band. Figure 12.1 shows where the unlicensed bands sit within the RF spectrum. A newer addition to this (not shown in the figure) is the 60 GHz band, which is used for the new 802.11ad standard that is a very high-speed, short-range wireless technology.

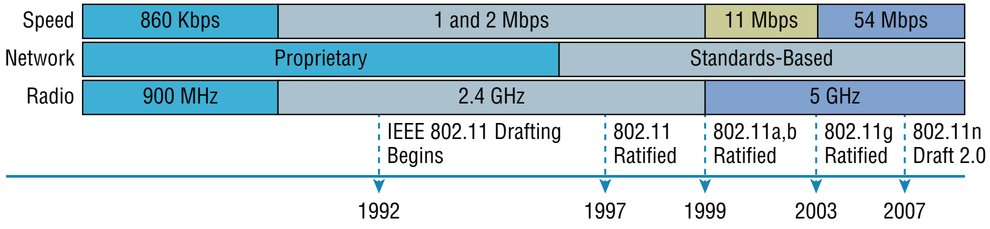
FIGURE 12.1 Unlicensed frequencies



So it follows that if you opt to deploy wireless in a range outside the three public bands shown in Figure 12.1, you need to get a specific license from the FCC to do so. Once the FCC opened the three frequency ranges for public use, many manufacturers were able to start offering myriad products that flooded the market, with 802.11b/g/n being the most widely used wireless network found today.

Figure 12.2 shows the WLAN history that is important to us. Although wireless transmissions date back many, many years, the type we really care about is wireless as related to WLANs starting in the 1990s. Use of the ISM band started in early 1990, and it's deployed today in multiple environments, including outdoor links, mesh networks, office buildings, healthcare facilities, warehouses, and homes.

FIGURE 12.2 Wireless LAN history



802.11ac was released in December 2013, and although it isn't shown in Figure 12.2, it will be the newest, hottest 802.11 standard in the next few years. I'll discuss 802.11ac in detail throughout this chapter.

The Wi-Fi Alliance grants certification for interoperability among 802.11 products offered by various vendors. This certification provides a sort of comfort zone for the users purchasing the many types of products, although in my personal experience, it's just a whole lot easier if you buy all your access points from the same manufacturer.

In the current U.S. WLAN market, there are several accepted operational standards and drafts created and maintained by the IEEE. We'll now take a look at these standards and then talk about how the most commonly used standards work.

Cellular

As part of implementing the appropriate cellular and mobile wireless technologies and configurations, consider the following options.

GSM Global System Mobile (GSM) is a type of cellphone that contains a Subscriber Identity Module (SIM) chip. These chips contain all the information about the subscriber and must be present in the phone for it to function. One of the dangers with these phones is cell phone cloning, a process where copies of the SIM chip are made, allowing another user to make calls as the original user. Secret key cryptography is used (using a common secret key) when authentication is performed between the phone and the network.

FDMA Frequency Division Multiple Access (FDMA) is one of the modulation techniques used in cellular wireless networks. It divides the frequency range into bands and assigns a band to each subscriber. This was used in 1G cellular networks.

TDMA Time Division Multiple Access (TDMA) increases the speed over FDMA by dividing the channels into time slots and assigning slots to calls. This also helps to prevent eavesdropping in calls.

CDMA Code Division Multiple Access (CDMA) assigns a unique code to each call or transmission and spreads the data across the spectrum, allowing a call to make use of all frequencies.

The 802.11 Standards

Taking off from what you learned in Chapter 1, "Introduction to Networks," wireless networking has its own 802 standards group—remember, Ethernet's committee is 802.3. Wireless starts with 802.11, and there are various other up-and-coming standard groups as well, like 802.11ac. And even cellular networks are becoming huge players in our wireless experience. But for now, we're going to concentrate on the 802.11 standards committee and subcommittees.

IEEE 802.11 was the first, original standardized WLAN at 1 Mbps and 2 Mbps. It runs in the 2.4 GHz radio frequency. It was ratified in 1997, although we didn't see many products pop up until around 1999 when 802.11b was introduced. All the committees listed in Table 12.2 made amendments to the original 802.11 standard except for 802.11F and 802.11T, which produced stand-alone documents.

TABLE 12.2 802.11 committees and subcommittees

Committee	Purpose
IEEE 802.11a	54 Mbps, 5 GHz standard
IEEE 802.11ac	1 Gbps, 5 GHz standard
IEEE 802.11b	Enhancements to 802.11 to support 5.5 Mbps and 11 Mbps
IEEE 802.11c	Bridge operation procedures; included in the IEEE 802.1D standard
IEEE 802.11d	International roaming extensions
IEEE 802.11e	Quality of service
IEEE 802.11F	Inter-Access Point Protocol
IEEE 802.11g	54 Mbps, 2.4 GHz standard (backward compatible with 802.11b)
IEEE 802.11h	Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC) at 5 GHz
IEEE 802.11i	Enhanced security
IEEE 802.11j	Extensions for Japan and U.S. public safety
IEEE 802.11k	Radio resource measurement enhancements
IEEE 802.11m	Maintenance of the standard; odds and ends
IEEE 802.11n	Higher throughput improvements using multiple-input, multiple-output (MIMO) antennas
IEEE 802.11p	Wireless Access for the Vehicular Environment (WAVE)
IEEE 802.11r	Fast roaming
IEEE 802.11s	ESS Extended Service Set Mesh Networking
IEEE 802.11T	Wireless Performance Prediction (WPP)
IEEE 802.11u	Internetworking with non-802 networks (cellular, for example)
IEEE 802.11v	Wireless network management
IEEE 802.11w	Protected management frames
IEEE 802.11y	3650–3700 operation in the US

NOTE One type of wireless networking that doesn't get a whole lot of attention is infrared wireless. Infrared wireless uses the same basic transmission method as many television remote controls—that's right, infrared technology. Infrared is used primarily for short-distance, point-to-point communications, like those between a peripheral and a PC, with the most widely used for peripherals being the IrDA standard.

Now let's discuss some important specifics of the most popular 802.11 WLANs.

2.4 GHz (802.11b)

First on the menu is the 802.11b standard. It was the most widely deployed wireless standard, and it operates in the 2.4 GHz unlicensed radio band that delivers a maximum data rate of 11 Mbps. The 802.11b standard has been widely adopted by both vendors and customers who found that its 11 Mbps data rate worked pretty well for most applications. But now that 802.11b has a big brother (802.11g), no one goes out and just buys an 802.11b card or access point anymore—why would you buy a 10 Mbps Ethernet card when you can score a 10/100 Ethernet card for the same price?

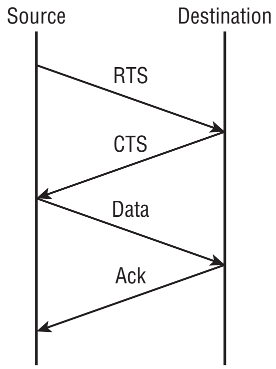
An interesting thing about all 802.11 WLAN products is that they have the ability to data-rate-shift while moving. This allows the person operating at 11 Mbps to shift to 5.5 Mbps, then 2 Mbps, and finally still communicate farthest from the access point at 1 Mbps. And furthermore, this rate shifting happens without losing the connection and with no interaction from the user. Rate shifting also occurs on a transmission-by-transmission basis. This is important because it means that the access point can support multiple clients at varying speeds depending upon the location of each client.

The problem with all 802.11b communication lies in how the Data Link layer is dealt with. In order to solve problems in the RF spectrum, a type of Ethernet contention management was created called *Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)*.

CSMA/CA also has an optional implementation called a *Request to Send, Clear to Send (RTS/CTS)* because of the way that hosts must communicate with the access point (AP). For every packet sent, an RTS/CTS and acknowledgment must be received, and because of this rather cumbersome process, it's kind of hard to believe it all actually works when you use this!

To get a clear picture of this, check out Figure 12.3.

FIGURE 12.3 802.11b CSMA/CA



2.4 GHz (802.11g)

The 802.11g standard was ratified in June 2003 and is backward compatible to 802.11b. The 802.11g standard delivers the same 54 Mbps maximum data rate as you'll find in the 802.11a range but runs in the 2.4 GHz range—the same as 802.11b.

Because 802.11b/g operates in the same 2.4 GHz unlicensed band, migrating to 802.11g is an affordable choice for organizations with existing 802.11b wireless infrastructures. Just keep in mind that 802.11b products can't be "software upgraded" to 802.11g. This limitation is because 802.11g radios use a different chipset in order to deliver the higher data rate.

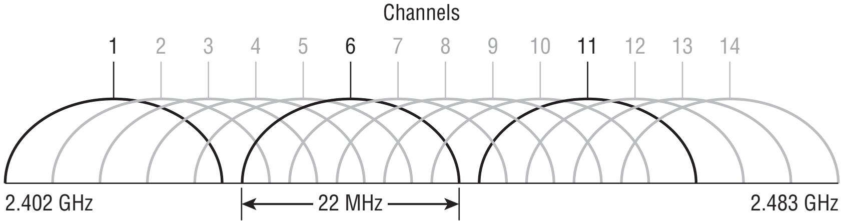
But still, much like Ethernet and Fast Ethernet, 802.11g products can be commingled with 802.11b products in the same network. Yet, for example, and completely unlike Ethernet, if you have four users running 802.11g cards and one user starts using an 802.11b card, everyone connected to the same access point is then forced to run the 802.11b signal modulation method—an ugly fact that really makes throughput suffer badly. So to optimize performance, it's recommended that you disable the 802.11b-only modes on all your access points.

To explain this further, 802.11b uses a *modulation technique* called *Direct Sequence Spread Spectrum (DSSS)* that's just not as robust as the *Orthogonal Frequency Division Multiplexing (OFDM)* modulation used by both 802.11g and 802.11a. 802.11g clients using OFDM enjoy much better performance at the same ranges as 802.11b clients do, but—and remember this—when 802.11g clients are operating at the 802.11b rates (11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps), they're actually using the same modulation 802.11b uses.

So, regarding the throughput of different WLAN standards, you know that 802.11b has a top throughput of 11 Mbps, and 802.11g has a top throughput of 54 Mbps. But with that said, do you really think we're actually getting that type of throughput? The answer is absolutely not! This is because in reality, about 70 percent or more of the RF bandwidth is used for management of the wireless network itself! The actual bandwidth the user experiences using an application is called goodput, even though you won't hear this term used a lot. Just remember that *goodput* refers to the actual data throughput, not the theoretical number that the standards describe.

Figure 12.4 shows the 14 different channels (each 22 MHz wide) that the FCC released in the 2.4 GHz range.

FIGURE 12.4 ISM 2.4 GHz channels

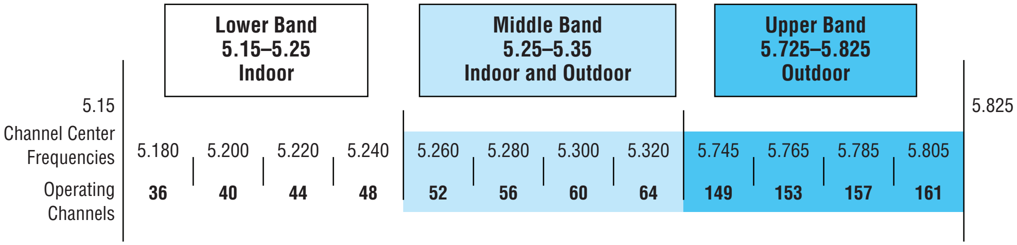


In the United States, only 11 channels are configurable, with channels 1, 6, and 11 being non-overlapping. This allows you to have three access points in the same area without experiencing interference. You must be aware of the channels when installing APs in a large environment so you do not overlap channels. If you configure one AP with channel 1, then the next AP would be configured in channel 11, the channel farthest from that configured on the first AP.

5 GHz (802.11a)

The IEEE ratified the 802.11a standard in 1999, but the first 802.11a products didn't begin appearing on the market until late 2001—and boy, were they pricey! The 802.11a standard delivers a maximum data rate of 54 Mbps with 12 non-overlapping frequency channels. Figure 12.5 shows the U-NII bands.

FIGURE 12.5 U-NII 5 GHz band has 12 non-overlapping channels (US)



Operating in the 5 GHz radio band, 802.11a is also immune to interference from devices that operate in the 2.4 GHz band, like microwave ovens, cordless phones, and Bluetooth devices. 802.11a isn't backward compatible with 802.11b because they are different frequencies, so you don't get to just "upgrade" part of your network and expect everything to work together in perfect harmony. But no worries—there are plenty of dual-radio devices that will work in both types of networks. A definite plus for 802.11a is that it can work in the same physical environment without interference from 802.11b users.

Similar to the 802.11b radios, all 802.11a products also have the ability to data-rate-shift while moving. The 802.11a products allow the person operating at 54 Mbps to shift to 48 Mbps, 36 Mbps, 24 Mbps, 18 Mbps, 12 Mbps, and 9 Mbps, and finally, still communicate farthest from the AP at 6 Mbps.

There's also an extension to the 802.11a specification called 802.11h, which is described next.

5 GHz (802.11h)

The FCC added 11 new channels in February 2004, and in 2008, we were finally able to begin using these channels based on manufacturers' releases of more 802.11a 5 GHz products. This means that we gained access to up to 23 non-overlapping channels! And there are even two new features to the 5 GHz radio that are part of the 802.11h specification: *Dynamic Frequency Selection (DFS)* and *Transmit Power Control (TPC)*.

Dynamic Frequency Selection (DFS) This cool feature continuously monitors a device's operating range for any radar signals that are allowed to operate in portions of the 5 GHz band as well as 802.11a before transmitting. If DFS discovers any radar signals, it'll either abandon the occupied channel or mark it as unavailable to prevent interference from occurring on the WLAN.

Transmit Power Control (TPC) Even though it's been employed by the mobile phone industry for a long time, this technology has some handy new uses. You can set the client machine's adapter and the access point's transmit power to cover various size ranges—a feature that's useful for many reasons. For one, setting the access point's transmit power to 5 milliwatts (mW) reduces cell range, which works great if you've got a compact area with high-density usage.

Further advantages include the fact that TPC enables the client and the access point to communicate with less power. This means the client machine can fine-tune its transmit power dynamically so it uses just enough energy to preserve its connection to the access point and conserve its battery power plus reduce interference on the neighboring WLAN cells—sweet!

2.4 GHz/5 GHz (802.11n)

802.11n builds on previous 802.11 standards by adding *multiple-input, multiple-output (MIMO)*, which employs multiple transmitters and receiver antennas to increase data throughput. 802.11n can have up to eight antennas, but most of today's access points use four. These are sometimes referred to as *smart antennas*, and if you did have four of them, two would be used for transmitting simultaneously with the other two receiving simultaneously. This setup would allow for much higher data rates than 802.11a/b/g. In fact, the marketing people claim it will provide about 250 Mbps, but personally, I've never really seen that level of throughput. Even if what they're saying is true, exactly how would that help if all you've got is a 100 Mbps DSL connection to the Internet?

NOTE 802.11n allows for communication at both the 2.4 GHz and 5 GHz frequencies by using channel bonding.

Unlike 802.11a and 802.11g, which are locked into using the 5.0 GHz and 2.4 GHz spectrums, respectively, with 802.11n you can control which of the spectrums (or both) you want to allow in your WLAN! Listed next are some additional components of 802.11n that give people reason to say 802.11n has greater reliability and predictability:

40 MHz Channels 802.11g and 802.11a use 20 MHz channels, and tones on the sides of each channel are not used to protect the main carrier, which means that 11 Mbps are unused or wasted. 802.11n aggregates two carriers to double the speed from 54 Mbps to 108 Mbps. Add the 11 Mbps that we gain from not wasting the side tones and we have 119 Mbps.

MAC Efficiency 802.11 protocols require acknowledgment of each and every frame. 802.11n can pass many packets before an acknowledgment is required, which saves you on overhead. This is called *block acknowledgment*.

So What Is Wi-Fi?

You may have seen products that are 802.11 compliant with a small sticker on them that says "Wi-Fi." You might be able to guess that this rather odd phrase stands for Wireless Fidelity, but you may not know what its implications are. Simply put, that sticker indicates that the product in question has passed certification testing for 802.11 interoperability by the Wi-Fi Alliance. This nonprofit group was formed to ensure that all 802.11a/b/g/n wireless devices would communicate seamlessly. So, Wi-Fi is a good thing.

Multiple-Input, Multiple-Output (MIMO) Several frames are sent by several antennas over several paths and are then recombined by another set of antennas to optimize throughput and multipath resistance. This is called *spatial multiplexing.*

5 GHz (802.11ac)

802.11ac is a Wi-Fi standard that works in the 5 GHz range and delivers up to 1 gigabit throughput that was approved by the 802.11 standards committee in January 2014. Still, just as it is with 802.11n, you won't find that the speeds described in the standard actually line up with the marketing material.

For example, for a single link, which is basically one host to AP, the best throughput you can hope to get would be 500 Mbps, which is fantastic if it actually happens! But unless you have a gigabit Internet connection, 802.11ac won't really help so much. To be fair, in a small network, or if you're transferring files in your internal WLAN or to your internal network, this new specification could actually be useful.

At this point, you're probably wondering how these people can claim to achieve these theoretical rates, right? That's an excellent question! They get these values by increasing the RF band usage from 20 MHz wide channels with 802.11a/b/g to 40 MHz with 802.11n and up to 160 MHz wide channels with 802.11ac. But again, for typical commercial 802.11ac products, 80 MHz would be a lot more realistic. The problem with this scenario centers on the fact that if any interference is found in the 80 MHz wide channel, it drops down to 40 MHz wide channels. Worse, if interference is still found at that level, it will drop even further down to 20 MHz wide channels.

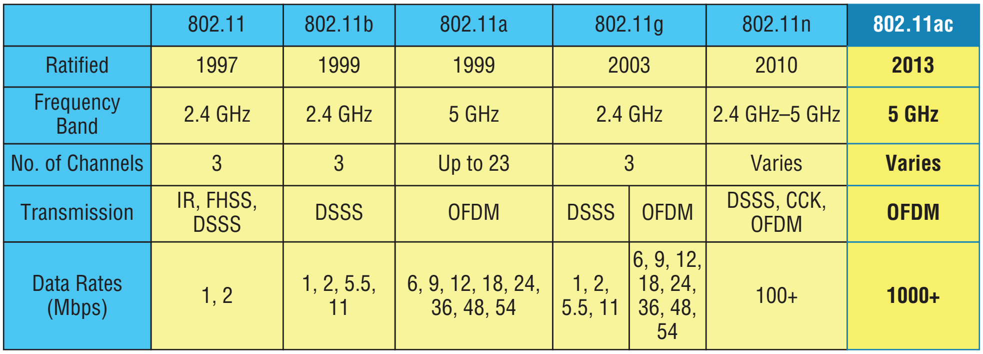
In addition to the wider channels, we can also get more MIMO spatial streams than we can with 802.11n—up to eight, where 802.11n only supported four. Furthermore, and optionally, a downlink of multi-user MIMO (MU-MIMO) supports up to four clients and, most important, a modulation of QAM-256 compared to QAM-64 with 802.11a/g.

The last thing I want to point out is the fact that 802.11n had added fields in the wireless frame to identify 802.11a and 802.11g as high throughput (HT), whereas 802.11ac adds four fields to identify the frames as very high throughput (VHT).

Comparing 802.11 Standards

Before I move on to wireless installations, take a look at Figure 12.6, which lists, for each of the IEEE standards in use today, the year of ratification as well as the frequency, number of non-overlapping channels, physical layer transmission technique, and data rates.

FIGURE 12.6 Standards for spectrums and speeds



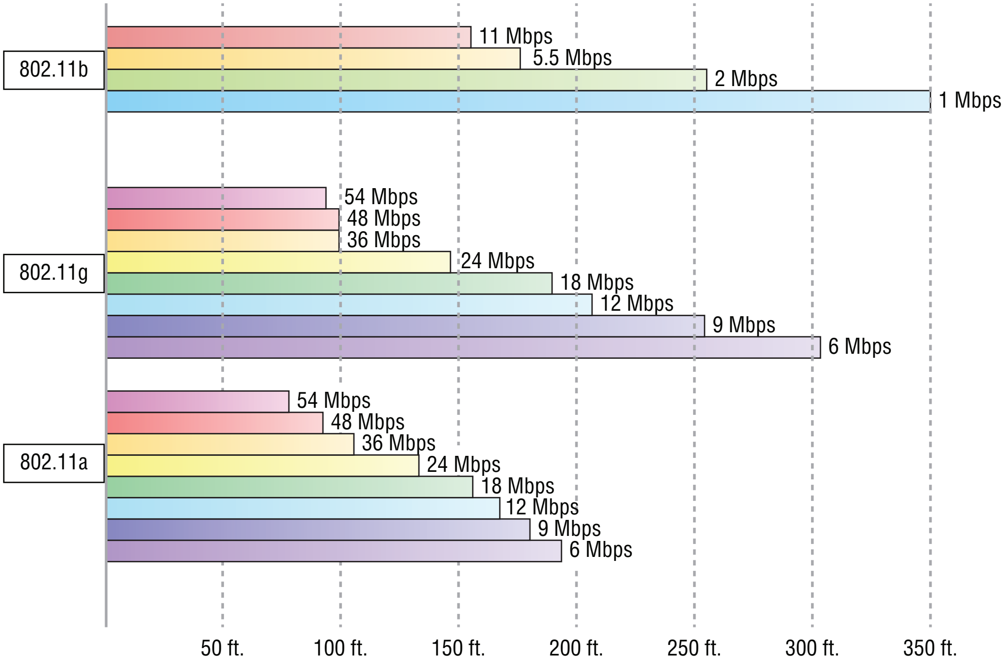
	802.11	802.11b	802.11a	802.11g	802.11n	**802.11ac**
Ratified	1997	1999	1999	2003	2010	**2013**
Frequency Band	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz	2.4 GHz–5 GHz	**5 GHz**
No. of Channels	3	3	Up to 23	3	Varies	**Varies**
Transmission	IR, FHSS, DSSS	DSSS	OFDM	DSSS OFDM	DSSS, CCK, OFDM	**OFDM**
Data Rates (Mbps)	1, 2	1, 2, 5.5, 11	6, 9, 12, 18, 24, 36, 48, 54	1, 2, 5.5, 11 6, 9, 12, 18, 24, 36, 48, 54	100+	**1000+**

I mentioned earlier that 802.11b runs DSSS, whereas 802.11g and 802.11a both run the OFDM modulation technique (802.11ac runs up to OFDM 256-QAM).

Range Comparisons

Now let's take a look at Figure 12.7, which delimits the range comparisons of each 802.11 standard and shows these different ranges using an indoor open-office environment as a factor. (We'll be using default power settings.)

FIGURE 12.7 Range comparisons of 802.11 standards



You can see that to get the full 54 Mbps benefit of both 802.11a and 802.11g, you need to be between 50 feet and 100 feet (maximum) away, which will likely be even less if there happen to be any obstructions between the client and the access point. 802.11n gives more distance than all three standards shown in the figure (up to twice the distance), and understand that 802.11ac just won't give you more distance than 802.11n.

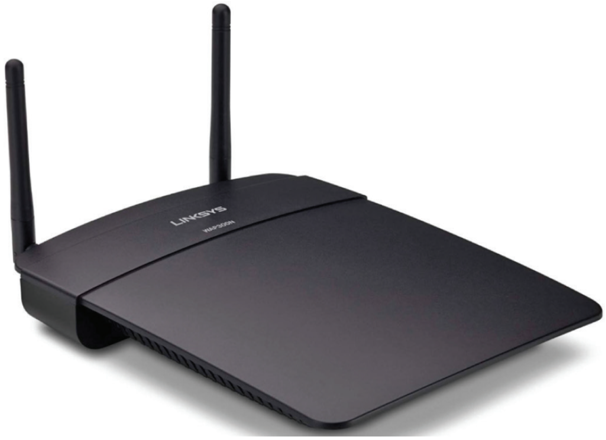
Wireless Network Components

Though it might not seem this way to you right now, wireless networks are less complex than their wired cousins because they require fewer components. To make a wireless network work properly, all you really need are two main devices: a wireless access point and a wireless NIC, the latter of which is typically built into your laptop. This also makes it a lot easier to install a wireless network because, basically, you just need an understanding of these two components in order to do so.

Wireless Access Points

You'll find a central component—like a hub or switch—in the vast majority of wired networks that serves to connect hosts together and allow them to communicate with each other. It's the same idea with wireless networks. They also have a component that connects all wireless devices together, only that device is known as a *wireless access point (WAP)*, or just AP. Wireless access points have at least one antenna (typically two for better reception—a solution called *diversity*, and up to eight to support 802.11ac) and an Ethernet port to connect them to a wired network. Figure 12.8 shows an example of a typical wireless access point.

FIGURE 12.8 A wireless access point



You can even think of an AP as a bridge between the wireless clients and the wired network. In fact, an AP can be used as a wireless bridge (depending on the settings) to bridge two wired network segments together.

In addition to the stand-alone AP, there is another type of AP that includes a built-in router, which you can use to connect both wired and wireless clients to the Internet (the most popular home brand being Linksys, a division of Cisco). In summation, an AP can operate as a repeater, bridge (switch), or router, depending on its hardware and its implementation.

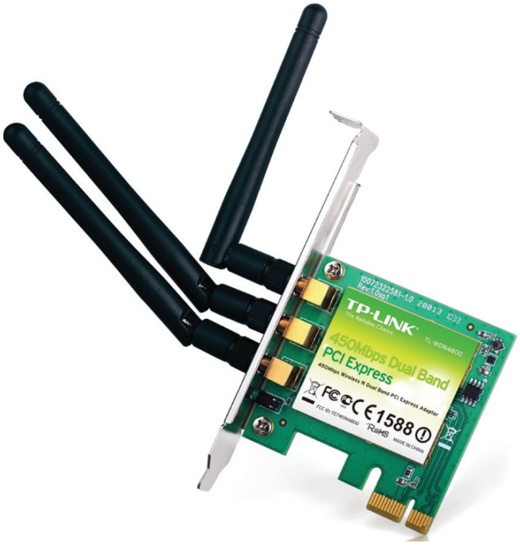
These devices are usually known as (surprise) wireless routers. They're usually employed as Network Address Translation (NAT) servers by using the one ISP-provided global IP address to multiplex numerous local IP addresses that are generally doled out to inside clients by the wireless router from a pool within the 192.168.*x*.*x* range.

Wireless Network Interface Card

Every host that wants to connect to a wireless network needs a wireless *network interface card (NIC)* to do so. Basically, a wireless NIC does the same job as a traditional NIC, but instead of having a socket to plug some cable into, the wireless NIC has a radio antenna. In addition to the different types of wireless networking (I'll talk about those in a minute), wireless NICs (like other NICs) can differ in the type of connection they use to connect to the host computer.

Figure 12.9 shows an example of a wireless NIC.

FIGURE 12.9 A wireless NIC



The wireless card shown in Figure 12.9 is used in a desktop PC. There are various options for laptops as well. All new laptops have wireless cards built into the motherboard.

NOTE These days, it's pretty rare to use an external wireless client card because all laptops come with them built in, and desktops can be ordered with them too. But it's good to know that you can still buy the client card shown in Figure 12.9. Typically, you would use cards like the one shown in the figure for areas of poor reception because they can have a better range—depending on the antenna you use, or because you want to upgrade the built-in card to 802.11n/ac.

Wireless Antennas

Wireless antennas act as both transmitters and receivers. There are two broad classes of antennas on the market today: *Omni directional* (or point-to-multipoint) and *directional,* or *Yagi* (point-to-point). Yagi antennas usually provide greater range than Omni antennas of equivalent gain. Why? Because Yagis focus all their power in a single direction, whereas Omnis must disperse the same amount of power in all directions at the same time. A downside to using a directional antenna is that you've got to be much more precise when aligning communication points. This is why a Yagi is really only a good choice for point-to-point bridging of access points. It's also why most APs use Omnis, because often, clients and other APs could be located in any direction at any given moment.

To get a picture of this, think of the antenna on your car. Yes, it's a non-networking example, but it's still a good one because it clarifies the fact that your car's particular orientation doesn't affect the signal reception of whatever radio station you happen to be listening to. Well, most of the time, anyway. If you're in the boonies, you're out of range—something that also applies to the networking version of Omnis.

The television aerials that *some* of us are old enough to remember rotating into a specific direction for a certain channel are examples of Yagi antennas. (How many of you labeled your set-top antenna dial for the actual TV stations you could receive?) Believe it or not, they still look the same to this day!

Both Omnis and Yagis are rated according to their signal gain with respect to an actual or theoretical laboratory reference antenna. These ratings are relative indicators of the corresponding production antenna's range. Range is also affected by the bit rate of the underlying technology, with higher bit rates extending shorter distances. Remember, a Yagi will always have a longer range than an equivalently rated Omni, but as I said, the straight-line Yagi will be very limited in its coverage area.

Both antennas are also rated in units of decibel isotropic (dBi) or decibel dipole (dBd), based on the type of reference antenna (isotropic or dipole) of equivalent frequency that was initially used to rate the production antenna. A positive value for either unit of measure represents a gain in signal strength with respect to the reference antenna. *Merriam-Webster* defines *isotropic* as "exhibiting properties (as velocity of light transmission) with the same values when measured along axes in all directions." Isotropic antennas are not able to be produced in reality, but their properties can be engineered from antenna theory for reference purposes.

As a practical example, I'm going to use the Cisco Systems series of Aironet access point (indoor) and bridge (outdoor) antennas. Table 12.3 describes the effect that gain ratings and attempted bit rates have on range limitations.

TABLE 12.3 Wireless antenna types and ranges

Model	Gain	Indoor range at 1 Mbps	Indoor range at 11 Mbps	Outdoor range at 2 Mbps	Outdoor range at 11 Mbps
AIR-ANT2410Y-R	10 dBi	800 ft	230 ft	Not specified	Not specified
AIR-ANT1728	5.2 dBi	497 ft	142 ft	Not specified	Not specified
AIR-ANT4941	2.2 dBi	350 ft	130 ft	Not specified	Not specified
AIR-ANT2506	5.2 dBi	Not specified	Not specified	5,000 ft	1,580 ft
AIR-ANT24120	12 dBi	Not specified	Not specified	24,288 ft	7,392ft

It's pretty much a given that antennas operating with frequencies below 1 GHz are measured in dBd while those operating above 1 GHz are measured in dBi. But because this rule doesn't always work definitively, sometimes we have to compare the strength of one antenna measured in dBd with another measured in numerically equivalent dBi in order to determine which one is stronger. This is exactly why it's important to know that a particular numerical magnitude of dBd is more powerful than the same numerical magnitude of dBi.

I know this sounds pretty complicated, but because the relationship between these two values is linear, it really makes the conversion a lot easier than you might think. Here's how it works: At the same operating frequency, a dipole antenna has about 2.2 dB gain over a 0 dBi theoretical isotropic antenna, which means you can easily convert from dBd to dBi by adding 2.2 to the dBd rating. Conversely, subtract 2.2 from the dBi rating and you get the equivalent dBd rating.

Armed with what you've learned about the difference between Omni and Yagi antennas and the difference between dBd and dBi gain ratings, you should be able to compare the relative range of transmission of one antenna with respect to another based on a combination of these characteristics. For example, the following four antenna ratings are given in relative order from greatest to least range:

- 7 dBd Yagi (equivalent to a 9.2 dBi Yagi)
- 7 dBi Yagi (longer range than 7 dBi Omni)
- 4.8 dBd Omni (equivalent to a 7 dBi Omni)
- 4.8 dBi Omni (equivalent to a 2.6 dBd Omni)

NOTE If you're having an intermittent problem with hosts connecting to the wireless network and varying signal strengths at different locations, check the location of your antennas in the office or warehouse to make sure you're getting the best coverage possible.

So now that you understand the basic components involved in a wireless network, it's time to use what you learned about the standards we use in our everyday home and corporate wireless networks and the different ways that they're actually installed.

Installing a Wireless Network

Let's say you just bought a wireless AP for your laptop to use to connect to the Internet. What's next? Well, that all depends on the type of installation you want to create with your new toys. First, it's important you understand where to place the AP. For example, you don't want to place the AP on or near a metal filing cabinet or other obstructions. Once you decide on the AP's placement, you can configure your wireless network.

There are two main installation types, ad hoc and infrastructure mode, and each 802.11 wireless network device can be installed in one of these two modes, also called *service sets*.

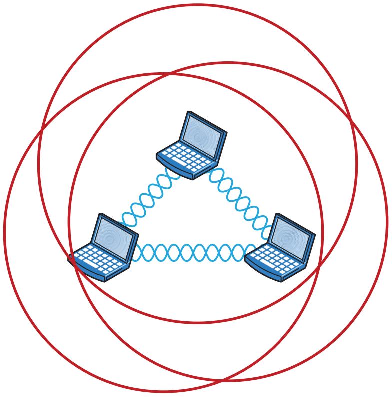
Ad Hoc Mode: Independent Basic Service Set

This is the easiest way to install wireless 802.11 devices. In this mode, the wireless NICs (or other devices) can communicate directly without the need for an AP. A good example of this is two laptops with wireless NICs installed. If both cards were set up to operate in ad hoc mode, they could connect and transfer files as long as the other network settings, like protocols, were set up to enable this as well. We'll also call this an *independent basic service set (IBSS)*, which is created as soon as two wireless devices communicate.

To set up a basic ad hoc wireless network, all you need are two wireless NICs and two computers. First (assuming they aren't built in), install the cards into the computers according to the manufacturer's directions. During the software installation, you'll be asked if you want to set up the NIC in ad hoc mode or infrastructure mode. For an ad hoc network, you would obviously go with the ad hoc mode setting. Once that's done, all you've got to do is bring the computers within range (90–100 m) of each other, and voilà—they'll "see" each other and be able to connect to each other.

Figure 12.10 shows an example of an ad hoc wireless network. (Note the absence of an access point.)

FIGURE 12.10 A wireless network in ad hoc mode



An ad hoc network would not scale well and really is not recommended due to collision and organization issues. With the low costs of APs, this type of network is just not needed today.

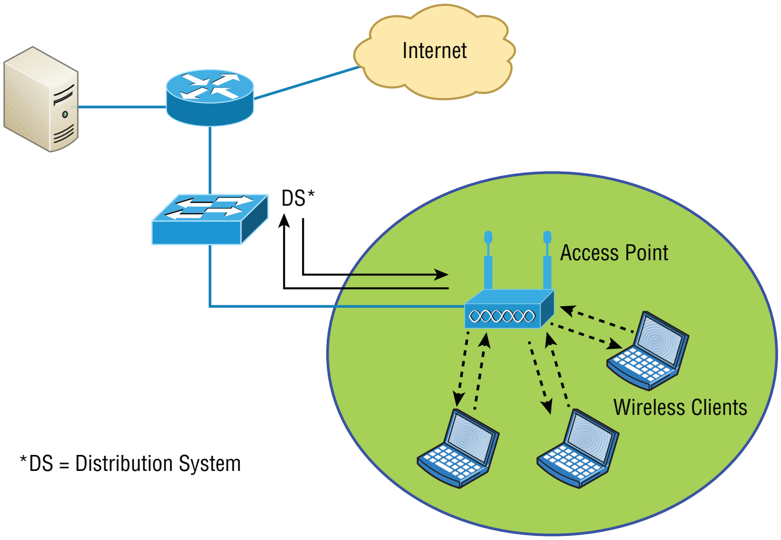
Infrastructure Mode: Basic Service Set

The most common use of wireless networking equipment is to give us the wireless equivalent of a wired network. To do this, all 802.11 wireless equipment has the ability to operate in what's known as infrastructure mode, also referred to as a *basic service set (BSS)*, which is provided by an AP. The term *basic service area (BSA)* is also used at times to define the area managed by the AP, but *BSS* is the most common term used to define the cell area.

In infrastructure mode, NICs communicate only with an access point instead of directly with each other as they do when they're in ad hoc mode. All communication between hosts, plus with any wired portion of the network, must go through the access point. A really important fact to remember is that in this mode, wireless clients actually appear to the rest of the network as though they were standard, wired hosts.

Figure 12.11 shows a typical infrastructure mode wireless network. Pay special attention to the access point and the fact that it's also connected to the wired network. This connection from the access point to the wired network is called the *distribution system (DS)* and is referred to as wireless bridging.

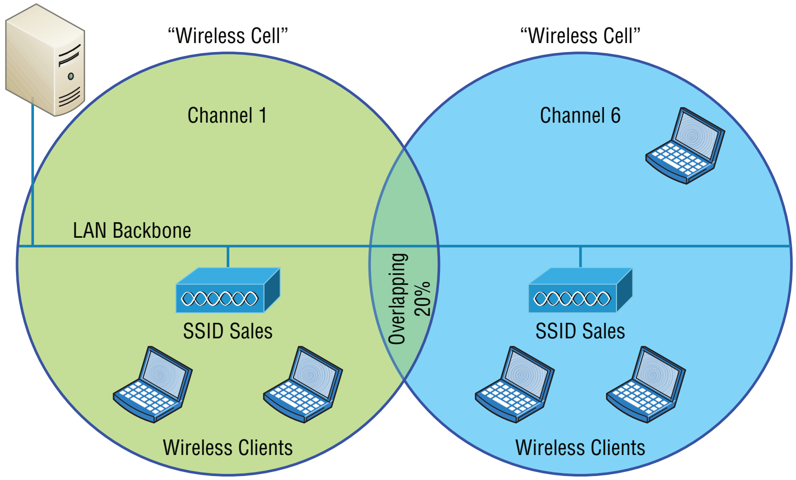
FIGURE 12.11 A wireless network in infrastructure mode



When you configure a client to operate in wireless infrastructure mode, you need to understand a couple of basic wireless concepts—namely, SSID and security. The *service set identifier (SSID)* refers to the unique 32-character identifier that represents a particular wireless network and defines the basic service set. Oh, and by the way, a lot of people use the terms *SSID* and *BSS* interchangeably, so don't let that confuse you! All devices involved in a particular wireless network must be configured with the same SSID.

Good to know is that if you set all your access points to the same SSID, mobile wireless clients can roam around freely within the same network. Doing this creates an *extended service set (ESS)* and provides more coverage than a single access point. Figure 12.12 shows two APs configured with the same SSID in an office, thereby creating the ESS network.

FIGURE 12.12 Extended service set (ESS)



For users to be able to roam throughout the wireless network—from AP to AP without losing their connection to the network—all AP signal areas must overlap by 10 percent of their signal or more. To make this happen, be sure the channels on each AP are set differently. And remember, in an 802.11b/g network, there are only three non-overlapping channels (1, 6, 11), so careful design is super important here!

Wireless Controllers

You'd be hard pressed to find an enterprise WLAN that doesn't use wireless controllers. In fact, every wireless enterprise manufacturer has a controller to manage the APs in the network.

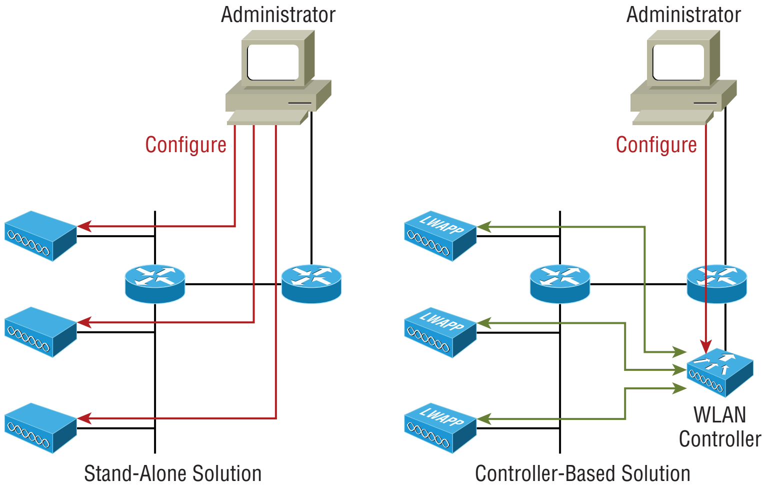
By looking at Figure 12.13, you can see the difference between what we call stand-alone APs and the controller solution. In a stand-alone solution, all the APs have a full operating system loaded and running, and each must be managed separately.

In the controller-based system, the APs are what we refer to as lightweight, meaning they do not have a full operating system running on them. The controller and AP split duties—a solution known as *split MAC*. APs running with a controller are referred to as lightweight, but you'll also hear the term *thin AP*, whereas you'll hear the term *thick* when referring to APs that run a full OS.

Take another look at Figure 12.13. You can also see that the administrator isn't managing each AP independently when using the WLAN controller solution. Instead, the administrator configures the controller, which in turn pushes out the configuration needed for each AP. Controllers allow us to design and implement larger enterprise wireless networks with less time and tedium, which is very important in today's world!

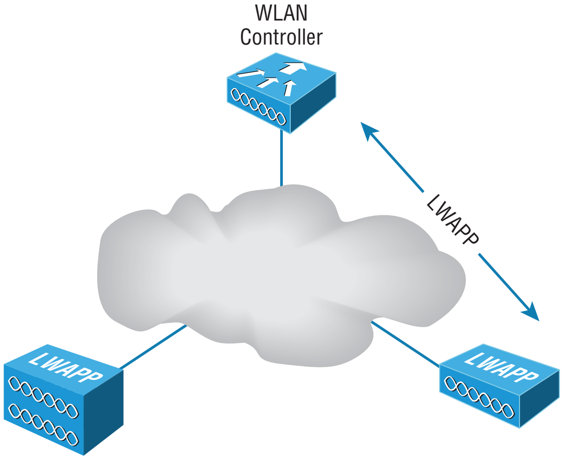
One feature that also gives controllers the ability to provide a great solution is when you're dealing with a location that's overloaded with clients because it utilizes VLAN pooling, or virtual LAN pooling. This is very cool because it allows you to partition a single large wireless broadcast domain into multiple VLANs and then either statically or randomly assign clients into a pool of VLANs. So, all clients get to keep the same SSID and stay connected to the wireless network, even when they roam. They're just in different broadcast domains.

FIGURE 12.13 Stand-alone and controller-based wireless networks



In order for split MAC to work in a wireless controller network, the APs and controller run a protocol to enable them to communicate. The proprietary protocol that Cisco used was called Lightweight Access Point Protocol (LWAPP), and it's pictured in Figure 12.14.

FIGURE 12.14 LWAPP



Keep in mind that LWAPP isn't used too much these days, but a newer, more secure protocol called Control and Provisioning of Wireless Access Points (CAPWAP), which also happens to be nonproprietary, has replaced it to become the standard that most controller manufacturers use today.

Mobile Hot Spots

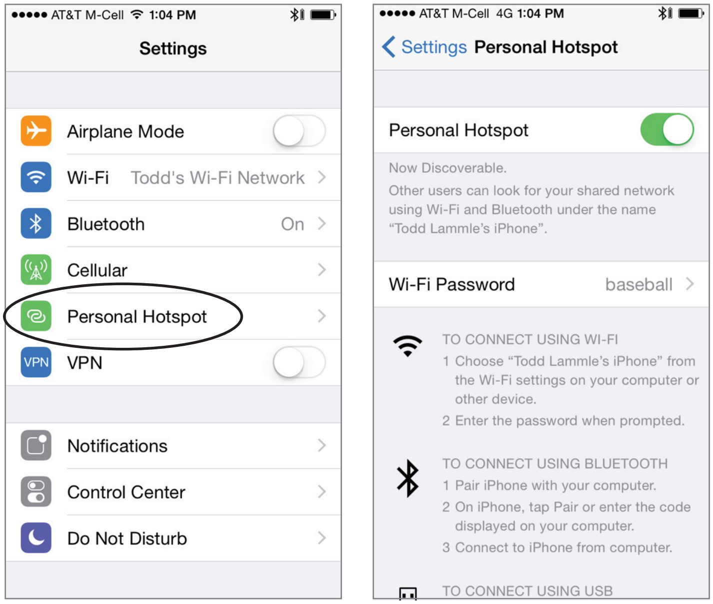
Let's say you're in a location that doesn't have an AP installed, or they want to charge you for access, and you want to connect your laptop, tablet, or even play a game. What can you do?

You've got a couple of options, but they all include the cellular network as an infrastructure. Not to be an ad for AT&T, but Figure 12.15 shows a mobile hot spot device that connects your laptop, tablet, media devices, or even a gaming device to the Internet at decent speeds. Pretty much all cellular vendors sell a version of these hot spots now.

FIGURE 12.15 Mobile hot spot

But let's say you don't want to carry yet another device around with you and you just want to use your phone instead. Figure 12.16 shows how I turned my iPhone into an AP for my laptop. First I went to Settings and then chose Personal Hotspot. If that option doesn't show up for you, just give a quick shout to your carrier and have it enabled.

FIGURE 12.16 iPhone hot spot



●●●●● AT&T M-Cell 1:04 PM

Settings

Airplane Mode
Wi-Fi Todd's Wi-Fi Network >
Bluetooth On >
Cellular >
Personal Hotspot >
VPN

Notifications >
Control Center >
Do Not Disturb >

●●●●● AT&T M-Cell 4G 1:04 PM

< Settings Personal Hotspot

Personal Hotspot

Now Discoverable.
Other users can look for your shared network using Wi-Fi and Bluetooth under the name "Todd Lammle's iPhone".

Wi-Fi Password baseball >

TO CONNECT USING WI-FI
1 Choose "Todd Lammle's iPhone" from the Wi-Fi settings on your computer or other device.
2 Enter the password when prompted.

TO CONNECT USING BLUETOOTH
1 Pair iPhone with your computer.
2 On iPhone, tap Pair or enter the code displayed on your computer.
3 Connect to iPhone from computer.

TO CONNECT USING USB

I pay very little to AT&T for my AP capability, but I still have to pay for my usage, so I use it only when I'm someplace like an airport and I want security without paying for access to their Internet wireless. Airport wireless hot spots are notoriously slow anyway, and you'd be dead in the water if you intend to use this type of wireless networking for something like gaming, which requires a ton of bandwidth!

Signal Degradation

Something that's really important to consider when installing a wireless network is signal degradation. Because the 802.11 wireless protocols use radio frequencies, the signal strength varies according to many factors. The weaker the signal, the less reliable the network connection will be and so the less usable as well. (Think dropped calls!) There are several key factors that affect signal strength:

Distance This one is definitely on the obvious side—the farther away from the WAP you get, the weaker the signal you get. Most APs have a very limited maximum range that equals less than 100 meters for most systems. You can extend this range to some degree using amplifiers or repeaters, or even by using different antennas.

Walls and Other Barriers Also easy to imagine is the fact that the more walls and other office barriers a wireless signal has to pass through, the more attenuated (reduced) the signal becomes. Also, the thicker the wall, the more it interrupts the signal. So in an indoor office area with lots of walls, the range of your wireless network could be as low as 25 feet! You really have to be careful where you place your APs!

Protocols Used This one isn't so apparent, but it certainly is a factor that affects, and can even determine, the range of a wireless LAN. The various wireless 802.11 protocols have different maximum ranges. As discussed earlier, and illustrated in Figure 12.7, the maximum effective range varies quite a bit depending on the 802.11 protocol used. For example, if you have a client running the 802.11g protocol but it connects to an AP running only the 802.11b protocol, you'll only get a throughput of 11 Mbps to the client.

Interference The final factor that affects wireless performance is outside interference. Because 802.11 wireless protocols operate in the 900 MHz, 2.4 GHz, and 5 GHz ranges, interference can come from many sources. These include wireless devices like Bluetooth, cordless telephones, cell phones, other wireless LANs, and any other device that transmits a radio frequency (RF) near the frequency bands that 802.11 protocols use. Even microwave ovens—a huge adversary of 802.11b and 802.11g—can be serious culprits!

Other Network Infrastructure Implementations

We've discussed the wireless LANs (WLANs) created by installing APs, but there are other technologies like personal area networks (PANs), which create wireless infrastructures too. By far, the best known is the ever-popular Bluetooth, but there are other wireless technologies we can use as well, and we'll take some time to explore these soon.

For now, it's back to Bluetooth, which happens to have a fantastic history behind it! The technology was actually named after a fabled 10th century Viking king, Harald I (Harald

“Blatand” Gormsson), who was faced with the challenge of dealing with many disparate tribes; he needed to communicate with them all and they needed to get along with each other. Blatand, who it’s said got his unique nickname due to sporting an unfortunately prominent blue tooth, was having a really tough time getting this to happen. However, the Viking king was a famously great diplomat possessing a wonderful way with words, and he effectively and nonviolently united ancient Norway and Denmark into a single territory via his powerful communication skills. Incidentally, *Blatand* just happens to translate into *Bluetooth* in English.

Fast-forward to modern times and a Scandinavian company called Ericsson and a highly gifted, technological innovator, Jim Kardach. As one of the founders of Bluetooth, Kardach’s challenge was a decent, modern-day analogy of the ancient Viking king’s—he was faced with making disparate phones, computers, and other devices communicate and cooperate effectively. To answer the challenge, Kardach came up with an elegant, technological wireless solution to make all these disparate devices communicate and play well with each other. To come up with an equally cool name for the brilliant innovation, he did some research, discovered the legend of the ancient Viking king, and codenamed the new technology Bluetooth. It stuck! Now all that was left was to create a super slick logo for it. Today’s Bluetooth icon is actually the legendary king’s initials in ancient Viking runes merged together—how cool is that?

Bluetooth operates in the 2.4 GHz range, so while it can cause some interference with 802.11b/g, it’s really low power. Plus, the electronics in our WLANs are much better today than they were in the past, so it really isn’t much of an issue anymore, and so at last, modern wireless communication works nicely for us today, making our technological lives so much easier!

To delve a little deeper into wireless technologies, the idea of PANs is to allow personal items such as keyboards, mice, and phones to communicate to our PC/laptop/display/TV wirelessly instead of having to use any wires at all—over short distances of up to 30 feet, of course. This idea of the wireless office hasn’t quite come to fruition completely yet, but you have to admit that Bluetooth really has helped us out tremendously in our offices and especially in our cars!

There are two other network infrastructure implementations in the PAN area: infrared (IR) and near-field communication (NFC).

Like Bluetooth, IR has some history behind it, but the technology’s idea only goes back to about 1800 because that’s when it was first said that the energy from the sun radiates to Earth in infrared. We can use IR to communicate short range with our devices, like Bluetooth-enabled ones, but it isn’t really as popular as Bluetooth to use within network infrastructures. Unlike Wi-Fi and Bluetooth, the infrared wireless signals cannot penetrate walls and only work line-of-sight. Last, the rates are super slow and most transfers are only 115 Kbps—up to 4 Mbps on a really good day!

The last implementation I want to cover is called near-field communication (NFC). For NFC to work, the actual antenna must be smaller than the wavelength on both the transmitter and receiver. For instance, if you look at a 2.4 GHz or 5 GHz antenna, they are the exact length of one wavelength for that specific frequency. With NFC, the antenna is about one-quarter the size of the wavelength, which means that the antenna can create either an electric field or a magnetic field but not an electromagnet field.

NFC can be used for wireless communication between devices like smartphones and/or tablets, but you need to be near the device transmitting the RF to pick up the signal—really close. A solid example would be when you're swiping your phone over a QR code.

Technologies that facilitate the Internet of Things (IoT)

The Internet of Things (IoT) is the newest buzzword in IT and it means the introduction of all sorts of devices to the network (and Internet) that were not formerly there. Refrigerators, alarm systems, building service systems, elevators and power system are now equipped with networked sensors allowing us to monitor and control these system from the Internet.

These systems depend on several technologies to facilitate their operations. They can include the services in the following sections.

Z-Wave Z-Wave is a wireless protocol used for home automation. It uses a mesh network using low-energy radio waves to communicate from appliance to appliance. Residential appliances and other devices, such as lighting control, security systems, thermostats, windows, locks, swimming pools and garage door openers can use this system.

Ant+ ANT+ is another wireless protocol for monitoring sensor data such as a person's heart rate or a bicycle's tire pressure, as well as the control of systems like indoor lighting or a television set. ANT+ is designed and maintained by the ANT+ Alliance which is owned by Garmin.

Bluetooth Some systems use Bluetooth. Bluetooth was discussed earlier in this chapter.

NFC Some systems use Near Field Communications. NFC was discussed earlier in this chapter.

IR Some systems use Infrared. Infrared was discussed earlier in this chapter.

RFID While RFID may most known for asset tracking, it can also be used in the IoT. Objects are given an RFID tag, so that the object is uniquely identifiable. Also, an RFID tag allows the object to wirelessly communicate certain types of information.

Truly smart objects will be embedded with both an RFID tag and a sensor to measure data. The sensor may capture fluctuations in the surrounding temperature, changes in quantity, or other types of information.

802.11 Finally, 802.11 can also be used for this communication. 802.11 was discussed earlier in this chapter.

Installing and Configuring WLAN Hardware

As I said earlier, installing 802.11 equipment is actually fairly simple—remember that there are really only two main types of components in 802.11 networks: APs and NICs. Wireless NIC installation is just like installing any other network card, but nowadays most, if not all, laptops have wireless cards preinstalled, and that's as easy as it gets! And just as with connecting an Ethernet card to a LAN switch, you need the wireless network card to connect to an access point.

The AP installation can be fairly simple as well. Take it out of the box, connect the antenna(s) if necessary, connect the power, and then place the AP where it can reach the highest number of clients. This last part is probably the trickiest, but it really just involves a little common sense and maybe a bit of trial and error. Knowing that walls obstruct the signal means that putting the AP out in the open—even indoors—works better. And you also know it should be placed away from sources of RF interference, so putting it next to the microwave or phone system is probably a really bad idea too. Near a metal filing cabinet is also not so good. So just experiment and move your AP around to find the spot that gives you the best signal strength for all the clients that need to use it.

Now that you have the hardware installed, it's time to configure it, right? Let's get started.

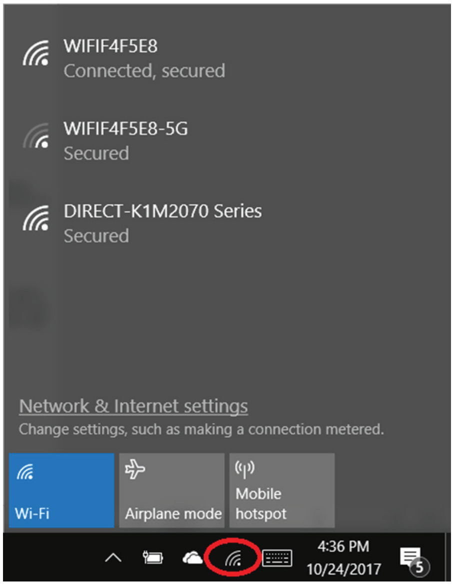
No worries—configuring your AP and NIC to work together isn't as tricky as it sounds. Most wireless equipment is designed to work almost without configuration, so by default, you can pretty much turn things on and start working. The only things you need to configure are customization settings (name, network address, and so on) and security settings, and even these aren't required. But because I do highly recommend configuring them, I'll take you through that now.

NIC Configuration

Windows XP, Windows Vista, Windows 7/8, and Windows Server 2003/2008/2012 include software to automatically configure a wireless connection, and they do so automatically when you install a wireless NIC—assuming that somehow you have a Windows machine without a wireless NIC installed on the motherboard. And if you have one without a NIC installed, your Windows machine is really old!

Configuring a Windows 10 client is pretty simple, but what do you if you can't get it to actually work afterward? If this happens to you, searching for the solution could eat up a serious amount of your time! Following these steps could save you from that frustrating quest:

1. To find a wireless network, just go to the lower-right corner of your screen and click the icon that looks like a wireless wave. You will see the box below



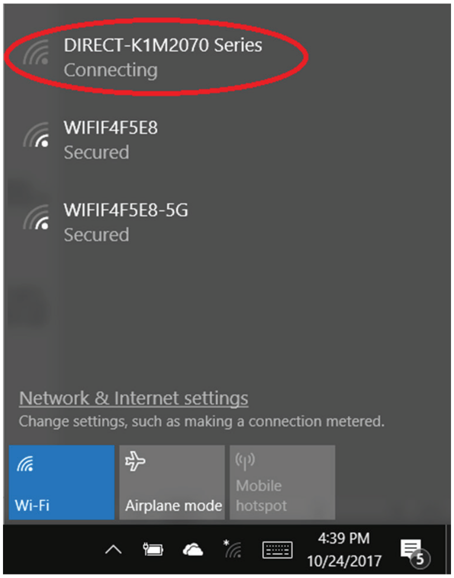
WIFIF4F5E8
Connected, secured

WIFIF4F5E8-5G
Secured

DIRECT-K1M2070 Series
Secured

Network & Internet settings
Change settings, such as making a connection metered.

2. Double-click the network you want to join, and click Connect Anyway, even if it's an unsecured network. You'll then see a screen showing that it's trying to connect.



DIRECT-K1M2070 Series
Connecting

WIFIF4F5E8
Secured

WIFIF4F5E8-5G
Secured

Network & Internet settings
Change settings, such as making a connection metered.

3. If you’re using security, the AP will ask you for your credentials.
4. Check your TCP/IP settings to find out if you’re not really connected to the Internet and troubleshoot from there.

AP Configuration

Once you’ve successfully configured your workstation(s), it’s time to move on and configure the AP. There are literally hundreds of different APs out there, and of course, each uses a different method to configure its internal software. The good news is that for the most part, they all follow the same general patterns:

1. First of all, out of the box, the AP should come configured with an IP address that’s usually something similar to 192.168.1.1. But check the documentation that comes with the AP to be sure. You can just take the AP out of its box, plug it into a power outlet, and connect it to your network, but in order to manage the AP, you’ve got to configure its IP address scheme to match your network’s.
2. You should receive a DHCP address from the AP when you connect, but if you don’t get one, start by configuring a workstation on the wired network with an IP address (192.168.1.2 or similar) and subnet mask on the same subnet as the AP’s. You should then be able to connect to the AP to begin the configuration process. Usually, you do this via a web browser or with a manufacturer-supplied configuration program.
3. Once you have successfully connected to the AP, you then get to configure its parameters.

   Following are the minimum parameters common to APs that you should configure for your AP to work properly. (Remember, typically, an AP works right out of the box, but it is unsecure too!)

SSID As I talked about earlier, this is the name of the wireless network that your AP will advertise. If this new AP is to be part of an existing wireless network, it needs to be configured with the same SSID as the existing network. In a network with only one AP, you can think of the SSID as the "name" of the AP.

AP IP Addresses Remember, even though most APs come preconfigured with an IP address, it may not be one that matches the wired network's IP addressing scheme. So it follows that you should configure the AP's IP addresses (including the address, subnet mask, and default gateway addresses) to match the wired network you want it connected to. An AP does not need an IP address to work in your network. The IP address of the AP is used only to manage the AP.

Operating Mode (Access Point or Bridging) Access points can operate in one of two main modes: *Access Point mode* or *Bridging mode*. Access Point mode allows the AP to operate as a traditional access point to allow a wireless client transparent access to a wired network. Alternatively, two APs set to Bridging mode provide a wireless bridge between two wired network segments.

Password Every access point has some kind of default password that's used to access the AP's configuration. For security reasons, it's a good idea to change this as soon as you can to connect to and configure the AP.

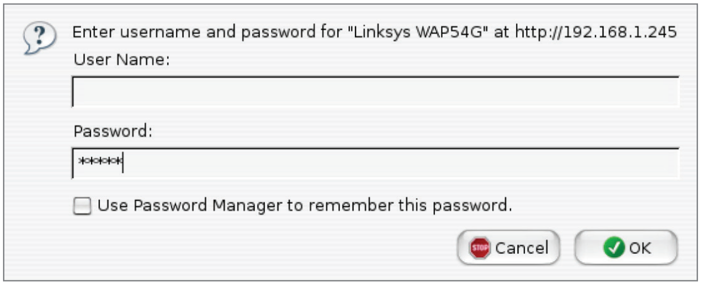
Wireless Channel 802.11 wireless networks can operate on different channels to avoid interference. Most wireless APs come set to work on a particular channel from the factory, and you can change it if other networks in the area are using that channel, but be aware that no particular channel is any more secure than another. Wireless stations do *not* use channel number as the criteria when seeking a connection. They only pay attention to SSIDs!

WEP/WPA Although it isn't a requirement per se, I definitely recommend enabling security right from the start as soon as you turn on the AP. Commercial APs typically come configured as an open network so that it's easy to log in, whereas enterprise APs come unconfigured and don't work until they are configured. WEP and Wi-Fi Protected Access (WPA) allow data to be encrypted before it's sent over the wireless connection, and all configuring entails is to enable it and pick a key to be used for the connections. Simple, easy-to-configure security is certainly worth your time!

So here's what you do: First, you'll be asked to enter one or more human-readable passphrases called *shared keys*—secret passwords that won't ever be sent over the wire. After entering each one, you'll generally click a button to initiate a one-way hash to produce a WEP key of a size related to the number of bits of WEP encryption you want. Entering the same passphrase on a wireless client causes the hash (not the passphrase) to be sent from the wireless client to the AP during a connection attempt. Most configuration utilities allow you to create multiple keys in case you want to grant someone temporary access to the network, but you still want to keep the primary passphrase a secret. You can just delete the key you enabled to permit temporary access after you don't need it anymore without affecting access by any primary LAN participants.

Here's an example of connecting to a Linksys access point (not a Linksys wireless router, which is a different device):

1. The first screen shows that I've connected using HTTP to configure the device. The IP address of the Linksys AP is 192.168.1.245. If it was a Linksys wireless router instead—the typical home DSL/cable modem wireless connection device around today—then the address would be 192.168.1.1.



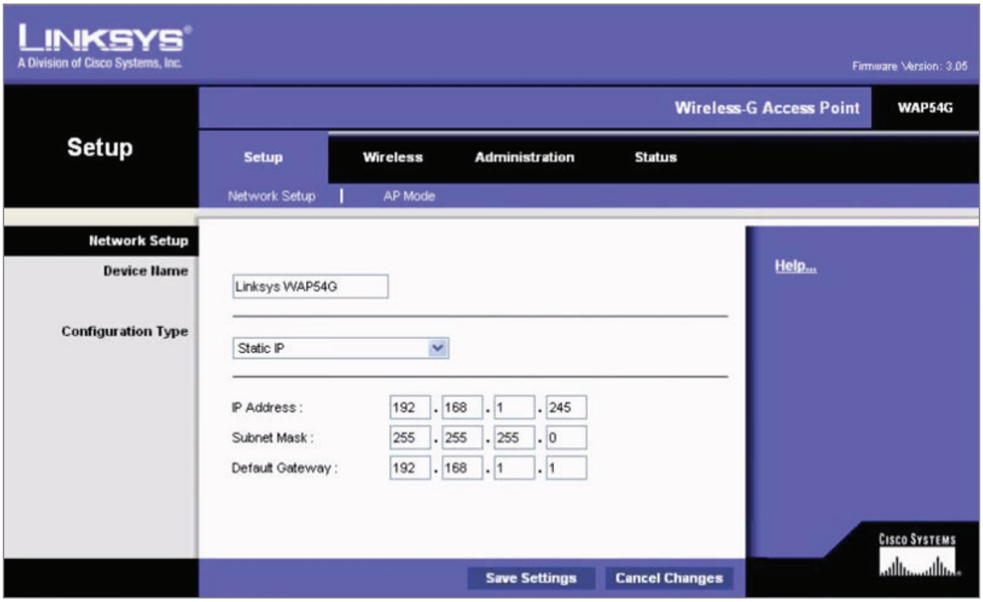
Enter username and password for "Linksys WAP54G" at http://192.168.1.245

User Name:

Password: *****

□ Use Password Manager to remember this password.

2. As you can see, there's no username required, and the password is just *admin*. Again, be sure not to leave this login configuration as the default! Once I click OK, I get taken to a screen where I can change my IP address.



Device Name: Linksys WAP54G

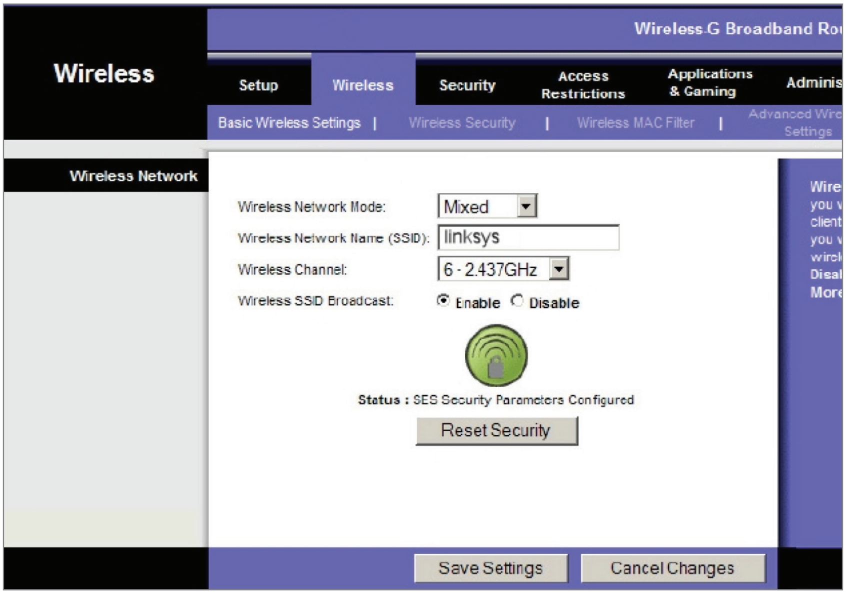
Configuration Type: Static IP

IP Address : 192 . 168 . 1 . 245

Subnet Mask : 255 . 255 . 255 . 0

Default Gateway : 192 . 168 . 1 . 1

3. It isn't vital for an AP to have an IP address, but it comes in handy for management purposes. You can change the IP address as well as the device name from this screen if you want to. I clicked the Wireless tab on top and this screen appeared.



Wireless Network Mode: Mixed

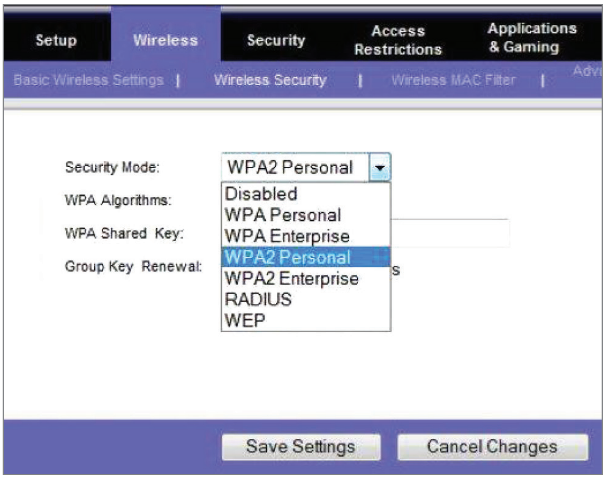
Wireless Network Name (SSID): linksys

Wireless Channel: 6 - 2.437GHz

Wireless SSID Broadcast: ● Enable ○ Disable

Status : SES Security Parameters Configured

4. From here, you can set the device to run b/g, only g, or even Mixed mode, which happens to be the default. You can also change the SSID from Linksys to another name, and I *highly* recommend doing this. The AP channel can also be changed, and you can turn off the AP beacons as well, which is also recommended, but understand that if you do this, you'll have to set the new SSID name in each of your clients! Last thing—you can see that by default, there's no encryption. Click the Wireless Security tab, and you'll get this screen.



Security Mode: WPA2 Personal

WPA Algorithms:

WPA Shared Key:

Group Key Renewal:

5. From the pull-down menu, you get to choose from various wireless security options if you want to.

I'll talk more about security after I hammer on about site surveys for a bit—they really are that important!

Site Survey

I want to be sure you're completely clear about where I stand regarding site surveys. They are absolutely and vitally imperative to bringing a premium-quality—even just a reasonably viable—WLAN into this world! You should carry out a predeployment survey and a postdeployment survey, but keep in mind that your predeployment survey isn't actually your first step to begin this key process.

So, because you positively must know how to formulate and implement a solid site survey, I'm going to walk you through executing the three major steps to doing that effectively. And just to be really thorough, I'm also going to cover some issues commonly encountered as we progress through these steps.

Information Gathering This is actually your first step, and during this stage, you must determine three key factors:

- The scope of the network, including all applications that will be used, data types that will be present, and how sensitive these data types are to delay
- The areas that must be covered and the expected capacity at each location
- The types of wireless devices that will need to be supported, such as, for example, laptops, iPads/iPhones, IP phones, and barcode readers

During this phase, a key goal of mine would be to create a coverage model that maps to all areas that need coverage, along with those that don't, and have my client sign off in agreement to this document before I do anything else. You definitely want to do this, too—just trust me!

Predeployment Site Survey In this phase, I use live APs to verify the optimal distances between their prospective locations. I base this placement on the expected speed at the edge of the cell, the anticipated number of devices, and other information gathered in step 1. Usually, after I get one AP positioned, I'll place the next one based on the distance from the first, with special consideration given to any sources of interference I've found.

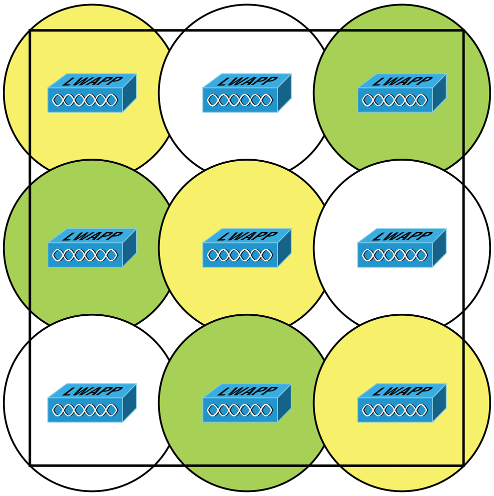
Postdeployment Site Survey I utilize the postdeployment survey phase to confirm and verify that the original design and placements are happily humming along, problem free, when all stations are using the network. This pretty much never happens, so at this point, it's likely changes will need to be made—sometimes, significant ones—in order to optimize the performance of a WLAN operating under full capacity.

Providing Capacity

Now here's a big issue that frequently rears its ugly head: providing enough capacity in areas where many wireless stations will be competing for the airwaves. Remember that stations share access to the RF environment with all other stations in the BSS, as well as with the AP, so really, the only way to increase capacity is by increasing the number of APs in an area requiring serious density.

This can get complicated, but basically it comes down to placing APs on non-overlapping channels while still sharing the same SSID. Take a look at Figure 12.17 for an example of this scenario.

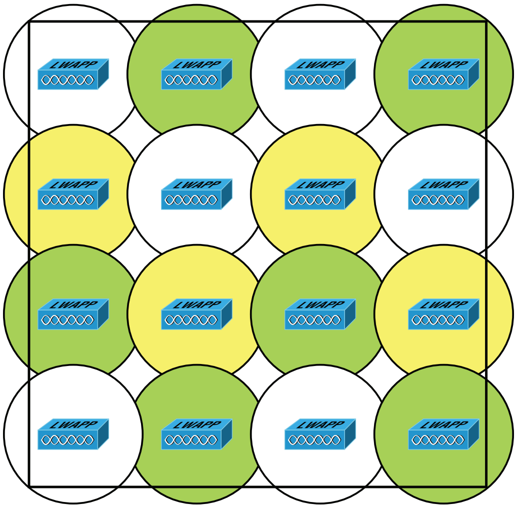
FIGURE 12.17 Basic coverage



In Figure 12.17, nine APs have been configured in the same area using the three non-overlapping channels in the 2.4 GHz frequency (1, 6, and 11). Each shade represents a different channel. Even though the APs on the same channel have been positioned far enough away from one another so that they don't overlap much and/or cause interference, surprisingly, it's actually better if there is some overlap. But bear in mind that the channels should be used in a way that no APs on the same channel overlap in a detrimental way. Another thing I want to point out that's not so ideal about this arrangement is that all the APs would have to run at full power. This isn't a good way to go because it doesn't give you much fault tolerance at all!

So, we've got two problems with our design: lack of overlap and lack of fault tolerance. To address both issues, you need more APs using 802.11a, b, and g, which would get you more channels and provide better throughput, as shown in Figure 12.18.

FIGURE 12.18 Enterprise design



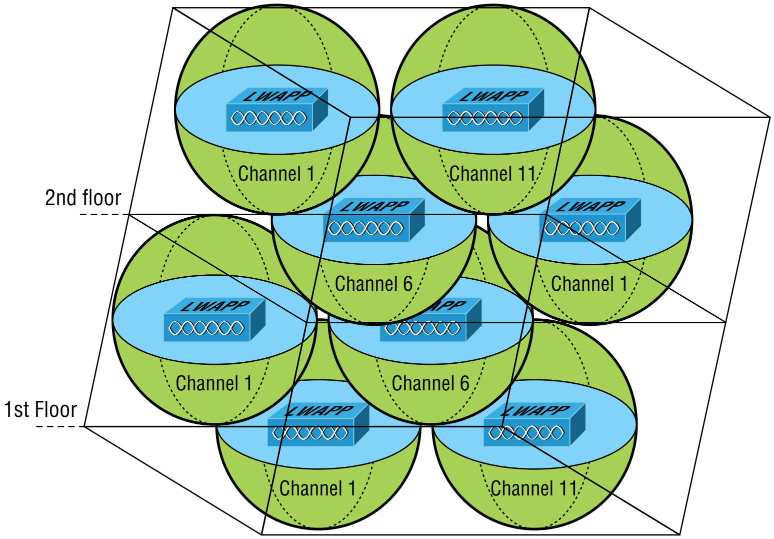
A key benefit to this design is it would also gain the critical ability to run the APs at less than full power. This allows the controller to strategically boost the power of specific APs in the event of an AP outage in a given area.

When you know exactly the type of applications and activity a WLAN will need to support, you can then determine the data rate that must be attained in a particular area. Since received signal strength indicator (RSSI), signal-to-noise ratio (SNR), and data rate are correlated, the required data rate will tell you what the required RSSI or SNR should be as seen at the AP from the stations. Keep in mind that stations located at the edge of the cell will automatically drop the data rate and that the data rate will increase as a station moves toward the AP.

Multiple Floors

Another special challenge is a multistory building where WLANs are located on all floors. In these conditions, you've got to think about channel usage in a three-dimensional way, and you'll have to play nicely with the other WLANs' administrators to make this work! Facing this scenario, your channel spacing should be deployed, as shown in Figure 12.19.

FIGURE 12.19 A multifloor installation



To prevent bleed from one floor to another, use semi-directional or patch antennas to control radiation patterns.

Location-Based WLAN

When using a location device such as the Cisco 2710, your restrictions get even tighter. The additional requirements for the location device to operate properly are as follows:

- APs should be placed at the edge even when they're not needed there for normal coverage purposes so that devices at the edge can be located.
- The density of APs must be higher. Each AP should be 50 to 70 feet apart—much closer than is normally required.
- Some APs will need to be set in monitor or scanner mode so that they won't transmit and interfere with other APs.

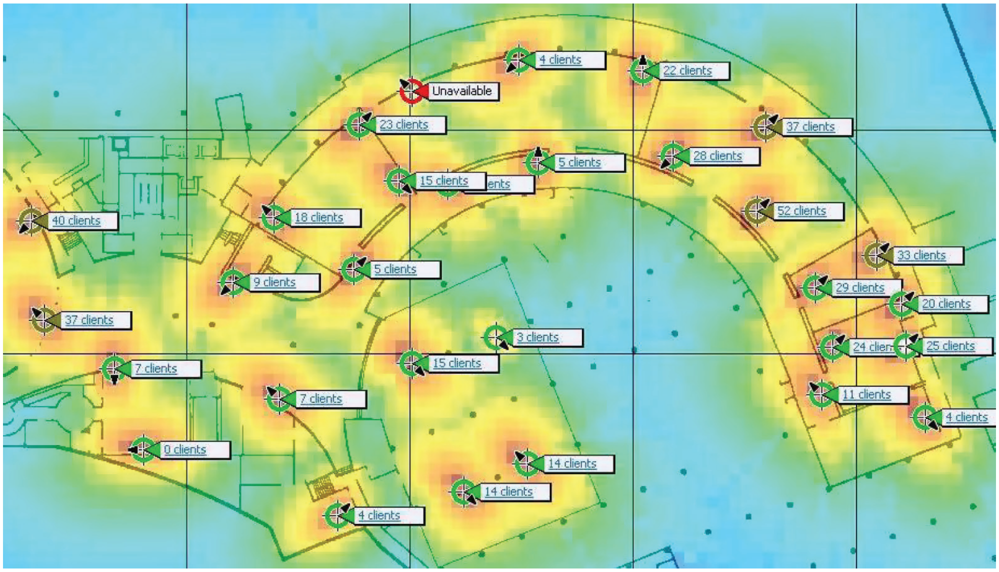
All of this means that the final placement will be denser and a bit more symmetrical than usual.

Site Survey Tools

As I touched upon at the beginning of our site survey section, there are some highly specialized, very cool site survey tools that can majorly help you achieve your goals. The AirMagnet Survey and Ekahau Site Survey tools make it possible to do a client walk-through with the unit running and you can click each location on the map.

These tools will gather RSSI and SNR from each AP in the range, and at the end of your tour, global heat map coverage will be magically displayed, as shown in Figure 12.20.

FIGURE 12.20 A heat map of a building



Wireless Security

So, wireless security is basically nonexistent on access points and clients. The original 802.11 committee just didn't imagine that wireless hosts would one day outnumber bounded media hosts, but that's actually where we're headed now. Also, unfortunately, just as with the IPv4 routed protocol, engineers and scientists didn't include security standards that are robust enough to work in a corporate environment. So we're left with proprietary solution add-ons to aid us in our quest to create a secure wireless network. And no—I'm not sitting here bashing the standards committees, because the security problems we're experiencing were also created by the U.S. government because of export issues with its own security standards. Our world is a complicated place, so it follows that our security solutions would have to be as well.

Wireless Threats

Protection of data and the authentication processes are certainly key threats, but there are other wireless security perils lurking out there as well. We'll dive deeper into the processes and procedures designed to mitigate these dangers in Chapter 14, but l want to briefly discuss them here.

Rogue APs

First, there's the evil we call rogue APs. These are APs that have been connected to your wired infrastructure without your knowledge. The rogue may have been placed there by a determined hacker who snuck into your facility and put it in an out-of-the-way location or, more innocently, by an employee who just wants wireless access and doesn't get just how dangerous doing this is. Either way, it's just like placing an open Ethernet port out in the parking lot with a sign that says "Corporate LAN access here—no password required!"

Clearly, the worst type of rogue AP is the one some hacker has cleverly slipped into your network. It's particularly nasty because the bad guy probably didn't do it to simply gain access to your network. Nope—the hacker likely did it to entice your wireless clients to disastrously associate with their rogue AP instead! This ugly trick is achieved by placing their AP on a different channel from your legitimate APs and then setting its SSID in accordance with your SSID. Wireless clients identify the network by the SSID, not the MAC address of the AP or the IP address of the AP, so jamming the channel that your AP is on will cause your stations to roam to the bad guy's AP instead. With the proper DHCP software installed on the AP, the hacker can issue the client an address, and once that's been done, the bad guy has basically "kidnapped" your client over to their network and can freely perform a peer-to-peer attack. Believe it or not, this can all be achieved from a laptop while Mr. Hacker simply sits in your parking lot, because there are many types of AP software that will run on a laptop—yikes!

Mitigation

But you're not helpless—one way to keep rogue APs out of the wireless network is to employ a wireless LAN controller (WLC) to manage your APs. This is a nice mitigation technique because APs and controllers communicate using Lightweight Access Point Protocol (LWAPP) or the newer CAPWAP, and it just so happens that one of the message types they share is called Radio Resource Management (RRM). Basically, your APs monitor all channels by momentarily switching from their configured channel and by collecting packets to check for rogue activity. If an AP is detected that isn't usually managed by the controller, it's classified as a rogue, and if a wireless control system is in use, that rogue can be plotted on a floor plan and located. Another great benefit to this mitigation approach is that it enables your APs to also prevent workstations from associating with the newly exposed rogue.

Ad Hoc Networks

As you already know, ad hoc networks are created peer to peer or directly between stations and not through an AP. This can be a dangerous configuration because there's no corporate security in place, and since these networks are often created by unsophisticated users, you end up with the scenario I just described that's primed for, and wide open to, a peer-to-peer attack. Even uglier, if the laptop happens to connect to the corporate LAN through an Ethernet connection at the same time the ad hoc network is created, the two connections could be bridged by a hacker to gain them access straight up into the wired LAN itself!

Mitigation

When you've got a Cisco Unified Wireless Network (CUWN) in operation, ad hoc networks can be identified over the air by the kind of frames they send, which are different from those belonging to an infrastructure network. When these frames are identified, the CUWN can prevent harmful intrusions by sending out something known as deauthentication frames to keep your stations from associating via ad hoc mode.

Denial of Service

Not all attacks are aimed at the goal of stealing information. Sometimes the hacker just wants to cause some major network grief, like jamming the frequency where your WLAN lives to cause a complete interruption of service until you manage to ferret out the jamming signal and disable it. This type of assault is known as a denial of service (DoS) attack.

Mitigation

And this is how we deal with them. First, if someone is jamming the frequency, there isn't much, if anything, you can do. However, many DoS, man-in-the-middle, and penetration attacks operate by deauthenticating, or disassociating, stations from their networks. Some DoS attacks take the form of simply flooding the wireless network with probe requests or association frames, which effectively makes the overwhelmed network unavailable for normal transmissions. These types of management frames are sent unauthenticated and unencrypted. Since deauthentication and disassociation frames are classified as management frames, the Management Frame Protection (MFP) mechanism can be used to prevent the deluge. There are two types of MFP you can use, referred to as infrastructure and client. Let's take a look at each of them now.

Infrastructure Mode

This sweet strategy doesn't require configuration on the station—only the AP. Controllers generate a specific signature for each WLAN, which is added to each management frame it sends, and any attempt to alter this is detected by the Message Integrity Check (MIC) in the frame. Therefore, when an AP receives a management frame from an unknown SSID, it reports the event to the controller and an alarm is generated.

When an AP receives an MFP protected frame from an unknown SSID, it queries the controller for the key. If the BSSID isn't recognized by the controller, it will return an "unknown BSSID" message, which causes the AP to drop the frame.

Client Mode

Often rogue APs attempt to impersonate the company AP. With client MFP, all management frames between the AP and the station are protected because clients can detect and drop spoofed or invalid management frames.

Passive Attacks

So far, the attacks I've talked about are in a category referred to as active attacks because in deploying them, the hacker is interacting with stations, the AP, and the network in real time. But beware—there are other ways into the fort!

Passive attacks are most often used to gather information to be used in an active attack a hacker is planning to execute later, and they usually involve wireless sniffing. During a passive attack, the hacker captures large amounts of raw frames to analyze online with sniffing software used to discover a key and decrypt it "on the fly." Or the data will be analyzed offline, which simply means the bad guy will take the data away and analyze it later.

Mitigation

In addition to the tools already described, you can use an intrusion detection system (IDS) or an intrusion protection system (IPS) to guard against passive attacks:

IDS An intrusion detection system (IDS) is used to detect several types of malicious behaviors that can compromise the security and trust of your system. These malicious behaviors include network attacks against vulnerable services; data-driven attacks on applications; host-based attacks like privilege escalation; unauthorized logins; access to sensitive files; and malware like viruses, Trojan horses, and worms.

IPS An intrusion prevention system (IPS) is a computer security device that monitors network and/or system activities for malicious or unwanted behavior and can react, in real time, to block or prevent those activities. For example, a network-based IPS will operate inline to monitor all network traffic for malicious code or attacks. When either is detected, it can drop the offending packets while still allowing all other traffic to pass.

Which approach you'll opt to go with depends on the size of your wireless network and how tight your security needs to be. The goal of a security mechanism is to provide three features:

- Confidentiality of the data
- Data integrity
- An assured identification process

And when faced with decisions about security, you need to consider these three things:

- The safety of the authentication process
- The strength of the encryption mechanism
- Its ability to protect the integrity of the data

Real World Scenario

War Driving

It's a fact—wireless networks are pretty much everywhere these days. You can get your hands on a wireless access point for less than $100.00, and they're flying off the shelves. You can find APs in public places like shopping malls, coffee shops, airports, and hotels, and in some cities, you can just hang out in a downtown area and zero in on a veritable menu of APs operating in almost every nearby business.

Predictably, this proliferation of APs has led to a new hobby for those with enough skill: It's called *war driving*. Not for the technologically challenged, war driving involves driving around in a car with a laptop, a wireless NIC, and a high-gain antenna, trying to locate open APs. If one with high-speed Internet access is found, it's like hitting the jackpot. People do this aided by various software programs and Global Positioning Systems (GPSs) to make their game even easier. But it's not always innocent—war drivers can be a serious security threat because they can potentially access anything on your wireless LAN as well as anything it's attached to! Even though they're not a sinister threat most of the time, realize that in the very least, they're consuming precious resources from your network. So, if you happen to notice unusually slow-moving vehicles outside your home or business—especially those with computer equipment inside—know that you're the potential target of a war driver.

A good place to start discussing Wi-Fi security is by talking about the basic security that was incorporated into the original 802.11 standards and why those standards are still way too flimsy and incomplete to help us create a secure wireless network relevant to today's challenges.

Open Access

All Wi-Fi Certified small-office, home-office (SOHO) wireless LAN products are shipped in "open-access" mode, with their security features turned off. Although open access or no security may be appropriate and acceptable for public hot spots such as coffee shops, college campuses, and maybe airports, it's definitely not an option for an enterprise organization, and it's probably not even adequate for your private home network.

With what I've told you so far, I'm sure you agree that security needs to be enabled on wireless devices during their installation in enterprise environments. Yet surprisingly, many companies actually don't enable any WLAN security features. Obviously, the companies that don't enable security features are exposing their networks to tremendous risk.

The reason that the products are shipped with open access is so that any person who knows absolutely nothing about computers can just buy an access point, plug it into their cable or DSL modem, and voilà—they're up and running. It's marketing, plain and simple, and simplicity sells.

Service Set Identifiers, Wired Equivalent Privacy, and Media Access Control Address Authentication

What the original designers of 802.11 did to create basic security was to include the use of SSIDs, open or shared-key authentication, static WEP, and optional *Media Access Control (MAC) authentication/MAC filtering*. Sounds like a lot, but none of these really offer any type of serious security solution—all they may be close to adequate for is use on a common home network. But we'll go over them anyway.

An SSID is a common network name for the devices in a WLAN system that create the wireless LAN. An SSID prevents access by any client device that doesn't have the SSID. The thing is, by default, an access point broadcasts its SSID in its beacon many times a second. And even if SSID broadcasting is turned off, a bad guy can discover the SSID by monitoring the network and just waiting for a client response to the access point. Why? Because, believe it or not, that information, as regulated in the original 802.11 specifications, must be sent in the clear—how secure!

If you cannot see an AP when trying to perform a site survey, verify that the AP has SSID beaconing enabled.

Two types of authentication were specified by the IEEE 802.11 committee: open authentication and shared-key authentication. Open authentication involves little more than supplying the correct SSID—but it's the most common method in use today. With shared-key authentication, the access point sends the client device a challenge-text packet that the client must then encrypt with the correct WEP key and return to the access point. Without the correct key, authentication will fail and the client won't be allowed to associate with the access point. But shared-key authentication is still not considered secure because all an intruder has to do to get around this is detect both the clear-text challenge and the same challenge encrypted with a WEP key and then decipher the WEP key. Surprise—shared key isn't used in today's WLANs because of clear-text challenge.

With open authentication, even if a client can complete authentication and associate with an access point, the use of WEP prevents the client from sending and receiving data from the access point unless the client has the correct WEP key. A WEP key is composed of either 40 or 128 bits, and in its basic form, it's usually statically defined by the network administrator on the access point and all clients that communicate with that access point. When static WEP keys are used, a network administrator must perform the time-consuming task of entering the same keys on every device in the WLAN. Obviously, we now have fixes for this because tackling this would be administratively impossible in today's huge corporate wireless networks!

Last, client MAC addresses can be statically typed into each access point, allowing MAC filtering, and any frames that show up to the AP without a known MAC address in the filter table will be denied access. Sounds good, but of course all MAC layer information must be sent in the clear—anyone equipped with a free wireless sniffer can just read the client packets sent to the access point and spoof their MAC address. If you have a small number of wireless clients and you don't want to deploy an encryption-based access method, MAC address filters may be sufficient.

NOTE

If you cannot connect to an AP and you've verified that your DHCP configuration and WEP key are correct, check the MAC address filtering on the AP.

WEP can actually work if administered correctly. But basic static WEP keys are no longer a viable option in today's corporate networks without some of the proprietary fixes that run on top of WEP.

Geofencing Geofencing is the process of defining the area in which an operation can be performed by using global positioning (GPS) or radio frequency identification (RFID) to define a geographic boundary. An example of usage involves a location-aware device of a location-based service (LBS) user entering or exiting a geo-fence. This activity could trigger an alert to the device's user as well as messaging to the geo-fence operator.

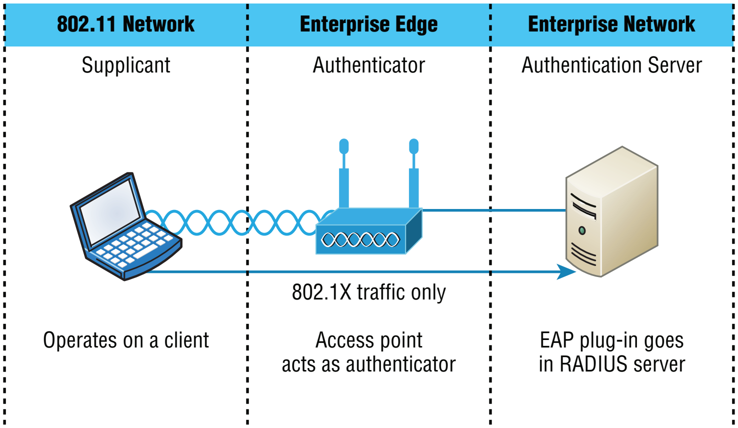
Remote Authentication Dial-In User Service (802.1X)

Remote Authentication Dial-In User Service (RADIUS) is a networking protocol that offers us several security benefits: authorization, centralized access, and accounting supervision regarding the users and/or computers that connect to and access our networks' services. Once RADIUS has authenticated the user, it allows us to specify the type of rights a user or workstation has, plus control what it, or they, can do within the network. It also creates a record of all access attempts and actions. The provision of authentication, authorization, and accounting is called AAA, which is pronounced just like the automobile insurance company, "triple A," and it's part of the IEEE 802.1X security standard.

RADIUS has risen to stardom because of its AAA features and is often employed by ISPs, web servers, wireless networks, and APs as well as network ports—basically, by anybody who wants or needs a AAA server. And these servers are only becoming more critically important in large corporate environments, and that's because they offer security for wireless networks. From the Linksys security screen shown earlier, you can see that RADIUS is an available option. If you choose it, you'll be asked for the IP address of the RADIUS server so the AP can send authentication packets.

Figure 12.21 shows how the AP becomes an authenticator when you choose the RADIUS authentication method.

FIGURE 12.21 RADIUS authentication server



Now packets must pass through the AP until the user and/or host gets authenticated by the RADIUS server.

Temporal Key Integrity Protocol

Put up a fence, and it's only a matter of time until bad guys find a way over, around, and through it. And true to form, they indeed found ways to get through WEP's defenses, leaving our Wi-Fi networks vulnerable—stripped of their Data Link layer security! So someone had to come to the rescue. In this case, it happened to be the IEEE 802.11i task group and the Wi-Fi Alliance, joining forces for the cause. They came up with a solution called Temporal Key Integrity Protocol (TKIP). The Wi-Fi Alliance unveiled it back in late 2002 and introduced it as *Wi-Fi Protected Access (WPA)*. This little beauty even saved us lots of money because TKIP—say this like “tee kip”—didn’t make us upgrade all our legacy hardware equipment in order to use it. Then, in the summer of 2004, the IEEE put its seal of approval on the final version and added even more defensive muscle with goodies like 802.1X and AES-CCMP (AES-Counter Mode CBC-MAC Protocol) upon publishing IEEE 802.11i-2004. The Wi-Fi Alliance responded positively by embracing the now-complete specification and dubbing it WPA2 for marketing purposes.

A big reason that TKIP doesn’t require buying new hardware to run is that it really just kind of wraps around the preexisting WEP encryption key (which was way too short) and upgrades it a whole lot to much more impenetrable 128-bit encryption. Another reason for TKIP’s innate compatibility is that both its encryption mechanism and the RC4 algorithm used to power and define WEP, respectively, remained the same.

But there are still significant differences that help make it the seriously tough shield it is, one of them being that it actually changes each packet’s key. Let me explain: Packet keys are made up of three things: a base key, the transmitting device’s MAC address, and the packet’s serial number. It’s an elegant design because, although it doesn’t place a ton of stress on workstations and APs, it serves up some truly formidable cryptographic force. Here’s how it works: Remember the packet serial number part of the transmission key? Well, it’s not just your average serial number; it’s special—very special.

TKIP-governed transmission ensures that each packet gets its very own 48-bit serial number, which is augmented with a sequence number whenever a new packet gets sent out, and not only serves as part of the key but also acts as the initialization vector. And the good news doesn’t end there—because each packet is now uniquely identified, the collision attacks that used to happen using WEP are also history. Plus, the fact that part of the packet’s serial number is also the initialization vector prevents something called *replay attacks*. It takes an ice age for a 48-bit value to repeat, so replaying packets from some past wireless connection is just not going to happen; those “recycled” packets won’t be in sequence, but they will be identified, thus preventing the attack.

Now for what may be the truly coolest thing about TKIP keys: the base key. Because each base key that TKIP creates is unique, no one can recycle a commonly known key over and over again to gain access to a formerly vulnerable WEP wireless LAN. This is because TKIP throws the base key into the mix when it assembles each packet’s unique key, meaning that even if a device has connected to a particular access point a bunch of times, it won’t be permitted access again unless it has a completely new key granting it permission.

Even the base key itself is a fusion of something called *nonces*—an assortment of random numbers gleaned from the workstation, the access point, and each of these devices’ MAC addresses, so this should also be referred to as a *session secret*. So basically, if you’ve got IEEE 802.1X authentication working for you, rest assured that a session secret absolutely will be transmitted securely to each machine every time it initiates a connection to the wireless LAN by the authentication server—unless you’re using pre-shared keys, that is, because if you happen to be using them, that important session secret always remains the same. Using TKIP with pre-shared keys is kind of like closing an automatically locking security door but not enabling its security settings and alarm—anyone who knows where the secret latch is can get right in!

Wi-Fi Protected Access or WPA2 Pre-Shared Key

These are both essentially another form of basic security that's really just an add-on to the specifications. Even though you can totally lock the vault, as I mentioned in the previous section, WPA/WPA2 Pre-Shared Key (PSK) is a better form of wireless security than any other basic wireless security method I've talked about so far. And note that I did say basic! But if you are using only MAC address filters and/or WEP, and you find that interlopers are still using your network and dragging down the performance, adding this layer of security should help tremendously since it's a better form of access control than either of those measures.

Wi-Fi Protected Access (WPA) is a standard developed by the Wi-Fi Alliance, formerly known as the Wireless Ethernet Compatibility Alliance (WECA). WPA provides a standard for authentication and encryption of WLANs that's intended to solve known security problems. The standard takes into account the well-publicized AirSnort and man-in-the-middle WLAN attacks. So of course we use WPA2 to help us with today's security issues.

The PSK verifies users via a password or identifying code (also called a *passphrase*) on both the client machine and the access point. A client gains access to the network only if its password matches the access point's password. The PSK also provides keying material that TKIP or Advanced Encryption Standard (AES) uses to generate an encryption key for each packet of transmitted data.

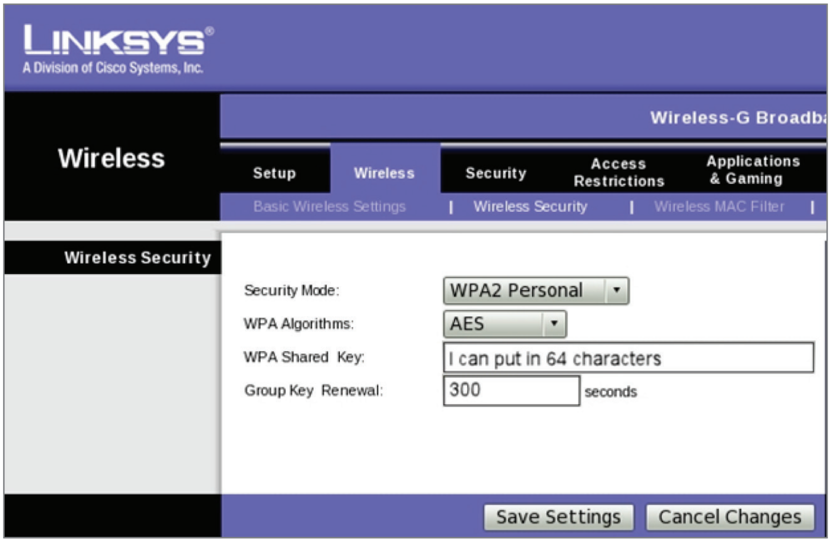
Although more secure than static WEP, PSK still has a lot in common with static WEP in that the PSK is stored on the client station and can be compromised if the client station is lost or stolen (even though finding this key isn't all that easy to do). It's a definite recommendation to use a strong PSK passphrase that includes a mixture of letters, numbers, and nonalphanumeric characters. With WPA, it's still actually possible to specify the use of dynamic encryption keys that change each time a client establishes a connection.

NOTE The benefit of WPA over a static WEP key is that WPA can change dynamically while the system is used.

WPA is a step toward the IEEE 802.11i standard and uses many of the same components, with the exception of encryption—802.11i (WPA2) uses AES-CCMP encryption. The IEEE 802.11i standard replaced WEP with a specific mode of AES known as the CCMP, as mentioned earlier. This allows AES-CCMP to provide both data confidentiality (encryption) and data integrity.

NOTE The highest level of wireless encryption you can run is WPA2-AES.

The following screen shows that if you choose WPA2 Personal on the Linksys AP, you can then enter your passphrase—it's really called WPA2 Pre-Shared Key, but whatever.



Security Mode: WPA2 Personal

WPA Algorithms: AES

WPA Shared Key: I can put in 64 characters

Group Key Renewal: 300 seconds

You have a choice of TKIP or AES as the encryption, and by the way, you can choose up to a 64-character key—pretty tight!

WPA's mechanisms are designed to be implementable by current hardware vendors, meaning that users should be able to implement WPA on their systems with only a firmware/software modification.

NOTE The IEEE 802.11i standard has been sanctioned by WPA and is called WPA version 2.

Certificates and PKI

WPA2 can use the Extensible Authentication Protocol (EAP) method for authentication. EAP isn't a single method but a framework that enhances the existing 802.1X framework. The EAP framework describes a basic set of actions that will take place, and each EAP type differs in the specifics of how it operates within the framework. These variables include things like whether they use passwords or certificates as well as the ultimate level of security provided. Some of the EAP methods require that certificates be used as the credential during authentication. This means that to implement those methods, you must have a Public Key Infrastructure (PKI) in your network. A PKI requires a certificate server that issues certificates to your users and/or devices. These certificates, which consist of a public/private key pair, must be securely installed on the devices and renewed at regular intervals.

In symmetric encryption, the two encryption keys are the same, just as they are with WEP keys, but in asymmetric encryption, the key used to encrypt is different from the key used to decrypt. In PKI, asymmetric keys are used, and the keys are called a public/private key pair. Certificates are binding regulations of a public/private key pair generated by a certificate server to a user or computer. As long as two parties trust the same certificate source, called the trusted certificate authority (CA), they can trust the certificate they're presented with for authentication. These keys can also be used for encryption and as digital signatures.

Despite the other uses of public/private keys, our focus here is the use of the certificates as a form of authentication and authorization. And as a means of identifying the device or the user, this is considered the highest form of authentication and authorization when compared to names and passwords. What all this means is that as long as the AP or controller and the station or user trust the CA that issued the certificates, the certificate is trusted as a means of identification as well.

EAP Extensible Authentication Protocol (EAP) is not a single protocol but a framework for port-based access control that uses the same three components that are used in RADIUS. A wide variety of these include certificates, a PKI, or even simple passwords.

PEAP Protected Extensible Authentication Protocol, also known as Protected EAP or simply PEAP, is a protocol that encapsulates the Extensible Authentication Protocol (EAP) within an encrypted and authenticated Transport Layer Security (TLS) tunnel. It requires only a server-side PKI certificate to create a secure TLS tunnel to protect user authentication.

EAP-FAST EAP-FAST works in two stages. In the first stage, a TLS tunnel is established. Unlike PEAP, however, EAP-FAST's first stage is established by using a pre-shared key called a Protected Authentication Credential (PAC). In the second stage, a series of type/length/value (TLV)-encoded data is used to carry a user authentication.

EAP-TLS

EAP Transport Layer Security (EAP-TLS) is the most secure method, but it's also the most difficult to configure and maintain. To use EAP-TLS, you must install a certificate on both the authentication server and the client. An authentication server pair of keys and a client pair of keys need to be generated first, signed using a PKI, and installed on the devices. On the station side, the keys can be issued for the machine itself and/or for the user.

In the authentication stage, the station, along with the authentication server (RADIUS, etc.), exchange certificates and identify each other. Mutual authentication is a solid beneficial feature, which ensures that the station it's communicating with is the proper authentication server. After this process is completed, random session keys are created for encryption.

Pre-shared key Finally, a preshared key can be used to secure wireless transmissions. This is most labor intensive as it requires that all devices use the same key as the AP and that the keys be changed frequently to provide adequate security.

NOTE

Tunneled Transport Layer Security (TTLS) provides authentication as strong as EAP-TLS, but it doesn't require each user to be issued a certificate. Instead, only the servers are issued certificates.

Summary

Like rock 'n' roll, wireless technologies are here to stay. And for those of us who have come to depend on wireless technologies, it's actually pretty hard to imagine a world without wireless networks—what did we do before cell phones?

So we began this chapter by exploring the essentials and fundamentals of how wireless networks function. Springing off that foundation, I then introduced you to the basics of wireless radio frequencies (RFs) and the IEEE standards. We discussed 802.11 from its inception through its evolution to current and near-future standards and talked about the subcommittees who create these standards.

All of this led into a discussion of wireless security—or rather, nonsecurity for the most part—which we went over in detail.

We finished the chapter by bringing you up to speed on TKIP and WPA/WPA2 security solutions—important tools used to protect the wireless LANs of today.

Exam Essentials

Understand the IEEE 802.11a specification. 802.11a runs in the 5 GHz spectrum, and if you use the 802.11h extensions, you have 23 non-overlapping channels. 802.11a can run up to 54 Mbps, but only if you are less than 50 feet from an access point.

Understand the IEEE 802.11b specification. IEEE 802.11b runs in the 2.4 GHz range and has three non-overlapping channels. It can handle long distances but with a maximum data rate of up to 11 Mpbs.

Understand the IEEE 802.11g specification. IEEE 802.11g is 802.11b's big brother and runs in the same 2.4 GHz range, but it has a higher data rate of 54 Mbps if you are less than 100 feet from an access point.

Remember the wireless LAN modulation techniques. Direct Sequence Spread Spectrum (DSSS) is the most widely used modulation technique, but it has speeds only to 11 Mbps. Frequency Hopping Spread Spectrum (FHSS), although it is used in wireless devices like Bluetooth, isn't the technique of choice for either vendors or the 802.11 working group. To get the higher speeds needed in today's WLANs, we use Orthogonal Frequency Division Multiplexing (OFDM) in 802.11g/a/n and ac networks.

Understand how WPA works in a WLAN. Wi-Fi Protected Access (WPA) is the security of choice in today's home and corporate networks. It provides both authentication and encryption (either TKIP or AES); the latest version is WPA2.

Written Lab

You can find the answers to the written labs in Appendix A. Write the answers to the following questions about wireless networking:

1. What is the maximum data rate of IEEE 802.11b?
2. What is the maximum data rate of IEEE 802.11g?
3. What is the maximum data rate of IEEE 802.11a?
4. What is the frequency range of IEEE 802.11b?
5. What is the frequency range of IEEE 802.11g?
6. What is the frequency range of IEEE 802.11a?
7. What is the possible bandwidth of 802.11ac?
8. Why would we use WPA instead of basic WEP?
9. Which IEEE committee has been sanctioned by WPA and is called WPA2?
10. The IEEE 802.11b/g basic standard has how many non-overlapping channels?

Review Questions

You can find the answers to the review questions in Appendix B.

1. You need to install wireless Internet access in an open warehouse environment. After installing the equipment, the technician notices varying signal strengths throughout the warehouse. How do you make sure there is full coverage?
   - **A.** Turn on broadcast key rotation.
   - **B.** Change the encryption method used on all the APs.
   - **C.** Change the antenna placement.
   - **D.** Use channel bonding.
   - **E.** Use channel shaping.
2. Which of the following uses a certificate on both the server and client to provide the best wireless security with 802.1X (but is hardest to implement)?
   - **A.** AES
   - **B.** TTLS
   - **C.** TLS
   - **D.** TKIP
3. What is the frequency range of the IEEE 802.11g standard?
   - **A.** 2.4 Gbps
   - **B.** 5 Gbps
   - **C.** 2.4 GHz
   - **D.** 5 GHz
4. Which devices can interfere with the operation of a wireless network because they operate on similar frequencies? (Choose two.)
   - **A.** Copier
   - **B.** Microwave oven
   - **C.** Toaster
   - **D.** Cordless phone
   - **E.** IP phone
   - **F.** AM radio
5. Which wireless standard allows you to channel-bond to increase bandwidth and uses both the 2.4 GHz and 5 GHz frequencies?
   - **A.** 802.11b
   - **B.** 802.11g
   - **C.** 802.11a
   - **D.** 802.11n
   - **E.** 802.11ac

6. Which of the following is considered a PAN?

A. AES

B. BSS

C. SSID

D. Bluetooth

7. How many non-overlapping channels are available with 802.11a?

A. 3

B. 12

C. 23

D. 40

8. What is the maximum data rate for the 802.11a standard?

A. 6 Mbps

B. 11 Mbps

C. 22 Mbps

D. 54 Mbps

9. You need to install wireless on multiple floors of a large building and maintenance area. What is your first concern before installing the APs?

A. Authentication

B. Encryption

C. Channel overlap

D. AP configuration

10. What is the maximum data rate for the 802.11b standard?

A. 6 Mbps

B. 11 Mbps

C. 22 Mbps

D. 54 Mbps

11. You connect a new host to your company's wireless network. The host is set to receive a DHCP address and the WPA2 key is entered correctly. However, the host cannot connect to the network. What can the problem be?

A. DNS is not configured on the host.

B. MAC filtering is enabled on the AP.

C. The network has run out of wireless connections.

D. The host is enabled to run 802.11b and 802.11g.

12. Which is the highest encryption that WPA2 can use?

    A. AES-CCMP

    B. PPK via IV

    C. PSK

    D. TKIP/MIC

13. Which additional configuration step is necessary in order to connect to an access point that has SSID broadcasting disabled?

    A. Set the SSID value in the client software to public.

    B. Configure open authentication on the AP and the client.

    C. Set the SSID value on the client to the SSID configured on the AP.

    D. Configure MAC address filtering to permit the client to connect to the AP.

14. Which spread-spectrum technology does the 802.11b standard define for operation?

    A. IR

    B. DSSS

    C. FHSS

    D. DSSS and FHSS

    E. IR, FHSS, and DSSS

15. Which wireless LAN design ensures that a mobile wireless client will not lose connectivity when moving from one access point to another?

    A. Using adapters and access points manufactured by the same company

    B. Overlapping the wireless cell coverage by at least 10 percent

    C. Configuring all access points to use the same channel

    D. Utilizing MAC address filtering to allow the client MAC address to authenticate with the surrounding APs

16. You have installed a point-to-point connection using wireless bridges and Omni directional antennas between two buildings. The throughput is low. What can you do to improve the link?

    A. Replace the bridges with APs.

    B. Replace the Omni directional antennas with Yagis.

    C. Configure 802.11a on the links.

    D. Install amps to boost the signal.

17. What does extended service set (ESS) ID mean?

    A. That you have more than one access point, and they are in the same SSID connected by a distribution system

    B. That you have more than one access point, and they are in separate SSIDs connected by a distribution system

    C. That you have multiple access points, but they are placed physically in different buildings

    D. That you have multiple access points, but one is a repeater access point

18. What is one reason that WPA encryption is preferred over WEP?

    A. A WPA key is longer and requires more special characters than the WEP key.

    B. The access point and the client are manually configured with different WPA key values.

    C. WPA key values remain the same until the client configuration is changed.

    D. The values of WPA keys can change dynamically while the system is used.

19. How wide are the channels used in 802.11n in order to gain the large bandwidth that the specification provides?

    A. 22 MHz

    B. 20 MHz

    C. 40 MHz

    D. 100 MHz

20. 802.11n uses MIMO. How does this optimize throughput to gain the high-speed advantage that 802.11n provides?

    A. By specifying an acknowledgment of each and every frame, 802.11n provides better overhead.

    B. Several frames are sent by several antennas over several paths and are then recombined by another set of antennas.

    C. One frame at a time is sent, but faster than in 802.11g because multiple antennas are used (multiple-in, multiple-out).

    D. MIMO packs smaller packets into a single unit, which improves throughput.

Chapter 13

Authentication and Access Control

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.1 Explain the purposes and uses of ports and protocols**

- SSH 22
- RDP 3389

✓ **1.3 Explain the concepts and characteristics of routing and switching**

- Access Control List

✓ **2.3 Explain the purposes and use cases for advanced networking devices**

- AAA/RADIUS server

✓ **3.4 Given a scenario, use remote access methods**

- VPN
  - IPSec
  - SSL/TLS/DTLS
  - Site-to-site
  - Client-to-site
- RDP
- SSH
- Out-of-band management
- Console Router
- VNC

✓ **3.5 Identify policies and best practices**

- Remote access policies

✓ **4.1 Summarize the purposes of physical security devices.**

- Smart cards

✓ **4.2 Explain authentication and access controls**

- Authorization, authentication, and accounting
  - RADIUS
  - TACACS+
  - Kerberos
  - Single sign-on
  - Local authentication
  - LDAP
  - Certificates
- Multifactor authentication
  - Something you know
  - Something you have
  - Something you are
  - Somewhere you are
  - Something you do
- Access control
  - 802.1X
  - NAC
  - MAC filtering
  - Captive portal
  - Access control lists

So far, you've learned a lot about networking standards and related technologies and even how to make computers and devices communicate so you can get a network up and running. But there's more—because network security is absolutely critical, I'm going to equip you with the knowledge you need to keep your network safe from intruders.

Yes, communication and accessing the information you need is all good, but knowing exactly who it is at the other end of the connection is vital. This means you need ways to confirm that the person or computer at the other end of the connection is really supposed to be accessing the resource it's trying to, and even whether the resources or entities that you're contacting are really who and what they appear to be. Seriously, if you don't have network security firmly in place, you're flying dangerously blind—you could be inadvertently exposing critical data to people who have no right to see that information and may even intend to exploit it in a big way! So, in this chapter, we'll focus on some very important pieces of the security puzzle; two of the first things on our list are security filtering and user authentication.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Security Filtering

How do we know who's really at the other end of our connections? The answer to that may seem simple enough because the computer or person on the other end must identify him/her/itself, right? Wrong! That's just not good enough because people—especially hackers—lie, so it's totally naïve to assume that the person or computer on the other end of the line is who they're claiming to be. Sad but true: Hackers use the many tools out there today with the precise goal of convincing us they're someone else, and way too many of us have been, or know of someone who has been, a victim of identity theft thanks to bad guys with the right spoofing software in hand.

This means it's imperative to control who or what can get into our network by identifying the specific computers and individuals who have the right to gain access to it and its resources. But how do we do this? Well, for starters, I'm going to cover some basic ways to safely allow the computers you want to have access into your network plus ways to keep out the ones you don't.

The first line of defense is something called *security filtering*, which broadly refers to ways to let people securely access your resources. This process is twofold and includes ensuring that only authorized computers get to enter your network and making sure data you're sending back and forth between networks is secured so it can't be intercepted and translated by bad guys.

Access Control Lists

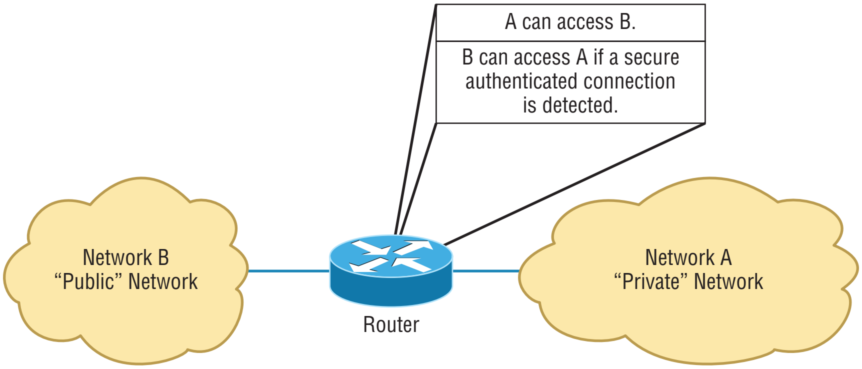
It's rare to find a network around these days that isn't connected to the Internet. The Internet is clearly a public internetwork that anyone can connect to, but your company's or personal network is, and should definitely be, a private one. The catch here is that every time you connect to the Internet (where everyone is welcome) from a private network, you're instantly vulnerable to security break-ins. This is where something we call a *firewall* comes into play. Firewalls are basically tools that you can implement to prevent any unauthorized users roaming around on public networks from gaining access to your private network.

NOTE I'll be covering the different types of firewalls, plus give you the skinny on exactly how they work, in Chapter 15, "Physical Security and Risk." For now, understand that firewalls can be either stand-alone devices or combined with another hardware device like a server or a router. And although firewalls can use a lot of various technologies to restrict information flow, their primary weapon is known as an access control list (ACL).

Access control lists (ACLs) typically reside on routers to determine which packets are allowed to route through them based on the requesting device's source or destination Internet Protocol (IP) address. Oh, and just so you know, ACLs have been around for decades and have other uses apart from firewalls.

Figure 13.1 demonstrates how ACLs prevent users on Network B from accessing Network A.

FIGURE 13.1 Two networks with an ACL-enabled router


A can access B.
B can access A if a secure authenticated connection is detected.
Network B "Public" Network
Router
Network A "Private" Network

Okay, what we see here is that users in Network A can pass through the router into Network B. This means that an IP spoofing attack, when someone pretends to have a network address on the inside of a firewall to gain network access, can still happen if a user in Network B pretends to be located in Network A. We'll go over things like IP spoofing more thoroughly in Chapter 14, "Network Threats and Mitigation," but for now, let's get back to ACLs.

You can create a wide array of ACLs, from the very simple to the highly complex, depending on exactly what you want to have them do for you. One example is placing separate inbound and outbound ACLs on a router to ensure that the data that's leaving your network comes from a different source than the data that's coming into it.

When configuring ACLs between the Internet and your private network to mitigate security problems, it's a good idea to include these four conditions:

- Deny any addresses from your internal networks.
- Deny any local host addresses (127.0.0.0/8).
- Deny any reserved private addresses.
- Deny any addresses in the IP multicast address range (224.0.0.0/4).

None of these addresses should ever be allowed to enter your internetwork. Interestingly enough, because of the way in which in-public IP addresses are issued, with some research you can create a filter that blocks a country, state, or even locale based on IP addresses!

MAC Filtering

Most of the time, it's wise to configure ACLs so that they'll allow or deny access based on the IP address of the source or destination device. If your network is running a protocol other than Transmission Control Protocol/Internet Protocol (TCP/IP), you can filter traffic based on a Media Access Control (MAC), or hardware, address instead of an IP address. You can still use a MAC address–based ACL if you're running TCP/IP, but keep in mind that it's a lot easier to deal with IP addresses than MAC addresses. Another point to remember is that even though most firewalls and routers will allow you to create both IP-based and MAC-based ACLs, doing so can create an exceptionally ugly situation where access is denied when it really shouldn't be.

Port Filtering

ACLs can also be used to filter based on port numbers as well as IP addresses. In fact, most firewalls default to allowing only the open ports that you specify. This is another version of the implicit deny (anything not allowed specifically is denied).

When managing a firewall, it's important to know the port numbers of all traffic that needs to be allowed through it. This means that for some of your applications, you will need to read and learn the port numbers being used.

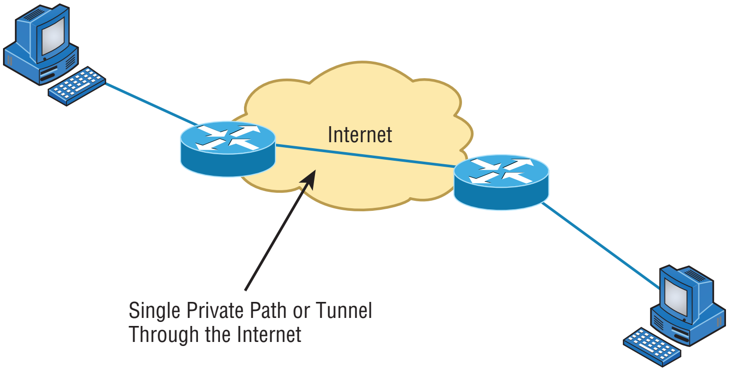
This also explains why it's a big deal to know the port numbers of security protocols like SSL and IPSec. Successful firewall management involves being aware of and allowing *only* the ports to keep things running.

Tunneling

Just thinking about the huge amount of sensitive data bouncing all over the Internet 24/7 makes me want to scream the word *security*! It's seriously clear that we need it almost as much as air. Worse, most of that data is sent out over the Internet without any encryption or security, but at least not the really sensitive stuff, which should be sent via one of several different security protocols available today—phew. These vital protocols are really sets of conditions or rules that define how a secure connection is maintained when we send sensitive data through an unsecure medium like the Internet or a wireless connection. Before talking about the security protocols that the Network+ exam is likely to quiz you on, I'd like to define a few terms.

The first is a concept called *tunneling*, which basically means encapsulating one protocol within another to ensure that a transmission is secure. Here's an example: The lion's share of us use IP, known as a *payload protocol*, which can be encapsulated within a *delivery protocol* like Internet Protocol Security (IPSec). If you took a look at these packets individually, you would see that they're encrypted. If you look at the process as a whole, it appears that a point-to-point tunnel is created on the Internet, as Figure 13.2 illustrates. (Make a note to yourself that usually the tunneled protocol is running at a higher layer in the OSI model than the payload protocol, but not always.)

FIGURE 13.2 A tunnel through the Internet



The Network+ exam will test your understanding of the following tunneling protocols:

- Virtual Private Network (VPN)
- Secure Sockets Layer (SSL)
- Secure Sockets Layer Virtual Private Network (SSL VPN)
- Datagram Transport Layer Security (DTLS)
- Layer 2 Tunneling Protocol (L2TP)
- Point-to-Point Tunneling Protocol (PPTP)
- Generic Routing Encapsulation (GRE)
- Internet Protocol Security (IPSec)
- ISAKMP

Let's dig in and take a detailed look at each one now.

Virtual Private Network

No worries—VPNs aren't really that hard to understand. A VPN fits somewhere between a LAN and WAN, and many times may seem just like a WAN link because your computer, on one LAN, connects to a different, remote LAN and uses its resources remotely. The key difference with VPNs is a big one—security! So the definition of connecting a LAN (or VLAN) to a WAN may sound the same, but a VPN is much more.

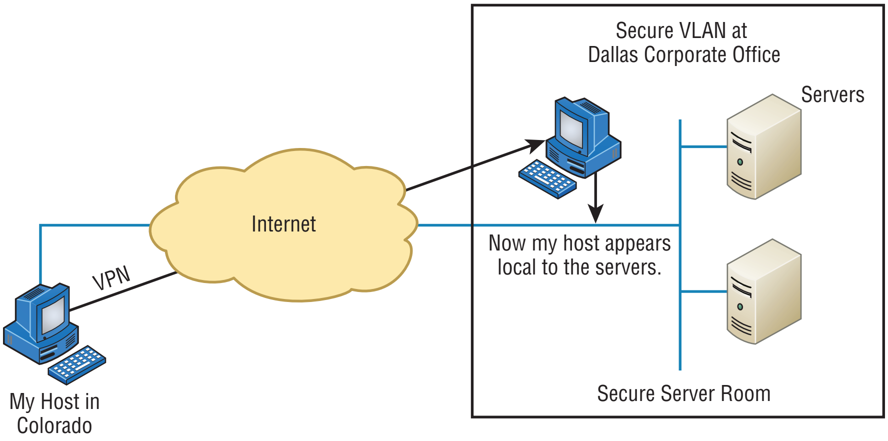
Here's the difference: A typical WAN connects two or more remote LANs together using someone else's network—like, say, your Internet service provider's (ISP's)—and a router. Your local host and router see these networks as remote networks and not as local networks or local resources. This would be a WAN in its most general definition. A VPN actually makes your local host part of the remote network by using the WAN link that connects you to the remote LAN. The VPN will make your host appear as though it's actually local on the remote network! This means that we now have access to the remote LAN's resources and that access is very secure.

This may sound a lot like the VLAN definition I just used in Chapter 11, "Switching and Virtual LANs," and really, the concept is the same: "Take my host and make it appear local to the remote resources." Just remember that for networks that are physically local, using VLANs is a good solution, but for networks that are physically remote—those that span a WAN—we'd opt for using VPNs instead.

For a simple VPN example, let's use my home office in Boulder, Colorado. Here, I have my personal host, but I want it to appear as if it's on a LAN in my corporate office in Dallas, Texas, so I can get to my remote servers. VPN is the solution I use for this because I need the security it provides.

Figure 13.3 shows this example of my host using a VPN connection from Boulder to Dallas, which allows me to access the remote network services and servers as if my host is right there on the same VLAN as my servers.

FIGURE 13.3 Example of using a VPN network



Why is this so important? If you answered, “Because my servers in Dallas are secure, and only the hosts on the same VLAN are allowed to connect to them and use their resources,” you nailed it! A VPN allows me to connect to these resources by locally attaching to the VLAN through a VPN across the WAN. The other option is to open up my network and servers to everyone on the Internet or another WAN service, in which case my security goes poof! So you can see that it’s a very good thing I have a VPN.

Types of VPNs are named based on the kind of role they play in a real-world business situation. There are three different categories of VPNs:

Client-to-Site (Remote-Access) VPNs *Remote-access VPNs* allow remote users like telecommuters to securely access the corporate network wherever and whenever they need to. It is typical that users can connect to the Internet but not to the office via their VPN client because they don’t have the correct VPN address and password. This is the most common problem and one you should always check first.

Host-to-Host VPN A host-to-host VPN is somewhat like a site-to-site in concept except that the endpoints of the tunnel are two individual hosts. In this case all traffic is protected from the time it leaves the NIC on one host until it reaches the NIC of the other host.

Site-to-Site VPNs *Site-to-site VPNs*, or intranet VPNs, allow a company to connect its remote sites to the corporate backbone securely over a public medium like the Internet instead of requiring more expensive wide area network (WAN) connections like Frame Relay. This is probably the *best* solution for connecting a remote office to a main company office.

Extranet VPNs *Extranet VPNs* allow an organization’s suppliers, partners, and customers to be connected to the corporate network in a limited way for business-to-business (B2B) communications.

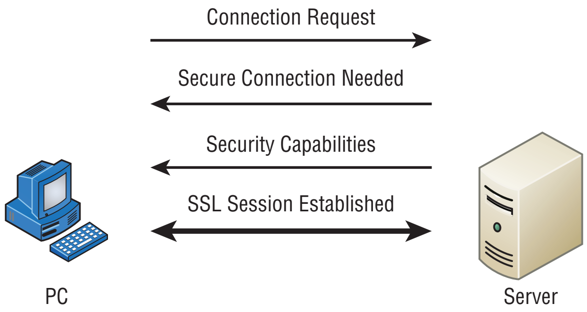
SSL and SSL VPN

Next on the list is *Secure Sockets Layer (SSL)*. This security protocol was developed by Netscape to work with its browser. It’s based on Rivest, Shamir, and Adleman (RSA) public-key encryption and used to enable secure Session layer connections over the Internet between a web browser and a web server. SSL is service independent, meaning a lot of different network applications can be secured with it—a famous one being the ubiquitous HTTP Secure (HTTPS) protocol. As time marched on, SSL was merged with other Transport layer security protocols to form a new protocol called Transport Layer Security (TLS). The latest version of Transport Layer Security (TLS 2.0) provides a number of enhancements over earlier versions. The following are the most noteworthy:

- Several improvements in the operation of a central component, the MD5/SHA-1 hashing function. Hashing functions are used to ensure that the data is not changed or altered (also known as maintaining data integrity).
- More flexibility in the choice of hashing and encryption algorithms on the part of the client and the server.
- Enhanced support for the Advanced Encryption Standard (AES).

Figure 13.4 shows the SSL connection process.

FIGURE 13.4 The SSL connection process



SSL VPN is really the process of using SSL to create a virtual private network (VPN). A VPN is a secured connection between two systems that would otherwise have to connect to each other through a non-secured network. Here's what I mean: Even though I'd never really let this happen, let's just say I could connect to the servers in my corporate office through the Internet like, snap! You know by now that this would be a very bad thing because the Internet is far from secure, right? But if I connected to those servers using a VPN with a tunneling protocol instead, anything I send from my PC to my corporate office would be locked up nice and securely.

Plus, VPNs also come in handy for data that's being sent within a private network that you probably wouldn't want everyone on that network to be able to see. Maybe you want a few specific computers on the intranet to be able to communicate with each other securely—like, say, the computers used by your top finance people. You wouldn't necessarily want that data just sent off in the clear to be viewed by the office gossip, now would you? No way. So, you can put those finance folks on a VPN that's just like having them on their own little private, secure subnetwork. Plus, what's even cooler about this setup is that the members of your intranet's VPN can still communicate with everyone else whenever they want; they just won't be doing that securely—nice solution!

DTLS

Datagram Transport Layer Security (DTLS) provides security for datagram-based applications by allowing them to communicate in a way that is designed to prevent eavesdropping, tampering, or message forgery. It is based on the stream-oriented Transport Layer Security (TLS) protocol and is intended to provide similar security guarantees.

L2TP

Next, we have the *Layer 2 Tunneling Protocol (L2TP)*, which was created by the Internet Engineering Task Force (IETF). It comes in handy for supporting non-TCP/IP protocols in VPNs over the Internet. L2TP is actually a combination of Microsoft's Point-to-Point Tunneling Protocol (PPTP) and Cisco's Layer 2 Forwarding (L2F) technologies. A nice L2TP feature is that, because it works way down there at the Data Link layer (Layer 2) of the OSI model, it can support tons of protocols beyond just TCP/IP—a couple of biggies being Internetwork Packet Exchange (IPX) and AppleTalk. It's a really great tool to implement if you happen to have two non-TCP/IP networks that need to be connected via the Internet.

PPTP

I just mentioned *Point-to-Point Tunneling Protocol (PPTP)*, and even though I said it was Microsoft's PPTP, this security protocol was really developed jointly by Microsoft, Lucent Technologies, 3COM, and a few other companies. Oh, and it's not actually sanctioned by the IETF, but that doesn't mean it doesn't work. PPTP acts by combining an unsecured Point-to-Point Protocol (PPP) session with a secured session using the *Generic Routing Encapsulation (GRE) protocol.*

Because PPTP uses two different protocols, it actually opens up two different network sessions: so be warned, PPTP can give you some grief when passing through a router. This is a big reason you won't find it around much nowadays. Another reason it's going the way of the dinosaurs is that it originally gained popularity because it was the first VPN protocol to be supported by Microsoft's dial-up networking services, and not too many of us depend on dial-up to get to the Internet anymore. As if these aren't reasons enough for PPTP's impending extinction, it's also not that secure. In fact, as you'd probably expect from a first-generation security protocol, it's now really vulnerable to spoofing attacks, which is why it's pretty much been replaced by L2TP and IPSec.

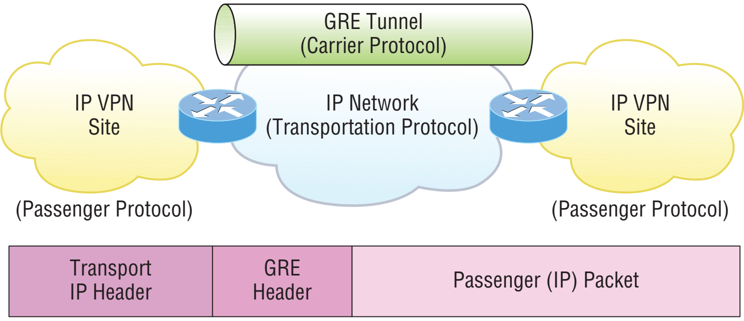
NOTE

PPTP is a VPN protocol that runs over port 1723 and allows encryption to be done at the Application (data) level. It is important to remember for the CompTIA Network+ exam that PPTP is a protocol that allows secure access to a VPN.

GRE

Generic Routing Encapsulation (GRE) is a tunneling protocol that can encapsulate many protocols inside IP tunnels. Some examples would be routing protocols such as EIGRP and OSPF and the routed protocol IPv6. Figure 13.5 shows GRE.

FIGURE 13.5 GRE encapsulation



A GRE tunnel interface supports a header for each of the following:

- A passenger protocol or encapsulated protocols like IP or IPv6, which is the protocol being encapsulated by GRE
- GRE protocol
- A Transport delivery protocol, typically IP

GRE tunnels have the following characteristics:

- GRE uses a protocol-type field in the GRE header so any Layer 3 protocol can be used through the tunnel.
- GRE is stateless and has no flow control.
- GRE offers no security.
- GRE creates additional overhead for tunneled packets—at least 24 bytes.

IPSec

On the other hand, IP Security (IPSec) was designed by the IETF for providing authentication and encryption over the Internet. It works at the Network layer of the OSI model (Layer 3) and secures all applications that operate in the layers above it. Because it's sanctioned by the IETF and designed to work with IPv4 and IPv6, it's got a huge amount of industry support, so it's the standard for VPNs on the Internet today.

The two major protocols you'll find working in IPSec are *Authentication Header (AH)* and *Encapsulating Security Payload (ESP)*. AH serves up authentication services only—no encryption—but ESP provides both authentication and encryption abilities. Both of these protocols can be used with either mode discussed in the following paragraphs.

NOTE The AH protocol within IPSec isn't compatible with networks running Network Address Translation (NAT).

IPSec works in two modes: transport mode and tunneling mode. Transport mode creates a secure tunnel between two devices end to end. This means that regardless of how many foreign networks (including the Internet) the packet traverses, it is protected. The data is protected by authentication and/or encryption. Figure 13.6 illustrates a TCP/IP packet and a TCP/IP packet in transport mode using AH. ESP can also be used with transport mode.

On the other hand, in tunnel mode, the tunnel is created between two endpoints, such as two routers or two gateway servers, protecting all traffic that goes through the tunnel. It is commonly used between two offices to protect all traffic going between the offices regardless of the source and destination. Figure 13.7 first shows a TCP/IP packet and then depicts one using ESP in tunnel mode. AH can also be used with tunnel mode.

FIGURE 13.6 TCP/IP packet in IPSec transport mode with AH

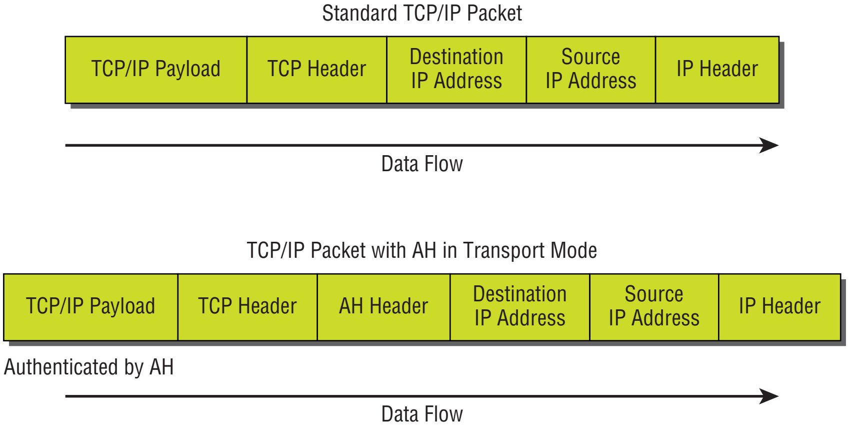
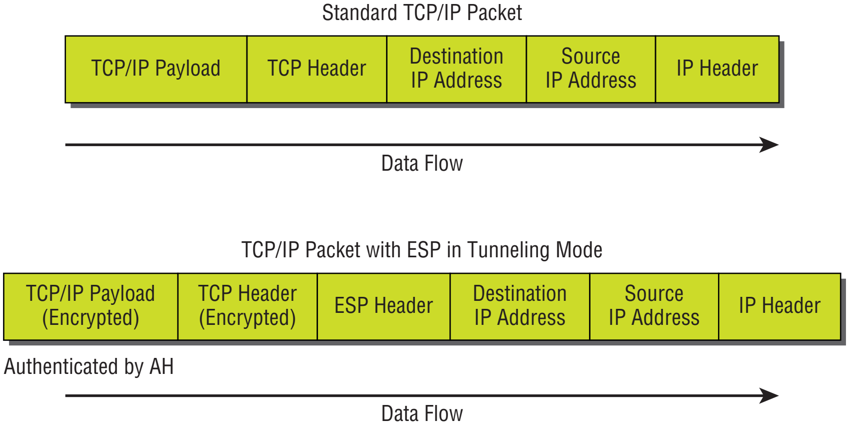


FIGURE 13.7 TCP/IP packet in IPSec tunnel mode with ESP



You can see here that when data is tunneled in this way, hackers can't even see what transport protocol you're using, let alone decipher the data you're transmitting.

ISAKMP

Internet Security Association and Key Management Protocol (ISAKMP) defines procedures and packet formats to establish, negotiate, modify, and delete security associations (SAs). SAs contain information required to execute security services, such as header authentication and payload encapsulation. ISAKMP's real value is its ability to provide a framework for safely transferring key and authentication data independent of the key generation technique, encryption algorithm, and authentication mechanism. ISAKMP is integrated into another security mechanism we have already discussed, IPSec.

Encryption

Sometimes, like it or not, sending out corporate financial and other types of sensitive data over the Internet just can't be avoided. This is why being able to hide or encode that data with encryption technologies is so vital for shielding it from the prying eyes of a company's competitors, identity thieves—anyone who wants to take a look. Without encryption, our sensitive files and information are essentially being paraded on full display as the data courses over the Internet.

Encryption works by running the data (which when encoded is represented as numbers) through a special encryption formula called a *key* that the designated sending and receiving devices both "know." When encrypted data arrives at its specified destination, the receiving device uses that key to decode the data back into its original form.

Back in 1979, the National Security Agency (NSA) classified encryption tools and their associated formulas as munitions, and the NSA has overseen their regulation ever since. The dangerous possibility that hostile nations, terrorists, and criminals may use encrypted communications to plan crimes and go undetected is the compelling reason for doing so. It's also the reason that we're only allowed to export weak encryption methods.

This brings up an important question: Exactly how do we measure an encryption algorithm's strength? One way to do that is to measure its bit strength. Until 1998, only software with 40-bit strength or less could be exported, but today, the bar has been raised to 64-bit strength. And by the way, exporting any software with a key length greater than 64 bits is subject to review by the Export Administration Regulations (EAR) required by the U.S. Department of Commerce's Bureau of Industry and Security. This doesn't include exporting to every country because some—like most of those in Western Europe plus Canada, Australia, and Japan—are countries we trust with the technology. But if you happen to be curious or just want to be really careful, check out the current regulations at `www.bis.doc.gov/index.php/regulations#ear`. Remember, these regulations aren't there to make life a hassle; they're in place to protect us. The greater the number of bits that are encrypted, the tougher it is to crack the code.

NOTE

Clearly, the security of monetary transfers is extremely important. The NSA does allow U.S. banks to use more secure encryption methods for this reason and to ensure that they communicate very securely with their overseas branches, customers, and affiliates.

Encrypting passwords being sent from a workstation to a server at login is the most basic need for internal networks, and it's done automatically by most network operating systems today. But legacy utilities like File Transfer Protocol (FTP) and Telnet don't have the ability to encrypt passwords. Most email systems also give users the option to encrypt individual (or all) email messages, and third-party software packages like Pretty Good Privacy (PGP) are used by email systems that don't come with encryption abilities of their own. And you already know how critical encryption is for data transmission over VPNs. Last but not least, encryption capability is clearly very important for e-commerce transactions, online banking, and investing.

I mentioned this earlier, but I didn't tell you exactly what it is: An encryption key is essentially a random string of characters that is used in conjunction with the encryption algorithm. The algorithm is the same for all transactions, but the key is unique to each transaction. Encryption keys come in two flavors: public and private. I'm going to tell you how each one is used next.

Symmetrical Encryption Keys

Using symmetrical key encryption, both the sender and receiver have the same key and use it to encrypt and decrypt all messages. The downside of this technique is that it becomes hard to maintain the security of the key. When the keys at each end are different, it is called asymmetrical or public key. We'll talk about that right after we discuss some encryption standards.

The Data Encryption Standard (DES)

Kudos go to IBM for coming up with one of the most widely used standards: *Data Encryption Standard (DES)*. It was made a standard back in 1977 by the U.S. government. If you want, you can look it up in the Federal Information Processing Standards Publication 46-2 (FIPS 46-2).

Basically, DES uses lookup and table functions, and it actually works much faster than more complex systems. It uses 56-bit keys. RSA Data Systems once issued a challenge to see if anyone could break the key. A group of Internet users worked together to attempt the task, with each member dealing with a portion of the 72 quadrillion possible combinations. They succeeded and cracked the key in June 1997, after searching only 18 quadrillion keys. Their prize? Knowing they had succeeded when they read a plain-text message that said, "Strong cryptography makes the world a safer place."

Back in the day, DES was a great security standard, but its 56-bit key length has proved to be too short. As I said, the key was first cracked in June 1997. A year later, one was cracked in just 56 hours, and in January 1999, a DES key was broken in a blazing 22 hours and 15 minutes! Not exactly secure, right? We definitely needed something stronger.

Triple Data Encryption Standard (3DES)

That's when *Triple Data Encryption Standard (3DES, also referred to as TDES)* came into its glory. Originally developed in the late 1970s, it became the recommended method of implementing DES encryption in 1999. As its name implies, 3DES is essentially three DES encryption methods combined into one.

So 3DES encrypts three times, and it allows us to use one, two, or three separate keys. Clearly, going with only one key is the most unsecure, and opting to use all three keys gives you the highest level of security. Three-key TDES has a key length of 168 bits (56 times 3), but due to a complex type of attack known as *meet-in-the-middle*, it really provides only 112 bits of security. It gets worse farther down the food chain—even though the two-key version has a key size of 112 bits, it actually arms you with only 80 bits of effective security.

Another problem with 3DES is that it's slow. No one likes that, so the National Institute of Standards and Technology (NIST) believes that 3DES will be an effective encryption standard only until sometime around 2030. Even now, it's being phased out in favor of faster methods like AES.

The Advanced Encryption Standard (AES)

The *Advanced Encryption Standard* (*AES*, also known as Rijndael) has been the "official" encryption standard in the United States since 2002. It specifies key lengths of 128, 192, and 256 bits.

The U.S. government has determined that 128-bit security is adequate for things like secure transactions and all materials deemed Secret, but all Top Secret information must be encoded using 192- or 256-bit keys.

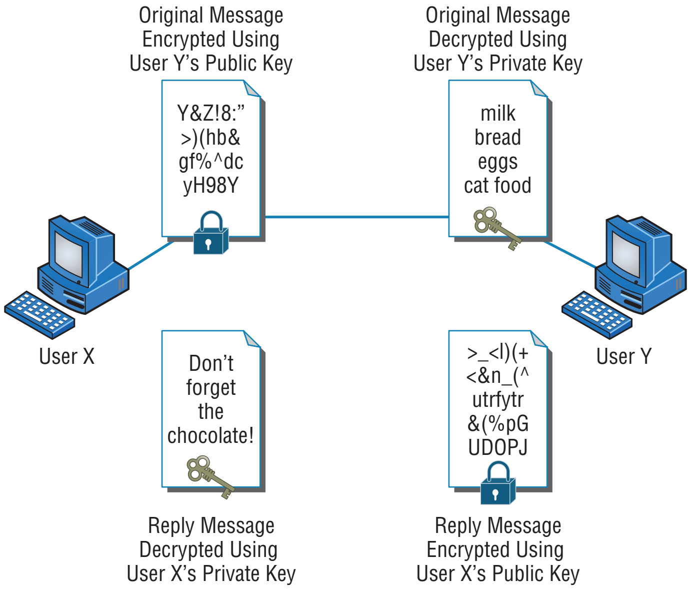
The good news is that the AES standard has proven amazingly difficult to crack. Those who try use a popular method involving something known as a *side channel attack*. This means that instead of going after the cipher directly, they attempt to gather the information they want from the physical implementation of a security system. Hackers attempt to use power consumption, electromagnetic leaks, or timing information (like the number of processor cycles taken to complete the encryption process) to give them critical clues about how to break the AES system. Although it's true that attacks like these are possible to pull off, they're not really practical to clinch over the Internet.

Public-Key Encryption

Public-key encryption uses the *Diffie-Hellman algorithm*, which employs a public key and a private key to encrypt and decrypt data. This is called asymmetric encryption. It works like this: The sending machine's public key is used to encrypt a message that is decrypted by the receiving machine with its private key. It's a one-way communication, but if the receiver wants to send a return message, it does so via the same process. If the original sender doesn't have a public key, the message can still be sent with a digital certificate that's often called a *digital ID*, which verifies the sender of the message.

Figure 13.8 shows public-key-encrypted communication between User X and User Y.

FIGURE 13.8 Public-key encryption



Here's a cool factoid for you—*Diffie-Hellman* refers to all public-key algorithms. Whitfield Diffie and Martin Hellman from the Stanford Research Institute invented public-key encryption. They introduced the dual-key concept in their 1976 paper "New Directions in Cryptography."

RSA Data Security

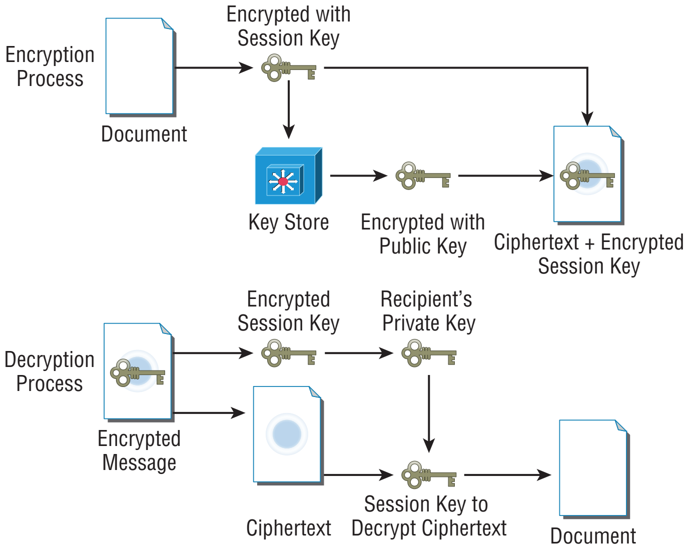
Rivest, Shamir, and Adleman (RSA) encryption is a public-key algorithm named after the three scientists from MIT who created it. They formed a commercial company in 1977 to develop asymmetric keys and nailed several U.S. patents. Their encryption software is used today in electronic commerce protocols.

For more information about RSA Data Security, go to `www.rsa.com`.

Pretty Good Privacy (PGP)

In the early 1990s, Phil Zimmerman (also from MIT) wrote most of the code for this freely available version of public-key encryption designed to encrypt data for email transmission. Zimmerman basically compared email to postcards, because anyone can read email messages traversing the Internet just as they can postcards traveling through the postal service. By contrast, he compared an encrypted message to a letter mailed inside an envelope. Figure 13.9 shows the PGP encryption system.

FIGURE 13.9 The PGP encryption system



In Figure 13.9, the document is encrypted with a session key, which is then encrypted with the public key of the recipient. Then the ciphertext and the encrypted session key are sent to the recipient. Since the recipient is the only person with the matching private key, only they can decrypt the session key and then use it to decrypt the document.

Zimmerman distributed the software for personal use only, and as the name implies, it's really pretty good security.

RSA Data Security and the U.S. federal government both had a problem with Zimmerman's product—the RSA complained about patent infringement, and the government actually decided to prosecute Zimmerman for exporting munitions-grade software. The government eventually dropped the charges, and now a licensing fee is paid to RSA, so today, PGP and other public-key-related products are readily available.

NOTE

Don't let the name fool you! PGP is a highly secure encryption standard.

Remote Access

Think of remote access as a telecommuting tool because it's used by companies to allow remote employees to connect to the internal network and access resources that are in the office. Remote access is great for users who work from home or travel frequently, but clearly, to a stalking hacker, using an unsecured remote-access connection is like stealing candy from a baby.

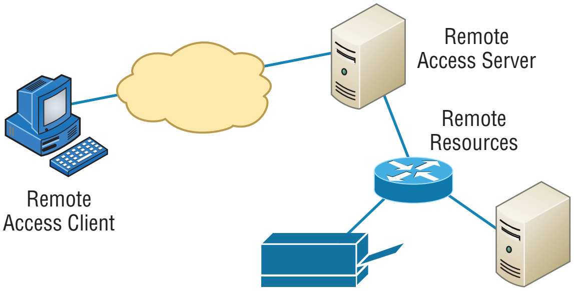
Using remote access requires a server configured to accept incoming calls and also requires remote-access software to be installed on the client. Microsoft Windows operating systems, since Windows 95, have had remote-access client software built in, and there are many third-party remote-access clients available as well. Several different methods exist to create remote-access connections.

RAS

Remote Access Services (RAS) is not a protocol but refers to the combination of hardware and software required to make a remote-access connection. The term was popularized by Microsoft when the company began referring to its Windows NT–based remote-access tools by this name. Users would dial in via a modem, be authenticated by the server, and then be asked for their username and password just as if they were on the local network. Once logged in, users had access to data on the internal network just as if they were logged in locally. Figure 13.10 gives you an idea of what this would look like.

RAS itself was not secure, but there are options within RAS to include a secure protocol for tunneling, such as PPTP, and for authentication, such as Microsoft Challenge Handshake Authentication Protocol (MS-CHAP) and Extensible Authentication Protocol (EAP). RAS is versatile because it supports several other network protocols in addition to TCP/IP.

FIGURE 13.10 A typical remote-access connection between a remote user and a server



RDP

Remote Desktop Protocol (RDP) allows users to connect to a computer running Microsoft's Remote Desktop Services, but a remote computer must have the right kind of client software installed for this to happen. Most Windows-based operating systems include an RDP client, and so do most other major operating systems, like Linux, Solaris, and Mac OS X. Microsoft's RDP client software is called either Remote Desktop Connection (RDC) or Terminal Services Client (TSC). Microsoft began calling all terminal services products *Remote Desktop* with Windows Server 2008 R2. RDP uses TCP port 3389.

After establishing a connection, the user sees a *terminal window* that's basically a preconfigured window that looks like a Windows desktop or another operating system's desktop. From there, the user on the client computer can access applications and files available to them by using the remote desktop.

The most current version of RDP is RDP 10.0. When logged in using RDP, clients are able to access local files and printers from the remote desktop just as if they were logged into the network. RDP offers 128-bit encryption using the RC4 encryption algorithm and also offers TLS 1.0 support.

PPP

Point-to-Point Protocol (PPP) is a Layer 2 protocol that provides authentication, encryption, and compression services to clients logging in remotely. ISPs use PPP a lot to authenticate clients dialing in with a dial-up modem or a DSL or cable modem. Many network servers that provide remote-access services (such as RAS) can also use PPP as an authentication protocol.

PPPoE

Point-to-Point Protocol over Ethernet (PPPoE) is an extension of PPP. Its purpose is to encapsulate PPP frames within Ethernet frames.

The need for PPPoE was born out of the need to deal with the massive increase in high-speed Internet connections. Service providers offering customers high-speed access using Asymmetric Digital Subscriber Line (ADSL) or cable modems needed a way to offer the authentication and encryption services of PPP. A Remote Authentication Dial In User Service (RADIUS) server—something I'll get into a bit later in this chapter—is commonly used to manage PPPoE connections.

PPPoE works in two stages: discovery and session. In the discovery phase, the MAC addresses of the endpoints are exchanged so that a secure PPP connection can be made. During this phase, a session ID is also created that's used to facilitate further data transmission during the session. Then, a point-to-point connection is created and the session stage begins.

ICA

Independent Computing Architecture (ICA) is a protocol designed by Citrix Systems to provide communication between servers and clients. The most common application that uses ICA is Citrix's WinFrame, which administrators can use to set up Windows applications on a Windows-based server and then allow clients with virtually any operating system to access those applications. Client computers running Linux, Unix, or Mac OSs can access Windows-based applications with the help of WinFrame, giving network administrators all kinds of flexibility with client operating systems. But again, there's a downside—connections like these tend to be slow because of the huge amount of translation that's required to enable the client and server to communicate with each other properly.

SSH

Secure Shell is a network protocol that is designed as an alternative to command-based utilities such as Telnet that transmit requests and responses in clear text. It creates a secure channel between the devices and provides confidentiality and integrity of the data transmission. It uses public-key cryptography to authenticate the remote computer and allow the remote computer to authenticate the user, if necessary.

This public key is placed on any computer that must allow access to the owner of a matching private key (the owner keeps the private key in secret). The private key is never transferred through the network during authentication.

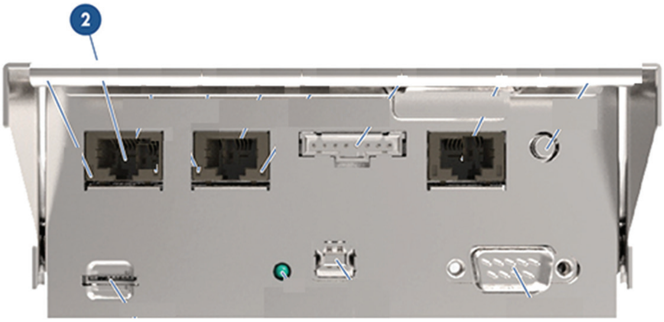
Out-of-band management

Out of band management refers to any method of managing the server that does use the network. An example of this technology is Integrated Lights-Out, or iLO, a technology embedded into HP servers that allows for out of band management of the server. The physical connection is an Ethernet port that will be on the server and will be labeled ILO. In Figure 13.11, one of these ILO ports is shown in an HP Moonshot chassis (these hold blade servers). HP iLO functions out-of-the-box without additional software installation regardless of the servers' state of operation giving you complete access to the server from any location via a web browser or the iLO Mobile App.

Console router

Another example of an out-of-band connection is the console port on a router or switch. This is a physical connection to the device that does not use the network and as such represents another example.

FIGURE 13.11 ILO port



VNC

Virtual Network Computing (VNC) is a remote desktop sharing system that uses the Remote Frame Buffer (RFB) protocol. It is platform independent and provides an experience much like Remote Desktop Protocol (RDP).

VNC includes the following components:

- VNC server: Software that runs on the machine sharing its screen
- VNC client (or viewer): Software on the machine that is remotely receiving the shared screen
- VNC protocol (RDP)

One big difference in VNC and RDP is that VNC sends raw pixel data (which does make it work on any desktop type) while RDP uses graphic primitives or higher-level commands for the screen transfer process.

Managing User Account and Password Security

A whole bunch of authentication schemes are used today, and although it's important to know about these different schemes and how they work, all that knowledge doesn't equal power if your network's users aren't schooled on how to manage their account names and passwords correctly. This is because if bad guys get their hands on usernames and passwords, it gives them a way to get into your network. Worse, if a hacker gains the administrator account name and password for your network, it doesn't matter what authentication protocol or server you're using—that hacker isn't just going to get in, they're going to get in armed with the escalated rights that type of account allows, meaning they can do some serious damage.

With that in mind, let's get into some solid ways to manage user accounts and passwords and follow that up by talking about the key authentication methods in use today.

Usernames and passwords are vital to network security because their whole purpose is to control initial access to the network. Even if the system administrator assigns individuals their usernames and passwords, users can and often do change them, so you need to make sure your network's users know the difference between a good password and a bad one and how to keep their passwords safe from theft.

I'll cover the important security issues related to user account and password management. Moreover, in the following sections, I'll discuss more secure methods of authentication (two-factor and multifactor authentication) and a widely used concept in the Enterprise networks: single sign-on.

Managing User Accounts

So, your first step in managing access to network resources is through user accounts and the rights you assign to the network resources. System administrators usually maintain user accounts on a daily basis, doing things like renaming accounts and setting the number of simultaneous connections. You can also specify where users can log in, how often, and when; plus, you can adjust how often their passwords expire and delimit when their accounts expire as well.

Disabling Accounts

This is important, so remember it—when a user leaves the organization, you have these three options:

- Leave the account in place.
- Delete the account.
- Disable the account.

The first option is not so good because if you just leave the account in place, anyone (including the user to whom it belonged) can still log in as that user if they know the password. This is clearly very bad security, but deleting the account presents its own set of problems. If you delete an account, the numeric ID associated with that user (UID in Unix, SID in Windows Server) will be lost, and it's through this magic number that passwords and rights to network resources are associated with the user account. This can be a good thing—but if you create a new user account with the same name as the one you deleted, the identification number of the new account will be different from the old one, so none of its settings will be there for the new account.

This means that disabling an account until you've made a decision about what should happen to it is your best bet because you'll probably just want to rename the account when someone new is hired. When you disable an account, it still exists, but no one can use it to log in. Another good time to disable an account is when someone leaves for an extended period, like taking maternity/paternity leave or other medical leaves or going on sabbatical.

Because it’s really common for companies today to have contract and temporary employees, you need to know how to manage temporary accounts that will be used for only a short time and then disabled.

Managing these temporary accounts is easy—you just set the account to expire on the employee’s expected last day of work.

Setting Up Anonymous Accounts

Anonymous accounts allow only extremely limited access for a large number of users who all log in with the same username—for instance, *anonymous* or *guest*. These logins are frequently used to access FTP files; you gain access when you log in with the username *anonymous* and enter your email address as the password.

NOTE Sometimes people don’t use their real email addresses. If you really want to know where a user is located on the Internet, use third-party software to verify IP addresses and Internet domain names.

It’s obviously a very bad idea to use anonymous accounts for regular network access—you just can’t track them. All Windows Server products from Windows NT on come with the anonymous account Guest disabled, and it’s usually a good thing to leave it that way. When you want to enable that account, like at a public kiosk, make sure you carefully manage what it is able to access by implementing strict group policies.

Some web servers create an Internet user account to allow anonymous access to the website through which a user is allowed to access the web server over the network. The password is always blank, and you never see a request to log in to the server because it’s done automatically. Without this kind of account, no one would be able to access your web pages.

NOTE Do not rename the Internet user account or set a password because if you do so, the general public won’t be able to view your website. If you want to secure documents, use a separate secure HTTP or Windows server.

Limiting Connections

There is a good reason to limit how many times a user can connect to the network. Users should normally be logged in to the network for one instance because they can only be in one place at a time. So if your system is telling you that someone is logged in from more than one place, it’s probably because someone else is using their account. By disallowing simultaneous connections, only a single user at a single workstation can gain access to the network using a specific user account. But there are times that some users need to log in multiple times to use certain applications or perform certain tasks, and you can allow that specific user to have multiple concurrent connections.

You may also want to limit the specific location from which a user logs in because most of the time, your users will be logging on to the network only from their own workstations. This makes sense, but this rule isn't usually enforced because sometimes users move around without taking their computers with them, or they log in at someone else's station to get their jobs done. So unless you require super tight security, imposing this rule can really complicate your job because it requires a lot of administration. Windows Server products can limit which station(s) a user is allowed to log in from, but they don't do so by default. A Windows feature that is enabled by default is not allowing average users to log in at the server console because they shouldn't be working directly on a server. They can do some serious damage accidentally!

Renaming the Maintenance Account

Network operating systems automatically give the network maintenance (or administration) account a default name. On Windows servers, it's (surprise) Administrator, and in Unix it's root. So it should be crystal clear that if you don't change this account name, bad guys already have half the information they need to break into your network. The only thing they're missing is the password—yikes!

By all means, rename that account to something cool and creative that you'll remember but that would be really hard for someone to guess—and don't write it on a Post-it and stick it to the server. Here's a "do not use" list of names:

- Admin
- Administrator
- Analyst
- Audit
- Comptroller
- Controller
- Manager
- Root
- Super
- Superuser
- Supervisor
- Wizard
- Any variation on the above

Managing Passwords

Like any other aspect of network security, passwords must be managed, and doing that involves ensuring that all passwords for user accounts follow security guidelines so bad guys can't easily guess or crack them. You've also got to implement certain features of your network operating system to prevent unauthorized access.

Basically, a strong password is some combination of alphanumeric and special characters that's easy for you to remember but really hard for someone else to guess. Like server account names, they should never be written down on anything that is then put into your desk or stuck onto your computer. Unfortunately, this guideline is only followed in a perfect world. Users invariably try to make things easy on themselves by choosing passwords that are so simple to guess that someone would have to be seriously mentally challenged not to be able to. Let's look at some characteristics of strong passwords.

Minimum Length

Strong passwords should be at least 8 characters (the more, the merrier), but they shouldn't be any longer than 15 characters to make them easier to remember. You absolutely must specify a minimum length for passwords because a short password is easily cracked—after all, there are only so many combinations of three characters, right? The upper limit depends on the capabilities of your operating system and the ability of your users to remember complex passwords. Here's what I call "The Weak List" for passwords—never use them!

- The word *password* (Not kidding—people actually do this!)
- Proper names
- Your pet's name
- Your spouse's name
- Your children's names
- Any word in the dictionary
- A license plate number
- Birth dates
- Anniversary dates
- Your username
- The word *server*
- Any text or label on the PC or monitor
- Your company's name
- Your occupation
- Your favorite color
- Any of the above with a leading number
- Any of the above with a trailing number
- Any of the above spelled backward

There are more, but you get the idea, and these really are the most commonly used brainless passwords.

Real World Scenario

Security Audits

A great way to begin a basic security audit to get a feel for any potential threats to your network is to simply take a walk through the company's halls and offices. I've done this a lot, and it always pays off because invariably I happen upon some new and different way that people are trying to "beat the system" regarding security. This doesn't necessarily indicate that a given user is trying to cause damage on purpose; it's just that following the rules can be a little inconvenient—especially when it comes to adhering to strict password policies. Your average user just doesn't get how important their role is in maintaining the security of the network (maybe even their job security as well) by sticking to the network's security policy, so you have to make sure they do.

Think about it. If you can easily discover user passwords just by taking a little tour of the premises, so can a bad guy, and once someone has a username and a password, it's pretty easy to hack into resources. I wasn't kidding about people slapping sticky notes with their usernames and/or passwords right on their monitors—this happens a lot more than you would think. Some users, thinking they're actually being really careful, glue them to the back of their keyboards instead, but you don't have to be James Bond to think about looking there either, right? People wouldn't think of leaving their cars unlocked with the windows down and the keys in the ignition, but that's exactly what they're doing by leaving sensitive info anywhere on or near their workstations.

Even though it might not make you Mr. or Ms. Popularity when you search workspaces or even inside desks for notes with interesting or odd words written on them, do it anyway. People will try to hide these goodies anywhere. Or sometimes, not so much. I kid you not—I had a user who actually wrote his password on the border of his monitor with a Sharpie, and when his password expired, he just crossed it off and wrote the new one underneath it. Sheer genius! But my personal favorite was when I glanced at this one guy's keyboard and noticed that some of the letter keys had numbers written on them. All you had to do was follow the numbers that (surprise!) led straight to his password. Oh sure—he'd followed policy to the, ahem, letter by choosing random letters and numbers, but a lot of good that did—he had to draw himself a little map in plain sight on his keyboard to remember the password.

So, like it or not, you have to walk your beat to find out if users are managing their accounts properly. If you find someone doing things the right way, praise them for it openly. If not, it's time for more training—or maybe worse, termination.

Using Characters to Make a Strong Password

The good news is that solid passwords don't have to be in ancient Mayan to be hard to crack. They just need to include a combination of numbers, letters, and special characters—that's it. Special characters aren't letters or numbers but symbols like $ % ^ # @). Here's an example of a strong password: tqbf4#jotld. Looks like gibberish, but remember that famous sentence, "The quick brown fox jumped over the lazy dog"? Well, this particular password uses the first letter of each word in that sentence with a 4# thrown in the middle of it. Sweet—solid and easy to remember. You can do this with favorite quotes, song lyrics, and so on, with a couple of numbers and symbols stuck in the middle. Just make sure you don't sing the song or quote Shakespeare every time you log in!

If you want to test the strength of passwords to make sure they're nice and tight, you can use auditing tools like crack programs that try to guess passwords. Clearly, if that program has a really tough time or even fails to crack the password, you have a good one. By the way, don't just use a regular word preceded by or ending with a special character because good crack programs strip off the leading and trailing characters during decryption attempts.

Password-Management Features

All network operating systems include built-in features for managing passwords to help ensure that your system remains secure and that passwords cannot be easily hacked with crack programs. These features usually include automatic account lockouts and password expiration.

Automatic Account Lockouts

Hackers, and even people who forget their passwords, usually try to log in by guessing passwords. This is why most network operating systems will lock you out after a few unsuccessful attempts. Some will even disable the account. Once that happens, the user won't be able to log in to that account even if they enter the correct password. This feature prevents a potential hacker from running an automated script to crack account passwords by continuously attempting to log in using different character combinations.

When an account is on lockdown, guards—I mean, network staff—will have to unlock the account if the network operating system doesn't unlock it after a preset period. In any high-security network, it's a good idea to require an administrator to manually unlock every locked account instead of setting the network operating system to do it automatically. This way, the administrator will be sure to know about any possible security breaches.

NOTE

Be careful not to lock yourself out. With many network operating systems, only administrators can reset passwords, so if you happen to be the administrator and you lock yourself out, only another administrator can unlock your account. Embarrassing, yes, but what if you're the only administrator? You're in trouble then, because even though many network operating system vendors do have solutions to this humiliating little problem, the cost of those solutions isn't going to be cheap!

NOTE

It's good to know that Windows-based servers allow you to configure accounts to be locked out after a number of bad login attempts, but the default Administrator account is exempt from this happening. This might sound convenient for you, but it's actually a security risk. You should definitely rename this account, and it's also a good idea not to use it for day-to-day administration. Create a new administrator account (with a different name, of course), and use it for administrative purposes instead.

Password Expiration and Password Histories

Unlike a good wine, even really good passwords don't age well over time; they just become more likely to be cracked. This is why it's good to set passwords so that they expire after a specific amount of time. Most organizations set up passwords to expire every 30 to 45 days, after which the network's users all must reset their passwords either immediately or during a preset grace period. The grace period is usually limited to a specific number of login attempts, or it may allow a couple of days.

NOTE By default, each network operating system delimits a specific password-expiration period that bad guys usually know about. So make sure you reset that time period to something other than the default, in accordance with your security policy.

Older network operating systems allowed users to reset their passwords back to their original form after using an intermediary password for a while, but today's network operating systems prevent this by employing password histories that consist of a record of the past several passwords used by a specific user. This record prevents users from using any password that's stored in the password history. If they try, the password will fail, and the operating system will then request a password change. What this means to you, the system administrator, is that if your security policy dictates that passwords be reset every two weeks, you should make sure your password history can hold at least 20 passwords. This would prevent a user from reusing a password until the password is at least 10 months old (two changes per month). They'll forget that password by then!

By the way, your more experienced users know about this history feature, and because coming up with a really tight password takes a little thought, when savvy users create ones they really like, they may have a hard time letting go. Maybe they just want to avoid the hassle of creating a tight new password and remembering it, so they'll try to find ways to get out of doing that by getting around the password-history feature. For instance, I knew one guy who actually admitted that he just changed his password as many times as it took to defeat the history log and then changed it one last time to his beloved, original password—all of which took him only about five minutes to accomplish.

You can force users to change their passwords to ones that are unique because the latest operating systems require unique passwords and can, depending on the network operating system, store more than 20 passwords. This feature makes it a whole lot harder to revert to any previous passwords. But it's still possible for users to beat the system, so don't rely completely on it.

Single Sign-On

In today's modern enterprises, users can be overwhelmed by the number of points in the network where they may be challenged to identify themselves. Most users have to log onto the domain to have network access at all, and then there may be company websites that require an authentication process to access databases, SharePoint sites, secured drives, personal folders, and on and on!

When users must remember multiple passwords, as the number increases, they begin to resort to unsafe security practices such as writing passwords on sticky notes, hiding passwords in their drawers, and even sharing them with coworkers. All of these practices undermine the security of the network.

Single sign-on addresses this problem. With single sign-on, when the user logs into the domain, the domain controller issues them an access token. This access token contains a list of all the resources (which can include folders, drives, websites, databases, and so on) to which they should have access. As a result, anytime the user accesses a resource, the token is verified behind the scenes, and the user never needs to provide another password!

Local Authentication

When users authenticate to their computer, the authentication can be either to a domain or to the local machine. When local authentication is performed, the user's local account and password are verified with the local user database. This local user database is called Security Accounts Manager (SAM) and is located in `C:\windows\system32\config\`. In Linux, the database is a text file, `/etc/passwd` (called the password file), which lists all valid usernames and their associated information.

LDAP

A directory service is a database designed to centralize data management regarding network subjects and objects. A typical directory contains a hierarchy that includes users, groups, systems, servers, client workstations, and so on. Because the directory service contains data about users and other network entities, it can be used by many applications that require access to that information. A common directory service standard is Lightweight Directory Access Protocol (LDAP), which is based on the earlier standard X.500.

X.500 uses Directory Access Protocol (DAP). In X.500, the distinguished name (DN) provides the full path in the X.500 database where the entry is found. The relative distinguished name (RDN) in X.500 is an entry's name without the full path.

LDAP is simpler than X.500. LDAP supports DN and RDN, but it includes more attributes, such as the common name (CN), domain component (DC), and organizational unit (OU) attributes. Using a client-server architecture, LDAP uses TCP port 389 to communicate. If advanced security is needed, LDAP over SSL communicates via TCP port 636.

Certificates

A digital certificate provides an entity, usually a user, with the credentials to prove its identity and associates that identity with a public key. At minimum, a digital certification must provide the serial number, the issuer, the subject (owner), and the public key.

An X.509 certificate complies with the X.509 standard. An X.509 certificate contains the following fields:

- Version
- Serial Number

- Algorithm ID
- Issuer
- Validity
- Subject
- Subject Public Key Info
    - Public Key Algorithm
    - Subject Public Key
- Issuer Unique Identifier (optional)
- Subject Unique Identifier (optional)
- Extensions (optional)

VeriSign first introduced the following digital certificate classes:

- Class 1: For individuals and intended for email. These certificates get saved by web browsers.
- Class 2: For organizations that must provide proof of identity.
- Class 3: For servers and software signing in which independent verification and identity and authority checking is done by the issuing CA.

Multifactor Authentication

Multifactor authentication is designed to add an additional level of security to the authentication process by verifying more than one characteristic of a user before allowing access to a resource. Users can be identified in one of five ways:

- By something they know (password)
- By something they are (retinas, fingerprint, facial recognition)
- By something they possess (smart card)
- By somewhere they are (location)
- By something they do (behavior)

Two-factor authentication is when two of the above factors are being tested, while multifactor is when more than two of the above factors are being tested. An example of two-factor authentication would be requiring both a smart card and a PIN to log onto the network. The possession of either by itself would not be sufficient to authenticate. This protects against the loss and theft of the card as well as the loss of the password. An example of multifactor would be when three items are required, such as a smart card, a PIN, and a username and password.

This process can get as involved as the security requires. In an extremely high-security situation, you might require a smart card, a password, a retina scan, and a fingerprint scan. The trade-off to all the increased security is an inconvenient authentication process for the user and the high cost of biometric authentication devices.

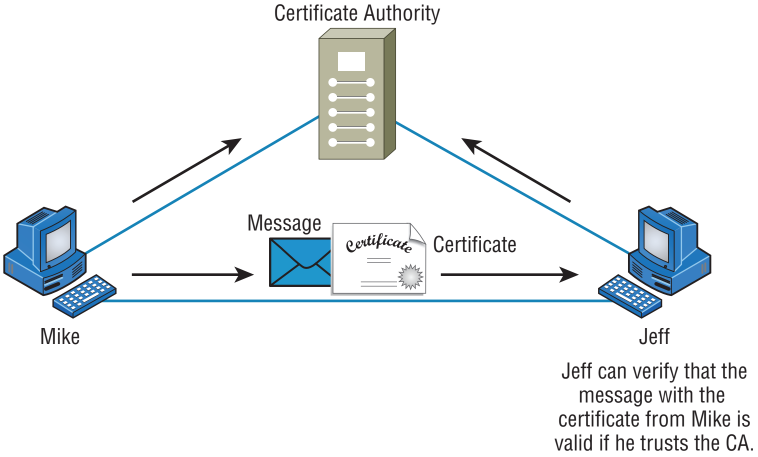
User-Authentication Methods

There are a number of authentication systems in use today, but I'm going to focus on the ones you're likely to be confronted with on the Network+ exam.

Public Key Infrastructure (PKI)

Public Key Infrastructure (PKI) is a system that links users to public keys and verifies a user's identity by using a *certificate authority (CA)*. Think of a CA as an online notary public—an organization that's responsible for validating user IDs and issuing unique identifiers to confirmed individuals to certify that their identity can really be trusted. Figure 13.12 shows how the CA process works in relation to two users.

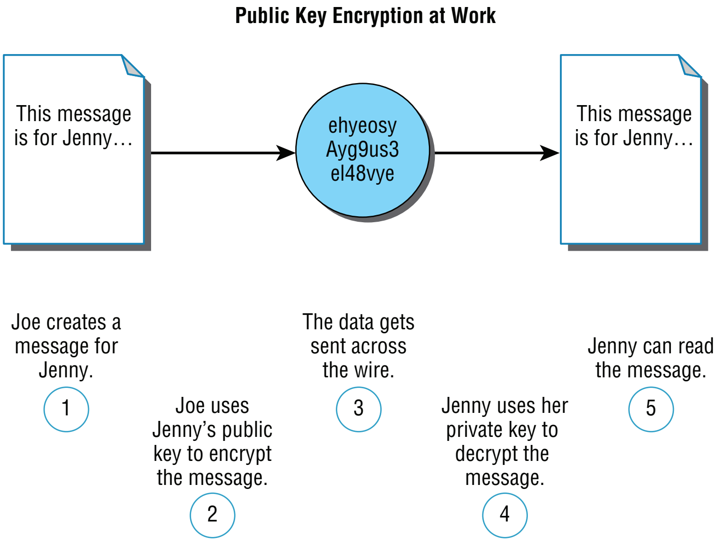
FIGURE 13.12 The certificate authority process


Certificate Authority
Message
Certificate
Certificate
Mike
Jeff
Jeff can verify that the message with the certificate from Mike is valid if he trusts the CA.

PKI allows people to communicate with each other with confidence that they're talking to whom they think they are talking to. It is used to establish confidentiality and to ensure message integrity without knowing anything about the other party prior to the conversation. It's also used to verify the digital signature of a private key's owner.

Public-key encryption operates through asymmetric cryptography, meaning that a different key is used to encrypt and decrypt the message, respectively. Symmetric cryptography uses the same key to encrypt and decrypt, so it's a lot less secure. Here's how it works: If I sent you a message using PKI, I'd use your public key to encrypt the message. When you received the message, you would use your private key, which is theoretically the only thing that can be used to decrypt the message back into something readable by humans. If a digital signature was required, you would sign the document with your private key, and anyone with access to your public key would be able to verify that the signature was truly yours. So clearly, you should be the only one who has access to your private key. Figure 13.13 illustrates what I just described.

FIGURE 13.13 PKI in action


Public Key Encryption at Work
This message is for Jenny…
ehyeosy Ayg9us3 el48vye
This message is for Jenny…
Joe creates a message for Jenny.
1
Joe uses Jenny's public key to encrypt the message.
2
The data gets sent across the wire.
3
Jenny uses her private key to decrypt the message.
4
Jenny can read the message.
5

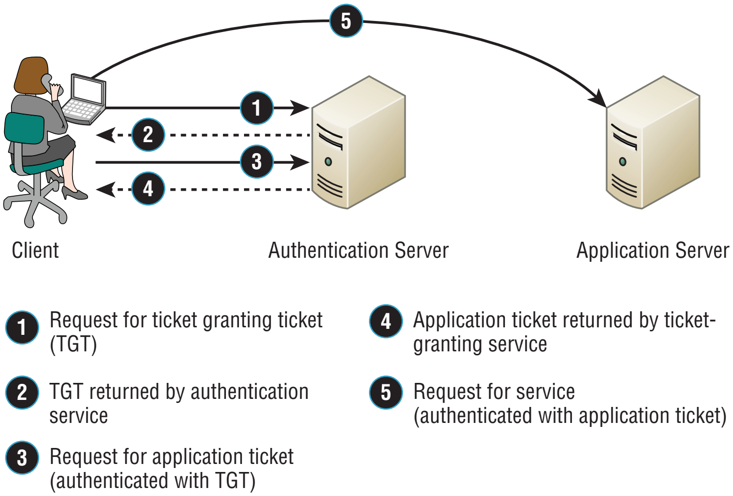
This type of authentication is used a lot in websites that perform transactions. You've probably experienced shopping online and having an error message pop up notifying you that a certain site's certificate or key has expired and asking if you want to proceed with the transaction. If you do, it's time to rethink things—you're probably way too trusting. Just say no!

Kerberos

Kerberos, created at MIT, isn't just a protocol, it's an entire security system that establishes a user's identity when they first log on to a system that's running it. It employs strong encryption for all transactions and communication, and it's readily available. The source code for Kerberos can be freely downloaded from lots of places on the Internet.

Kerberos works by issuing tickets to users who log in, kind of like going to an amusement park—as long as you have your ticket to ride, you're good to go. Even though the tickets expire quickly, they're automatically refreshed as long as you remain logged in. Because of this refresh feature, all systems participating in a Kerberos domain must have synchronized clocks. This synchronicity is a bit complicated to set up, although in Microsoft servers and domains the process is automatic, requiring only access to a recognized time server (which Microsoft also operates). The real negative hits happen if you have only one Kerberos authentication server—if it goes down, no one can log in to the network. So when running Kerberos, having redundant servers is clearly vital. You should also know that because all users' secret keys are stored in one centralized database, if that's compromised, you have a security tsunami on your hands. Luckily these keys are stored in an encrypted state. Figure 13.14 shows Kerberos in action.

FIGURE 13.14 The Kerberos authentication process


5
1
2
3
4
Client
Authentication Server
Application Server
1 Request for ticket granting ticket (TGT)
2 TGT returned by authentication service
3 Request for application ticket (authenticated with TGT)
4 Application ticket returned by ticket-granting service
5 Request for service (authenticated with application ticket)

Authentication, Authorization, and Accounting (AAA)

In computer security speak, *AAA* (triple A, like the auto club) refers to authentication, authorization, and accounting. *AAAA* is a more robust version that adds auditing into the mix. AAA and AAAA aren't really protocols; instead, they're systematized, conceptual models for managing network security through one central location. Two common implementations of AAA are RADIUS and TACACS+.

RADIUS

Although its name implies it, the *Remote Authentication Dial In User Service (RADIUS)* is not a dial-up server. Like pretty much everything else, it originated that way, but it's evolved into more of a verification service. Today, RADIUS is an authentication and accounting service that's used for verifying users over various types of links, including dial-up. Many ISPs use a RADIUS server to store the usernames and passwords of their clients in a central spot through which connections are configured to pass authentication requests. RADIUS servers are client-server-based authentication and encryption services maintaining user profiles in a central database.

RADIUS is also used in firewalls. Purposed this way, when a user wants to access a particular TCP/IP port, they must provide a username and a password. The firewall then contacts the RADIUS server to verify the credentials given. If the verification is successful, the user is granted access to that port.

NOTE

RADIUS is an authentication server that allows for domain-level authentication on both wired and wireless networks.

TACACS+

The Terminal Access Controller Access-Control System Plus (TACACS+) protocol is also a AAA method and an alternative to RADIUS. Like RADIUS, it is capable of performing authentication on behalf of multiple wireless APs, RAS servers, or even LAN switches that are 802.1X capable. Based on its name, you would think it's an extension of the TACACS protocol (and in some ways it is), but the two definitely are not compatible.

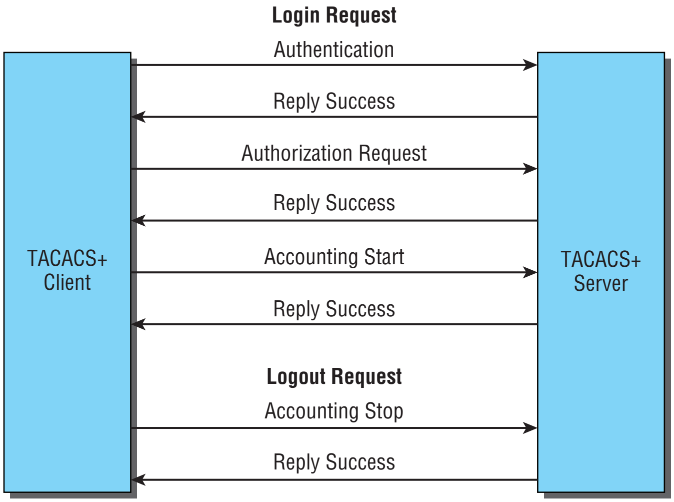
Here are two major differences between TACACS+ and RADIUS:

- RADIUS combines user authentication and authorization into one profile, but TACACS+ separates the two.
- TACACS+ utilizes the connection-based TCP protocol, but RADIUS uses UDP instead.

Even though both are commonly used today, because of these two reasons TACACS+ is considered more stable and secure than RADIUS.

Figure 13.15 shows how TACACS+ works.

FIGURE 13.15 TACACS+ login and logout sequence



Just to clarify things, in the IT world, *accounting* has nothing to do with money. Here's what I mean: When a TACACS+ session is closed, the information in the following list is logged, or accounted for. This isn't a complete list; it's just meant to give you an idea of the type of accounting information that TACACS+ gathers:

- Connection start time and stop time
- The number of bytes sent and received by the user
- The number of packets sent and received by the user
- The reason for the disconnection

The only time the accounting feature has anything to do with money is if your service provider is charging you based on the amount of time you've spent logged in or for the amount of data sent and received.

Web Services

Secure connections to web services can be configured using several variations of HTTP, which is unsecured. The following protocols can be used:

- Hypertext Transfer Protocol Secure (HTTPS) protects HTTP traffic by layering it on top of SSL/TLS. It requires a certificate on the server.
- Secure Hypertext Transfer Protocol (S-HTTP) is a little-used alternative to HTTPS. While HTTPS wraps the entire communication within SSL, S-HTTP only encrypts the served page data and the submitted data like POST fields. It leaves the initiation of the protocol unchanged.

Unified Voice Services

Unified voice services, or *unified communications*, is a term that describes combining traffic formerly confined to the phone network with IP data traffic and video traffic. It takes voice and video information and encapsulates it within IP packets to be transmitted on the data network.

VoIP and video streaming are two examples of this. In both cases, incoming data is consumed in real time as it is received, thus placing a premium on performance. To ensure this, QoS mechanisms must be utilized to give these traffic types priority over traffic that's less sensitive to latency.

Specifically, *unified voice* can also mean the integration of voice with other messaging systems such as IM, presence, and email services. It will include voicemail as well.

Network Controllers

There are several meanings for the term *network controller*, but in most cases it refers to a network interface card, or NIC. Newer cards are available that can support both LAN and SAN traffic at the same time. Moreover, these devices usually offload the processing usually placed on the CPU. Special models also perform their own encryption, thus easing the workload further on the CPU.

In other cases you may see this term used to describe a device that controls admission or access to a network. A good example of this is a system that goes beyond simple authentication and ensures that systems are safe and secure before they are allowed to access the network (Network Admission Control). In the next section, you'll be introduced to another such system, called 802.1X.

Network Access Control (NAC)

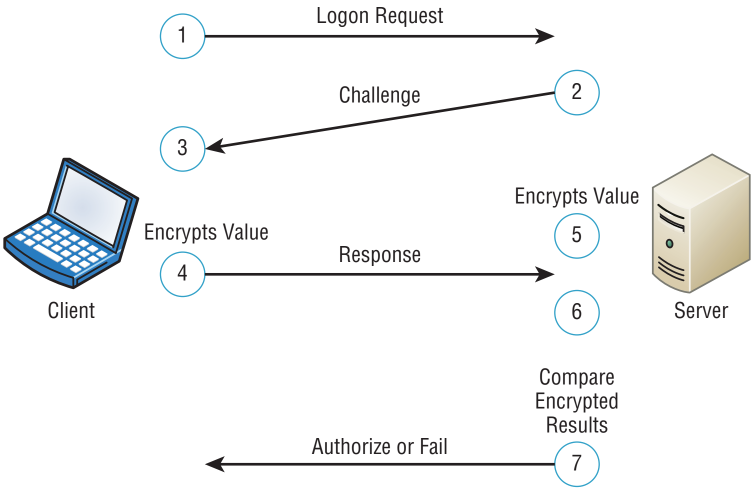
Network Access Control (NAC) is a method of securing network hosts before they're allowed to access the network. The most common implications for NAC are in wireless networking, where nodes are often added to and removed from the network freely. One of the most common forms of NAC is IEEE 802.1X.

Even the Institute of Electrical and Electronics Engineers (IEEE) recognizes the potential security holes in wireless networking, so it came up with the *IEEE 802.1X* standard as a way to authenticate wireless users. 802.1X is an open framework that's designed to support multiple authentication schemes. Before a client, called a *supplicant* in 802.1X-speak, can communicate on a wireless network, it asks the access point, or *authenticator*, for permission to join and then provides its credentials. The access point passes those credentials to a centralized authentication server that sends back an accept message to the access point if the authentication is accepted. Only then will the access point allow a user to connect to the wireless network.

Challenge Handshake Authentication Protocol (CHAP)

The *Challenge Handshake Authentication Protocol (CHAP)* is a secure authentication protocol because with CHAP, the username and password never cross the wire. Instead, both the client and server are configured with the same text phrase that's known as a *shared secret*. When a client sends out an authentication request, the server responds by sending a random value called a *nonce* plus an ID value back to the client. The client takes these two strings, sequences them with the shared secret, and then generates a one-way hash value using the MD5 Message-Digest Algorithm (MD5) encryption algorithm. This hash value is transmitted back to the server, which performs the same algorithm using the same values and shared secret. The server basically compares the hash value that it's received from the client with the hash value it has calculated, and if they match, the client gets to be authenticated. I know this sounds pretty complicated, so let me give you a visual demonstration of how CHAP works in Figure 13.16.

FIGURE 13.16 CHAP authentication process



CHAP has replaced the older Password Authentication Protocol (PAP) because PAP sends usernames and passwords in clear text and CHAP does not.

MS-CHAP

Microsoft has its own variation of CHAP known as *Microsoft Challenge Handshake Authentication Protocol (MS-CHAP)*. It works basically the same way as CHAP, except that unlike CHAP, which requires the shared secret to be stored locally in clear text, MS-CHAP encrypts the secret locally. And whereas CHAP provides authentication of the client by the server only, MS-CHAP version 2 is capable of mutual authentication so that the client can be sure the server is legitimate as well. Also, the encryption method used to generate the one-way hash in MS-CHAP is DES. Finally, and predictably, MS-CHAP doesn't work on Linux or other platforms—it's a Windows proprietary protocol.

Extensible Authentication Protocol (EAP)

Extensible Authentication Protocol (EAP) is an extension to PPP that provides a host of additional authentication methods for remote-access clients. Some examples include smart cards, certificates, Kerberos, and biometric schemes like retinal scans and fingerprint and voice recognition. Although EAP itself doesn't allow for mutual authentication, enhanced forms of the protocol do. For example, EAP-TLS and EAP-TTLS, a tunneled version of EAP-TLS, create a secure tunnel through which password-based versions like EAP-MD5 can run.

Hashes

Hashing is a cryptographic process that uses an algorithm to derive a value from a set of clear text to verify that the information came from where it says and that it has not changed. Therefore, we say hashes are used to provide data integrity and origin authentication. Two of the most well-known hashing algorithms are discussed in the following sections.

MD5

The MD5 message-digest algorithm was designed by Ron Rivest, and while it has been shown to have some flaws that cause many to prefer SHA (described in the next section), those flaws are not considered fatal and it is still widely used to ensure the integrity of transmission. As is the case with most hashing processes, the hash is created from the clear text and then sent along with the clear-text message. At the other end, a second hash of the clear-text data is created using the same algorithm, and if the two hashes match, the data is deemed to be unchanged.

SHA

Secure Hash Algorithm is a family of algorithm versions, much like MD5 having multiple versions on its way to becoming MD5. It is published by the National Institute of Standards and Technology (NIST) as a U.S. Federal Information Processing Standard (FIPS). It operates as any hash does and is considered to be superior to MD5.

Network Access Control

Network Access Control systems that control access to devices based on their security settings include Cisco's Network Admission Control (NAC) and Microsoft's Network Policy and Access Services (NPAS). These systems examine the state of a computer's operating system updates and anti-malware updates before allowing access, and in some cases they can even remediate the devices prior to permitting access. In the following sections, key components of network access control systems are covered.

Posture Assessment

When devices attempt to access the network, the devices are examined closely, which is called a posture assessment. The following items can be checked:

- Anti-malware updates
- Operating system updates
- Windows Registry settings

When the assessment is complete and is positive, admission is granted. If problems are found, admission may be denied and the user notified that action must be taken, or the device may be directed to a remediation server that can install missing updates or quarantine the device if necessary.

Guest Network

When a device is attempting to connect to a network using a form of network access control, the device is first placed in a guest network until a posture assessment is performed. Until it is either approved or remediated, it will remain in the guest network. The guest network will not allow access to the balance of the network to prevent the device from introducing issues to the network.

Persistent vs. Nonpersistent Agents

Network access control systems can be deployed using either persistent or nonpersistent agents on the devices. A persistent agent is one that is installed on a NAC client and starts when the operating system loads. This agent provides functionality that may not be present in the nonpersistent agent, such as system-wide notifications and alerts and auto and manual remediation.

A nonpersistent agent is one that is used to assess the device only during the onetime check-in at login, usually through a captive web portal. The nonpersistent or dissolvable agent is removed from the device when the authentication web page is closed. It can be used to support the assessment of endpoints not owned by the organization and as such can help to make a Bring Your Own Device (BYOD) policy possible.

Captive Portal

When a wireless network is in use, one method of securing access to the WLAN is using a captive portal. This is a web page to which users are directed when they attempt to connect to the WLAN. This web page may ask for network credentials, or in the case of a guest network it may only ask for agreement to the usage policy of the guest network.

Quarantine Network

When a guest machine is found to be out of compliance with the security posture required by a NAC system, the device is placed in a quarantine network, which prevents the device from exposing the rest of the network to the security risks that have been identified by the posture assessment. It will remain in this quarantine network until it is able to pass the assessment.

In cases where the NAC system supports remediation, the device may be connected to a remediation server that can make the required changes or updates to the system. Once the remediation is complete and the device is able to pass the assessment, it is then allowed to proceed on to the protected network.

Edge vs. Access Control

While controlling access to the network at the edge or boundary of the network (typically using firewalls) is certainly a proven method of protecting a network, it is somewhat of a blunt instrument of access control. Certainly the use of certain protocols and services can be prevented, and firewalls can even be granular enough to single out IP addresses and subnets, but at some point more sophisticated means of control are indicated.

Access controls that are applied where the resource resides often can be much more granular and can be more easily placed under the control of the resource owner. It is also less likely that mistakes in the application of access control lists on the resource will cause the type of widespread access problems that mistakes in ACLs on firewalls may have.

In today's network, there is a place for both access and edge control. Understanding the role that each can play and properly utilizing them can result in a layered approach to network security.

Summary

In this chapter, you learned about the two most basic security concerns: security filtering and user authentication. First, we talked about how to allow remote computers to join your network and how to specify the way traffic leaves your network using access control lists.

Then, you learned about various tunneling and encryption protocols like SSL, VPN, L2TP, PPTP, and IPSec.

Moving on, we examined several of the ways used today to remotely access networks, including RAS, RDP, PPP, PPPoE, and ICA.

We wrapped things up by discussing solid user-account and password-management policies and why those policies are essential to maintaining tight security on your network. Finally, you learned about authentication methods like PKI, Kerberos, RADIUS, TACACS+, 802.1X, CHAP, MS-CHAP, and EAP—good stuff!

Exam Essentials

Know two ways you can filter traffic using an access control list. Access control lists can filter traffic by IP address or MAC address.

Know which protocols can be used for tunneling and encryption of data. Tunneling and encryption protocols include SSL, VPN, L2TP, PPTP, GRE, and IPSec.

Know which services allow you to remotely access computers across a network. RAS, RDP, PPP, PPPoE, and ICA are remote-access services and protocols.

Know different user-authentication protocols used on networks. User-authentication protocols and systems include PKI, Kerberos, RADIUS, TACACS+, 802.1X, CHAP, MS-CHAP, and EAP.

Understand the operation of Network Access Control systems such as Cisco Network Admission Control. When devices attempt to access the network, the devices are examined closely, which is called a posture assessment. When the assessment is complete and is positive, admission is granted.

Written Lab

In this section, write the answers to the following authentication and access-control questions. You can find the answers to the written labs in Appendix A.

1. What are two possible items checked during a posture assessment?
2. Which type of agent is one that is installed on a NAC client and starts when the operating system loads?
3. Which encryption protocol or standard allows you to create a private network on an intranet?
4. Which user-authentication method uses a public key and private key pair?

5. In an authentication system that uses private and public keys, who should have access to the private key?

6. Which authentication method relies on tickets to grant access to resources?

7. In computer security, what does AAA stand for?

8. Which network access security method is commonly used in wireless networks?

9. Which user-authentication method is available only in an all-Windows environment?

10. Which user-authentication method utilizes the TCP protocol?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Nonpersistent or dissolvable NAC agents may help to make what possible?

   A. BYOD initiative

   B. Edge control

   C. Unified voice services

   D. Host-based IDS

2. What is the main difference between a private network and a public network?

   A. In a private network, everyone has access; in a public network, only authorized users have access.

   B. There is no difference; in both a private and public network, only authorized users have access.

   C. In a private network, only authorized users have access; in a public network, everyone that is connected has access.

   D. In a private network, everyone has access; in a public network, only the first 100 people have access.

3. You have a remote user who can connect to the Internet but not to the office via their VPN client. After determining the problem, which should be your next step?

   A. Have the client reboot their host.

   B. Make sure the user has the correct VPN address and password.

   C. Have the client reinstall their VPN software.

   D. Reboot the router at the corporate office.

4. Which IP address should you deny into your internetwork?

   A. 126.10.10.0/8

   B. 168.0.0.0/8

   C. 128.0.0.0/8

   D. 127.0.0.0/8

5. Which of the following is a tunneling protocol?

   A. Layer 2 Tunneling Protocol (L2TP)

   B. Internet Protocol Security (IPSec)

   C. Secure Sockets Layer (SSL)

   D. All of the above

6. Which tunneling protocol is based on RSA public-key encryption?

   A. SSL

   B. L2TP

   C. IPSec

   D. SSL VPN

7. What is the minimum number of characters you should use when creating a secure password?

   A. 6

   B. 7

   C. 8

   D. 15

8. In which layer of the OSI model does IPSec operate?

   A. Physical

   B. Network

   C. Transport

   D. Application

9. Which protocol works in both the transport mode and tunneling mode?

   A. SSL

   B. L2TP

   C. PPTP

   D. IPSec

10. Companies that want to ensure that their data is secure during transit should use which of the following?

    A. Firewalls

    B. Encryption

    C. Data accounting

    D. Routing table

11. Which network utilities do not have the ability to encrypt passwords? (Select two.)

    A. FTP

    B. SSH

    C. Telnet

    D. SCP

12. To encode or read an encrypted message, what tool is necessary?

- **A.** Routing table
- **B.** Internet access
- **C.** Encryption key
- **D.** Email address

13. Which of the following is *not* an enhancement provided by TLS version 2.0?

- **A.** Improvements in the operation of the MD5/SHA-1 hashing function
- **B.** Enhanced support for the Advanced Encryption Standard (AES)
- **C.** Expansion of the use of TLS to VPNs
- **D.** More flexibility in the choice of hashing and encryption algorithm

14. Which of the following is not a type of public-key encryption?

- **A.** Diffie-Hellman algorithm
- **B.** RSA Data Security
- **C.** Pretty Good Privacy (PGP)
- **D.** DES

15. Which of the following VPN protocols runs over TCP port 1723, allows encryption to be done at the data level, and allows secure access?

- **A.** RAS
- **B.** RADIUS
- **C.** PPPoE
- **D.** PPTP

16. At which stage of PPPoE are the MAC addresses of the endpoints exchanged?

- **A.** Session
- **B.** Discovery
- **C.** Transport
- **D.** Final

17. When utilizing multifactor authentication, which of the following is an example of verifying something you are?

- **A.** Smart card
- **B.** Password
- **C.** Fingerprint
- **D.** Certificate

18. Which of the following authentication methods allows for domain authentication on both wired and wireless networks?

    A. RADIUS

    B. CHAP

    C. PKI

    D. RDP

19. Which user-client-server authentication software system combines user authentication and authorization into one central database and maintains user profiles?

    A. RADIUS

    B. TACACS+

    C. Kerberos

    D. PKI

20. Which of the following is not a Network Access Control method?

    A. CHAP

    B. 802.1X

    C. EAP

    D. ICA

Chapter 14

Network Threats and Mitigation

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **3.3 Explain common scanning, monitoring, and patching processes and summarize their expected outputs**

- Port scanning
- Patch management—Rollback
- Reviewing baselines

✓ **3.5 Identify policies and best practices**

- Licensing restrictions
- International export controls
- Incident response policies
- System life cycle
  - Asset disposal

✓ **4.1 Summarize the purposes of physical security devices**

- Detection
  - Motion detection
- Video surveillance
  - Asset tracking tags
  - Tamper detection

✓ **4.3 Given a scenario, secure a basic wireless network**

- WPA
- WPA2

✓ **4.4 Summarize common networking attacks**

- DoS
  - Reflective
  - Amplified
  - Distributed

- Social engineering
- Insider threat
- Logic bomb
- Rogue access point
- Evil twin
- War-driving
- Phishing
- Ransomware
- DNS poisoning
- ARP poisoning
- Spoofing
- Deauthentication
- Brute force
- VLAN hopping
- Man-in-the-middle
- Exploits vs. vulnerabilities

✓ **4.5 Given a scenario, implement network device hardening**

- Changing default credentials
- Avoiding common passwords
- Upgrading firmware
- Patching and updates
- File hashing
- Disabling unnecessary services
- Using secure protocols
- Generating new keys
- Disabling unused ports
  - IP ports
  - Device ports (physical and virtual)

✓ **4.6 Explain common mitigation techniques and their purposes**

- Privileged user account
- File integrity monitoring
- Role separation
- Restricting access via ACLs

It's true…you're not paranoid if they really *are* out to get you. Although "they" probably aren't after you personally; your network—no matter the size—is seriously vulnerable, so it's wise to be very concerned about keeping it secure. Unfortunately, it's also true that no matter how secure you think your network is, it's a good bet that there are still some very real threats out there that could breach its security and totally cripple your infrastructure!

I'm not trying to scare you; it's just that networks, by their very nature, are not secure environments. Think about it—the whole point of a having a network is to make resources available to people who aren't at the same physical location as the network's resources. Because of this, it follows that you've got to open access to those resources to users you may not be able to identify. One network administrator I know referred to a server running a much-maligned network operating system as "a perfectly secure server until you install the NIC." You can see the dilemma here, right?

Okay, with all this doom and gloom, what's a network administrator to do? Well, the first line of defense is to know about the types of threats out there because you can't do anything to protect yourself from something you don't know about. But once you understand the threats, you can begin to design defenses to combat bad guys lurking in the depths of cyberspace just waiting for an opportunity to strike.

I'm going to introduce you to some of the more common security threats and teach you about the ways to mitigate them. I'll be honest—the information I'll be giving you in this chapter is definitely not exhaustive. Securing computers and networks is a huge task and there are literally hundreds of books on this subject alone. If you want to learn more about security on a much deeper level (and get another powerful certification in the process), get your hands on the *CompTIA Security+ Study Guide: Exam SY0-501 7th Edition* by Emmett Dulaney and Chuck Easttom (Sybex 2018).

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Recognizing Security Threats

I'm not trying to freak you out, but I'm not exaggerating the dangers to your network security either. Here's an example: Recently, I hooked up a friend's computer to a high-speed network connection from his phone company. He had antivirus software but no personal firewall in place yet, and before I could get that firewall set up (which usually takes about 10 minutes), 15 virus alerts popped up!

Although viruses are common threats that we hear about all the time, there are many other nasty things out there as well. Bad guys who create threats to a network generally have one of two purposes in mind: destruction or reconnaissance. They're seeking to destroy data or deny access, and maybe even nick information that you definitely don't want them to have. Some types of attacks can accomplish both, but they're usually combinations of simpler forms. In the following sections, we'll look at several common approaches that bad guys use to breach the security of our precious networks.

Denial of Service

A *denial of service (DoS) attack* does exactly what it sounds like it would do—it prevents users from accessing the network and/or its resources. Today, DoS attacks are commonly launched against a major company's intranet and especially its websites. "Joe the Hacker" (formerly a plumber) thinks that if he can make a mess of, say, Microsoft's or Amazon's website, he's done that company some serious damage. And you know what? He's right!

Even though DoS attacks are nasty, strangely, hackers don't respect other hackers who execute them because they're really easy to deploy. It's true—even a pesky little 10-year-old can execute one and bring you to your knees. (That's just wrong!) This means that "real" bad guys have no respect for someone who uses DoS attacks, and they usually employ much more sophisticated methods of wreaking havoc on you instead. I guess it comes down to that "honor among thieves" thing. Still, know that even though a DoS-type attack won't gain the guilty party any esteemed status among "real" hackers, it's still not exactly a day at the beach to deal with.

Worse, DoS attacks come in a variety of flavors. Let's talk about some of them now.

The Ping of Death

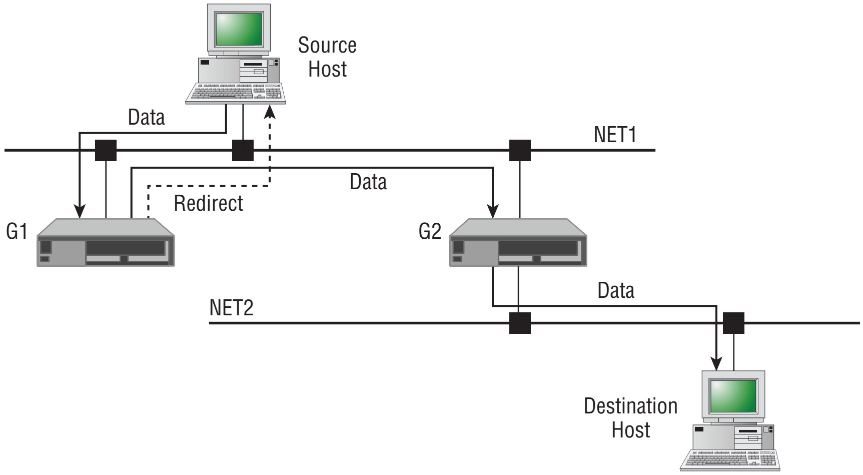
Ping is primarily used to see whether a computer is responding to IP requests. Usually, when you ping a remote host, what you're really doing is sending four normal-sized Internet Control Message Protocol (ICMP) packets to the remote host to see if it's available. But during a *Ping of Death* attack, a humongous ICMP packet is sent to the remote host victim, totally flooding the victim's buffer and causing the system to reboot or helplessly hang there, drowning. It's good to know that patches are available for most operating systems to prevent a Ping of Death attack from working.

Unreachable Gateway

An attacker can make a host's default gateway unreachable; the end game is to get the host to change their gateway address to that of one controlled by the attacker to accomplish a man-in-the-middle attack.

1. First, the attacker takes control of a secondary gateway available to the host, shown as G1 in Figure 14.1.

FIGURE 14.1 Unreachable gateway



2. The attacker, acting as the destination host, sends a TCP open packet to the acting source host.
3. While a reply is in transit from the source host to the destination host through gateway G2, the attacker, spoofing as G2, sends an ICMP route redirect message to the source host.
4. The source host will accept the route change control message as valid and thus change its routing table to route all traffic bound for the destination host through gateway G1.
5. Now the attacker, acting as a man-in-the-middle host, will quietly read/modify and forward all traffic bound for the destination host to gateway G2.

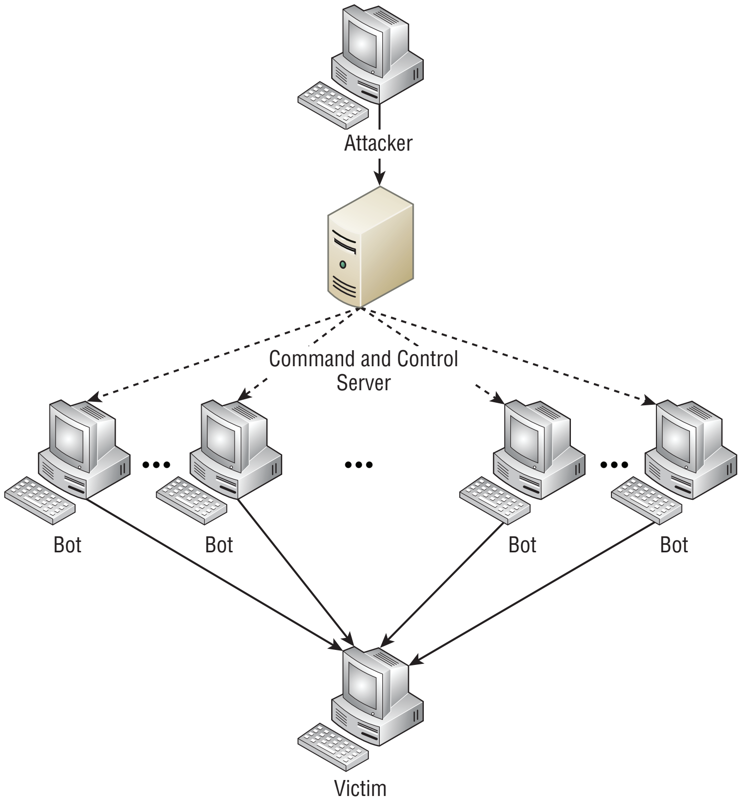
Distributed DoS (DDoS)

Denial of service attacks can be made more effective if they can be amplified by recruiting helpers in the attack process. In the following sections, some terms and concepts that apply to a distributed denial of service attack are explained.

Botnet

A botnet is a group of programs connected on the Internet for the purpose of performing a task in a coordinated manner. Some botnets, such as those created to maintain control of Internet Relay Chat (IRC) channels, are legal, while others are illegally created to foist a DDoS. An attacker can recruit and build a botnet to help amplify a DoS attack, as illustrated in Figure 14.2.

FIGURE 14.2 Botnet



The steps in the process of building a botnet are as follows:

1. A botnet operator sends out viruses or worms whose payloads are malicious applications, the bots, infecting ordinary users' computers.
2. The bots on the infected PCs log into a server called a command and control (C&C) server under the control of the attacker.
3. At the appropriate time, the attacker, through the C&C server, sends a command to all bots to attack the victim at the same time, thereby significantly amplifying the effect of the attack.

Traffic Spike

One of the hallmarks of a DDoS attack is a major spike in traffic in the network as bots that have been recruited mount the attack. For this reason, any major spike in traffic should be regarded with suspicion. A network intrusion detection system (IDS) can recognize these traffic spikes and may be able to prevent them from growing larger or in some cases prevent the traffic in the first place.

Some smaller organizations that cannot afford some of the more pricy intrusion prevention systems (IPSs) or IDSs make use of features present on their load balancers. Many of these products include DDoS mitigation features such as the TCP SYN cookie option. It allows the load balancer to react when the number of SYN requests reaches a certain point. At that point, the device will start dropping requests when the SYN queue is full.

Coordinated Attack

Another unmistakable feature of a DDoS attack is the presence of a coordinated attack. As shown in Figure 14.2 and as just described in the section "Botnet," to properly amplify the attack the bots must attack the victim at the same time. The coordination of the bots is orchestrated by the command and control server depicted in Figure 14.2. If all the bots can be instructed to attack at precisely the same second, the attack becomes much more dangerous to the victim.

Friendly/Unintentional DoS

An unintentional DoS attack (also referred to as attack from "friendly fire") is not one that is not caused by malicious individuals; instead, it's a spike in activity to a website or resource that overpowers its ability to respond. In many cases, it is the result of a relatively unknown URL suddenly being shared in a larger medium such as a popular TV or news show. For example, when Michael Jackson died, the amount of Twitter and Google traffic spiked so much that at first it was thought that an automated attack was under way.

Physical Attack

Physical attacks are those that cause hardware damage to a device. These attacks can be mitigated, but not eliminated, by preventing physical access to the device. Routers, switches, firewalls, servers, and other infrastructure devices should be locked away and protected by strong access controls. Otherwise, you may be confronted with a permanent DoS, covered in the next section.

Permanent DoS

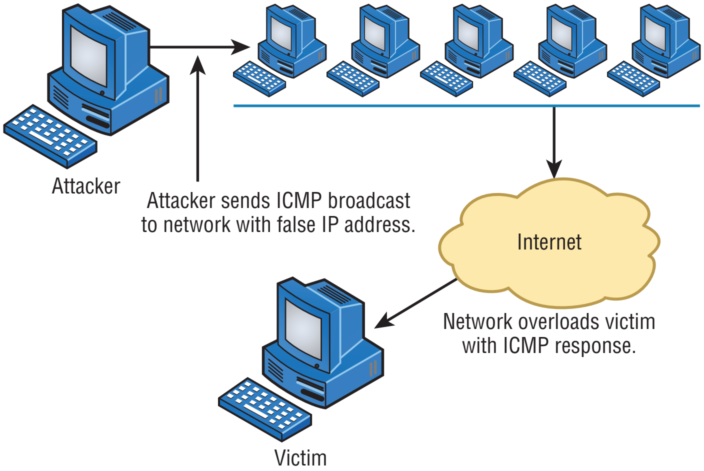
A permanent DoS attack is one in which the device is damaged and must be replaced. It requires physical access to the device, or does it? Actually, it doesn't! An attack called a phlashing denial of service (PDoS) attacks the firmware located in many systems. Using tools that fuzz (introduce errors) the firmware, attackers cause the device to be unusable. Another approach is to introduce a firmware image containing a Trojan or other types of malware.

Smurf

Smurfs are happy little blue creatures that like to sing and dance, but a *Smurf attack* is far more nefarious. It's a version of a DoS attack that floods its victim with spoofed broadcast ping messages. I'll talk about spoofing in more detail later; for now, understand that it basically involves stealing someone else's IP address.

Here's how it works: The bad guy spoofs the intended victim's IP address and then sends a large number of pings (IP echo requests) to IP broadcast addresses. The receiving router responds by delivering the broadcast to all hosts in the subnet, and all the hosts respond with an IP echo reply—all of them at the same time. On a network with hundreds of hosts, this results in major network gridlock because all the machines are kept busy responding to each echo request. The situation is even worse if the routers have not been configured to keep these types of broadcasts confined to the local subnet (which thankfully they are by default!). Figure 14.3 shows a Smurf attack in progress.

FIGURE 14.3 Smurf attack in progress


Attacker
Attacker sends ICMP broadcast to network with false IP address.
Internet
Network overloads victim with ICMP response.
Victim

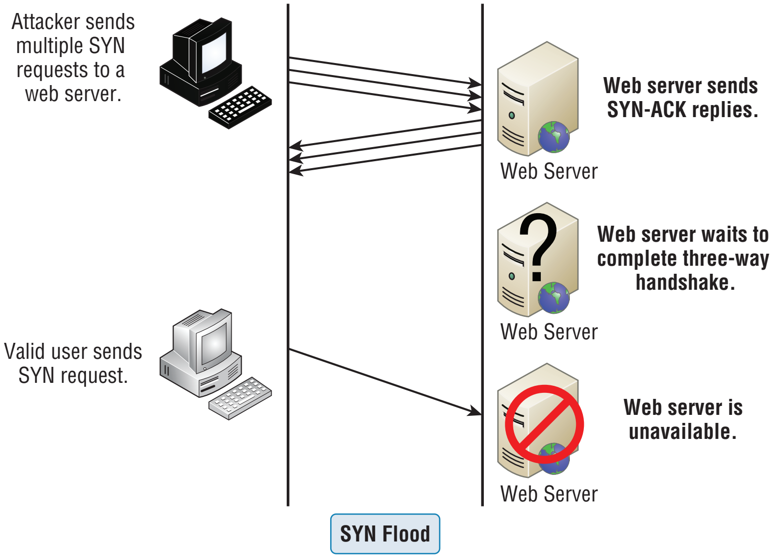
Fortunately, Smurf attacks aren't very common anymore because most routers are configured in a way that prevents them from forwarding broadcast packets to other networks. Plus, it's really easy to configure routers and hosts so they won't respond to ping requests directed toward broadcast addresses.

SYN Flood

A *SYN flood* is also a DoS attack that inundates the receiving machine with lots of packets that cause the victim to waste resources by holding connections open. In normal communications, a workstation that wants to open a Transmission Control Protocol/Internet Protocol (TCP/IP) communication with a server sends a TCP/IP packet with the SYN flag set to 1. The server automatically responds to the request, indicating that it's ready to start communicating with a SYN-ACK. In the SYN flood, the attacker sends a SYN, the victim sends back a SYN-ACK, and the attacker leaves the victim waiting for the final ACK. While the server is waiting for the response, a small part of memory is reserved for it. As the SYNs continue to arrive, memory is gradually consumed.

Figure 14.4 shows an example of a simple DoS/SYN flood attack.

FIGURE 14.4 A simple DoS/SYN flood attack


Attacker sends multiple SYN requests to a web server.
Web server sends SYN-ACK replies.
Web Server
Web server waits to complete three-way handshake.
Web Server
Valid user sends SYN request.
Web server is unavailable.
Web Server
SYN Flood

You can see that the preyed-upon machine can't respond to any other requests because its buffers are already overloaded, and it therefore rejects all packets requesting connections, even valid ones, which is the idea behind the attack. The good news is that patches to help guard against this type of attack are available for the various network operating systems today.

Stacheldraht

This is actually a mélange of techniques that translates from the German word for *barbed wire*. It basically incorporates Tribal Flood Network (TFN) techniques (certain botnet attacks including ICMP floods, SYN floods, UDP floods, and Smurf attacks) and adds a dash of encryption to the mix. The nightmare begins with a huge invasion at the root level, followed with a DoS attack finale.

Reflective/Amplified Attacks

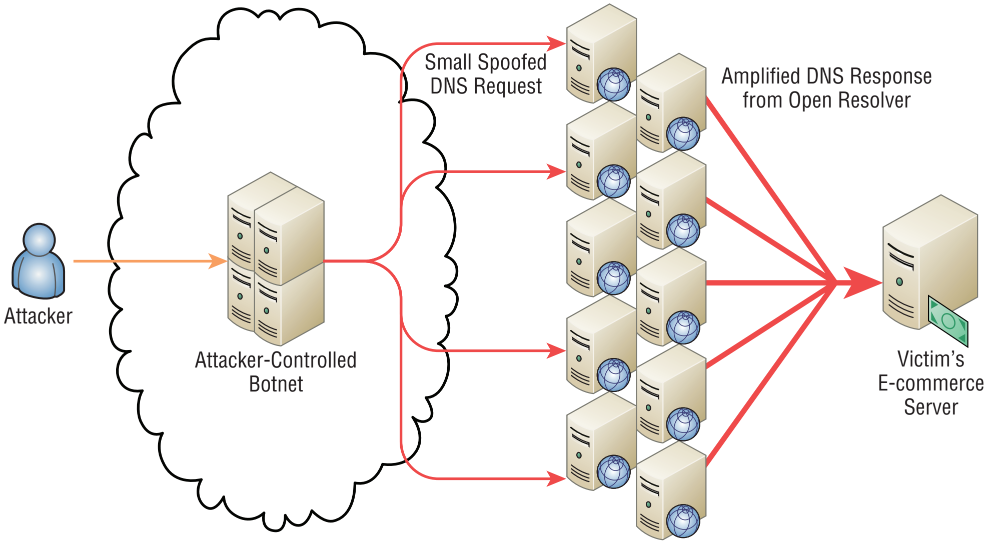
Reflected or amplified attacks increase the effectiveness of a DoS attack. Two of the more effective of these types of attacks involve leveraging two functions that almost all networks use, DNS and NTP. In the next two sections these attacks are described.

DNS

A DNS amplification attack is a form of reflection attack in that the attacker delivers traffic to the victim by reflecting it off a third party. Reflection conceals the source of the attack. It relies on the exploitation of publicly accessible open DNS servers to deluge victims with DNS response traffic.

The attacker sends a small DNS message using the victim's IP address as the source to an open resolver. The type of request used returns all known information about the DNS zone, which allows for the maximum level of response amplification directed to the victim's server. The attack is magnified by recruiting a botnet to send the small messages to a large list of open resolvers (DNS servers). The response from the DNS server overwhelms the victim, as shown in Figure 14.5.

FIGURE 14.5 DNS amplification attack


Small Spoofed DNS Request
Amplified DNS Response from Open Resolver
Attacker
Attacker-Controlled Botnet
Victim's E-commerce Server

NTP

While NTP refection attacks use the same process of recruiting bots to aid the attack, the attacks are not reflected off DNS servers; they are instead reflected off Network Time Protocol (NTP) servers. These servers are used to maintain time synchronization between devices in a network.

The attacker (and his bots) sends a small spoofed 8-byte UDP packet to vulnerable NTP servers that requests a large amount of data (megabytes worth of traffic) be sent to the DDoS's target IP address. The attackers use the `monlist` command, a remote command in older versions of NTP, that sends the requester a list of the last 600 hosts who have connected to that server. This attack can be prevented by using at least NTP version 4.2.7 (which was released in 2010).

ARP Cache Poisoning

ARP cache poisoning is usually a part of a man-in-the middle attack. The ARP cache contains IP address to MAC address mappings that a device has learned through the ARP process. One of the ways this cache can be poisoned is by pinging a device with a spoofed IP address. In this way, an attacker can force the victim to insert an incorrect IP address to MAC address mapping into its ARP cache. If the attacker can accomplish this with two computers having a conversation, they can effectively be placed in the middle of the transmission. After the ARP cache is poisoned on both machines, they will be sending data packets to the attacker, all the while thinking they are sending them to the other member of the conversation.

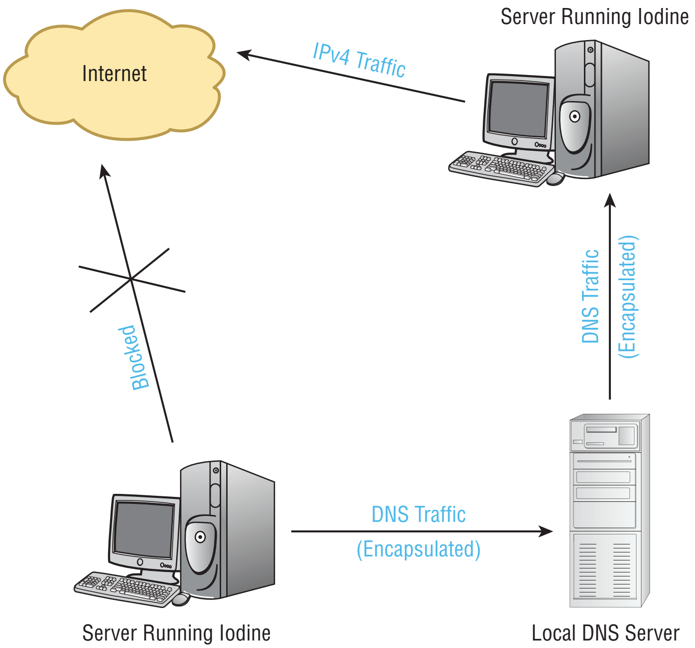
Packet/Protocol Abuse

After an attacker has broken into the system, attained access, and escalated their privileges, it is important for them to maintain their authority on the system so they can access it at a later time. They could put an operating system backdoor on the target, but in some cases the firewall on the victim may not allow outgoing TCP connections.

One of the ways in which a hacker can get traffic through a firewall that would typically not be allowed is by concealing one protocol within another, which is a form of tunneling. TCP can be encapsulated into either DNS or ICMP, thereby bypassing the firewall restrictions.

An example of this is using a program called Iodine to encapsulate IP traffic in DNS packets. Once the DNS packets reach the local DNS server, they are forwarded to a second machine running Iodine that de-encapsulates the packets and sends them on to the hacker. The DNS traffic is allowed by the firewall and is able to reach the client. In this way, the attacker is able to communicate with the victim machine. This process is illustrated in Figure 14.6.

FIGURE 14.6 IP4 packets tunneled in DNS



Spoofing

IP spoofing is the process of changing a source IP address so that one computer appears to be a different computer. It's usually done to get traffic through a firewall that would normally not be allowed. It may also be used to access a server to which the hacker would normally be disallowed access by their IP address.

While IP spoofing may be the most well-known type of spoofing, it is not the only type used by hackers. The following forms of this subterfuge also exist:

- ARP spoofing (discussed earlier in the section "ARP Cache Poisoning").
- Referrer spoofing, in which the referrer header of an HTTP packet is changed to reflect an allowed referral page, which some sites require for access.
- Email spoofing, in which the "from" field is changed to hide the true origin of an email. In most cases this is to conceal the identity of an email spammer.

Brute Force

A brute force attack is a form of password cracking. The attacker attempts every possible combination of numbers and letters that could be in a password. Theoretically, given enough time and processing power, any password can be cracked. When long, complex passwords are used, however, it can take years.

Setting an account lockout policy is the simplest mitigation technique to defeat brute force attacks. With such a policy applied, the account becomes locked after a set number of failed attempts.

Session Hijacking

Session hijacking attacks attempt to take over a user's session with a secure server after the user has been authenticated. This can be done in the following ways:

Session Fixation The attacker sets the session ID ahead of time by sending a link to the victim with the ID preset. When the user connects, the attacker waits for the authentication to complete and takes over the session by disconnecting the user and using the ID to reconnect.

Session Sidejacking The attacker uses a sniffer to steal a session cookie from the user. Alternately, if the attacker has physical access to the user's machine, they can steal the session key from memory.

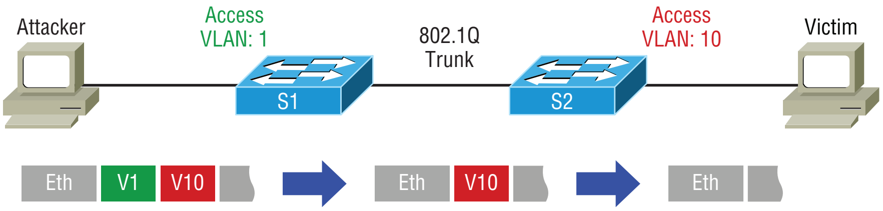
Cross-Site Scripting The attacker uses the user's computer to run code on the site that may allow him to obtain the cookie. The attacker does this by putting malware on the user's computer; the malware runs the code on the site after the user authenticates to the site.

VLAN Hopping

VLANs, or virtual LANs, are Layer 2 subdivisions of the ports in a single switch. A VLAN may also span multiple switches. When devices are segregated into VLANs, access control lists (ACLs) can be used in a router to control access between VLANs in the same way it is done between real LANs. When VLANs span switches, the connection between the switches is called a trunk link, and it carries the traffic of multiple VLANs. Trunk links are also used for the connection from the switch to the router.

A VLAN hopping attack results in traffic from one VLAN being sent to the wrong VLAN. Normally, this is prevented by the trunking protocol placing a VLAN tag in the packet to identify the VLAN to which the traffic belongs. The attacker can circumvent this by a process called double tagging, which is placing a fake VLAN tag into the packet along with the real tag. When the frame goes through multiple switches, the real tag is taken off by the first switch, leaving the fake tag. When the frame reaches the second switch, the fake tag is read and the frame is sent to the VLAN to which the hacker intended the frame to go. This process is shown in Figure 14.7.

FIGURE 14.7 VLAN hopping



Authentication Issues

Since the process of authenticating a user or a device forms the basis for securing most resources, authentication issues can lead to improper access, stolen data, and a whole host of other problems. In the following sections, we'll look at some common authentication issues.

TACACS/RADIUS Misconfiguration

Terminal Access Controller Access-Control System Plus (TACACS+) and Remote Access Dial-In User Service (RADIUS) are both examples of authentication, authorization, and accounting (AAA) servers that verify the identity of, grant access to, and track the actions of users. Misconfiguration of these devices can result in an inability of users and devices to connect to the access devices that are clients of the AAA server (switches, WAPs, dial-up servers, VPN servers). Some of the most common mistakes that result in this situation prevent communication between the AAA server and the AAA client. When this happens, check the following:

- Verify the port numbers. Even if standard port numbers for these services have been selected, that doesn't mean the product you are using uses those port numbers. Make sure the client and server are using the correct port numbers.
- Check to see if there is a mismatch in the pre-shared key between the client and the server.

When the problem is an issue between the supplicant (user or device requesting access) and the authenticating server (switch, WAP, dial-up server), check the following:

- Verify that the AAA method configured on the supplicant lists the appropriate RADIUS or TACACS+ server group.

- Verify that the authentication port number matches the configured port number.
- Verify that the user is configured on the AAA server (user account).

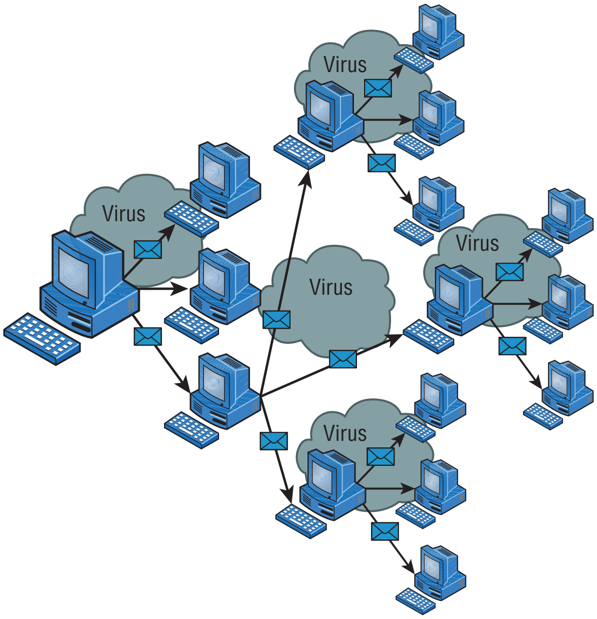
Default Passwords/Settings

All network devices are configured with default administrator accounts and their default passwords. These accounts should be disabled and renamed if possible. At the very least, the passwords for these accounts should be changed from the default because they are well known, available in documentation that comes with the product, and also widely available on the Internet.

Viruses

Viruses with catchy names like Chernobyl, Michelangelo, Melissa, I Love You, and Love Bug are probably the best-known threats to your computer's security because they get a lot of media coverage as they proliferate and cause tons of damage to legions of people. In their simplest form, viruses are basically little programs that cause a variety of very bad things to happen on your computer, ranging from merely annoying to totally devastating. They can display a message, delete files, or even send huge amounts of meaningless data over a network to block legitimate messages. A key trait of viruses is that they can't replicate themselves to other computers or systems without a user doing something like opening an executable attachment in an email to propagate them. Figure 14.8 shows how fast a virus can spread through an email system.

FIGURE 14.8 An email virus spreading rapidly



There are several different kinds of viruses, but the most popular ones are file viruses, macro (data file) viruses, and boot-sector viruses. Each type differs slightly in the way it works and how it infects your system. Predictably, many viruses attack popular applications like Microsoft Word, Excel, and PowerPoint because those programs are easy to use so it's easy to create a virus for them. Unlike with DoS attacks, writing a unique virus is considered a programming challenge, so the scoundrel who's able to come up with it not only gains respect from the hacking community but also gets to bask in the glow of the media frenzy that results from their creation and relish their 15 minutes of fame. This is also a big reason why viruses are becoming more and more complex and harder to eliminate.

Logic Bomb

A logic bomb is a type of malware that executes when a particular event takes place. For example, that event could be a time of day or a specific date or it could be the first time you open `notepad.exe`. Some logic bombs execute when forensics are being undertaken, and in that case the bomb might delete all digital evidence.

Ransomware

Ransomware is a class of malware that prevents or limits users from accessing their information or systems. In many cases the data is encrypted and the decryption key is only made available to the user when the ransom has been paid.

Effect of Malware on the Network

Malicious software (or *malware*) is a term that describes any software that harms a computer, deletes data, or takes actions the user did not authorize. There is a wide array of malware types, including ones you have probably heard of, like viruses. Some types of malware require the assistance of a user to spread, while others do not.

A worm is a type of malware that can spread without the assistance of the user. A worm is a small program that, like a virus, is used to deliver a payload. One way to help mitigate the effects of worms is to place limits on sharing, writing, and executing programs. However, the real solution is to deploy antivirus and anti-malware software to all devices in the network. This software is designed to identify viruses, Trojans, and worms and delete them, or at least quarantine them until they can be removed.

File Viruses

A *file virus* attacks executable application and system program files like those with filenames ending in `.com`, `.exe`, and `.dll`. These viruses do their damage by replacing some or all of the target program's code with their own. Only when the compromised file is executed can the virus do its dirty work. First, it loads itself into memory and waits to infect other executables, propagating its destructive effects throughout a system or network. A couple of well-known file viruses are Jerusalem and Nimda, the latter of which is actually an Internet worm that infects common Windows files and other files with filename extensions like `.html`, `.htm`, and `.asp`.

NOTE

Don't fall into the trap of thinking that just because you have a Mac, you don't need to worry about viruses. It's a common misconception that Mac operating systems are immune to viruses, but they're not. Today's Macs are really BSD Unix machines with a couple of proprietary programs running on top that provide users with a slick interface. And although it's true that more sophisticated programming skills are required to write viruses for Mac, BSD Unix, and Linux operating systems than for DOS-based operating systems like Windows, all operating systems are vulnerable to attacks. True, it's a lot easier for a bad guy to write malicious code for Windows machines, but the real reason few programmers spend their time creating viruses for Sun workstations and Macs is that there aren't nearly as many people using them. On the other hand, Windows machines are everywhere, so viruses written for them will clearly infect multitudes, giving bad guys who want to infect as many computers as possible a lot more bang for their evil programming buck!

Macro Viruses

A macro is basically a script of commonly enacted commands used to automatically carry out tasks without requiring a user to initiate them. Some popular programs even give you the option of creating your own, personal scripts to perform tasks you do repeatedly in a single step instead of having to enter the individual commands one by one.

Similar to this, a *macro virus* uses something known as the Visual Basic macro-scripting language to perform nasty things in data files created with programs like those in the Microsoft Office Suite. Because macros are so easy to write, they're really common and usually fairly harmless, but they can be super annoying! People frequently find them infecting the files they're working on in Microsoft Word and PowerPoint. Suddenly you can't save the file even though the Save function is working, or you can't open a new document, only a template. As I said, these viruses won't crash your system, but they can ruin your day. Cap and Cap A are examples of macro viruses.

Boot-Sector Viruses

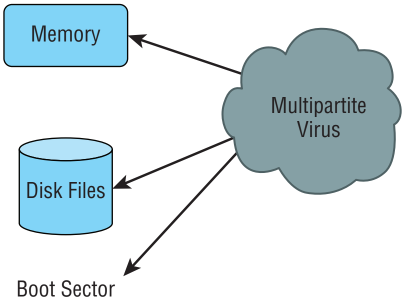
Boot-sector viruses work their way into the master boot record that's essentially the ground-zero sector on your hard disk where applications aren't supposed to live. When a computer boots up, it checks this area to find a pointer for its operating system. Boot-sector viruses overwrite your boot sector, making it appear as if there's no pointer to your operating system. You know you've got this type of virus when you power up the computer and get a Missing Operating System or Hard Disk Not Found error message. Monkey B, Michelangelo, Stoned, and Stealth Boot are a few examples of boot-sector viruses.

Multipartite Viruses

A multipartite virus is one that affects both the boot sector and files on your computer, making such a virus particularly dangerous and exasperatingly difficult to remove. Figure 14.9

gives you an idea of how a multipartite virus works. You can see that it is attacking the boot sector, memory, and the disk at once.

FIGURE 14.9 Multipartite virus



Anthrax and Tequila are both multipartite viruses. These viruses are so nasty that you might end up reformatting your computer if you get one. The Anthrax virus, however, was more of a hoax then a real virus; what is really interesting about the Tequila virus is that it does nothing until the next reboot—it was no hoax!

Although many software companies can handle these, the best way to save your computer from a complete overhaul is to make sure you do not get a virus in the first place by using a good virus scan program as well as Windows Defender.

NOTE

Some viruses infect your system through something known as a *Trojan horse*. Troy was successfully invaded by troops hidden inside a giant horse; a Trojan virus hides within other programs and is launched when the program it's lurking in starts up.

Often viruses come as attachments to emails with double filename extensions to hide the true extension. `Dmsetup.exe` and `love-letter-for-you.txt.vbs` are examples of viruses. Displaying filename extensions for known file types can help spot naming tricks like these, but they make up only a short list of the viruses out there. For a more complete inventory, see your antivirus software manufacturer's website.

Zero-Day Attacks

Antivirus software uses *definition files* that identify known malware. These files must be updated frequently, but the update process can usually be automated so that it requires no help from the user. If a new virus is created that has not yet been identified in the list, you will not be protected until the virus definition is added and the new definition file is downloaded. This condition is known as a zero-day attack because it is the first day the virus has been released and therefore no known fix exists. This term may also be applied to an operating system bug that has not been corrected.

Insider Threat/Malicious Employee

It is often said that an organization has the most to fear from its own employees. They have already completed two phases of the hacking process, that is, discovery and penetration. They are already inside your network and probably have learned quite a bit about the network just doing their job.

The first step to mitigating damage that may be caused by disgruntled or malicious employees is to adhere to the principle of least privilege. This concept prescribes that users should be given access only to resources required to do their job.

Another principle that should be followed is called separation of duties. It calls for breaking up sensitive operations into two parts and having different users perform each part. This means there would have to be collusion between the two to take advantage of the process, which is not likely to occur.

Finally, all network access should be taken from a user who has been terminated before they have a chance to access the network.

Vulnerabilities

While malware certainly presents an ongoing danger to your network, it is not the only concern of the security professional. In the following sections, I'll cover some other issues.

Exploits vs. Vulnerabilities

A vulnerability is the absence of a countermeasure or a weakness in a countermeasure that is in place. Vulnerabilities can occur in software, hardware, or personnel. An example of a vulnerability is unrestricted access to a folder on a computer. Most organizations implement a vulnerability assessment to identify vulnerabilities.

An exploit occurs when a threat agent takes advantage of a vulnerability and uses it to advance an attack.

Unnecessary Running Services

Services that are not required to be running on a system should be disabled. Running services present an additional attack surface to the hacker. Once they identify the running services on a machine, they will research all the vulnerabilities presented by those services and attempt to use them to compromise the target.

Open Ports

In the same way that unnecessary services present attack options, so do open ports. Software port numbers are used to identify protocols and services and serve as a connection point to a service on a target machine. Port scanners can be used to identify the ports that are open on all machines in a network. An open port means the device is listening on that port number and is willing to make a connection using that port. Unused ports should be shut down.

Unpatched/Legacy Systems

Systems that use older or legacy operating systems and applications may lack the security required in today's networks. These devices may require special protection, such as placing them in a secure VLAN or installing host-based IPSs.

Even modern operating systems and applications will not be secure if they are not maintained by applying updates and security patches as they are released. A formal, and preferably automated, process should be set up to ensure that this maintenance is ongoing.

Unencrypted Channels

If it isn't clear to you by now, in any situation where sensitive data is being transmitted, attention should be given to the type of channel across which the data is traveling. When no other method is available, IPSec is a Network layer protocol suite that can be used to provide end-to-end protection of any data that resides above the Network layer.

Many protocols provide the ability to control access through authentication. However, while some protect the confidentiality of the process by hiding the credentials as they are exchanged, others do not. For example, Telnet (a protocol used for remote command-line management of devices) transmits credentials in clear text; Secure Shell (SSH) does not.

Another example is Password Authentication Protocol (PAP), one of two authentication options offered when a PPP connection is being set up. PAP transmits credentials in clear text, while Challenge-Handshake Authentication Protocol (CHAP), the other option, uses a process that never sends the credential across the network. You should never use a protocol that transmits credentials in clear text.

TEMPEST/RF Emanation

Spying on information systems can also be accomplished by capturing and analyzing leaking emanations of things like radio or electrical signals, sounds, and vibrations. TEMPEST is a National Security Agency specification and NATO certification that addresses methods of spying used and how to protect against them. Distance, shielding, filtering, and masking are used to protect equipment from spying. The TEMPEST standards are used to describe the level of protection a system is certified to provide.

Malicious Users

Damaging activity on your network can come from both inside and outside the network. In the following sections, we'll look at the two types of malicious users you will encounter and an operation often performed in the execution of their mayhem.

Trusted Users

While we would like to think that all of our own people can be trusted, that's often not the case. Even your "trusted" users can go to the dark side with the proper motivation. The following are among the motives that can turn a trusted user into a malicious user:

- Perceived slight by the company
- Jealousy of other employees
- Monetary reward

The real danger presented by a trusted employee who turns malicious is that the employee is already inside your network and probably knows quite a bit about it. This is the reason for following the principle of least privilege, which prescribes that users be given access only to resources required to do their job.

Untrusted Users

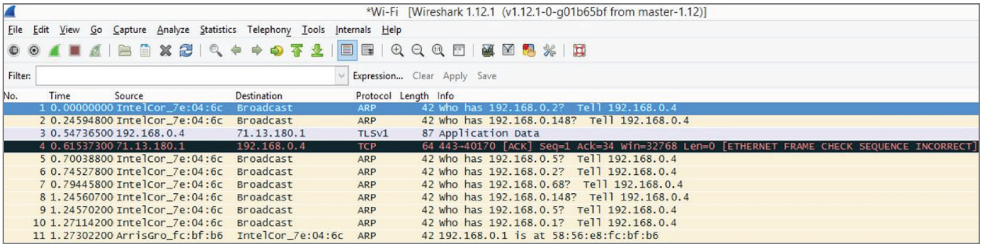
While it may take untrusted users or users outside your network a bit longer to make their way into your network, once they get there they will probably have a significantly higher level of skill than a disgruntled employee has. Discovering and penetrating your network from outside takes some skill. The best mitigation for these attacks is a combination of perimeter defense (keep them out) and strong access control at the point of resource access (prevent access to devices holding information). A multilayer approach works best.

Packet Sniffing

One of the basic tools a hacker will possess is a protocol analyzer, or packet sniffer. These devices capture raw packets off the network for analysis. Normally, a device will only process packets that are destined for itself, but this software places the network interface of the hacker's device in promiscuous mode, which means it captures all packets on the network.

This software can also be used legitimately to examine your network traffic for things that should not be there. Figure 14.10 shows an example of the output from the packet analyzer Wireshark. In the output, it can be seen that packet 4 failed a Frame Check Sequence, which would require it to be sent again. While the list of packets captured is displayed, you can click on any packet and examine it in detail. If the data is in clear text, you will be able to read it.

FIGURE 14.10 Wireshark



*Wi-Fi [Wireshark 1.12.1 (v1.12.1-0-g01b65bf from master-1.12)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save

```
No.   Time       Source               Destination          Protocol Length Info
    1 0.00000000 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.2?  Tell 192.168.0.4
    2 0.24594800 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.148?  Tell 192.168.0.4
    3 0.54736500 192.168.0.4          71.13.180.1          TLSv1    87 Application Data
    4 0.61537300 71.13.180.1          192.168.0.4          TCP      64 443→40170 [ACK] Seq=1 Ack=34 Win=32768 Len=0 [ETHERNET FRAME CHECK SEQUENCE INCORRECT]
    5 0.70038800 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.5?  Tell 192.168.0.4
    6 0.74527800 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.2?  Tell 192.168.0.4
    7 0.79445800 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.68?  Tell 192.168.0.4
    8 1.24560700 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.148?  Tell 192.168.0.4
    9 1.24570200 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.5?  Tell 192.168.0.4
   10 1.27114200 IntelCor_7e:04:6c    Broadcast            ARP      42 Who has 192.168.0.1?  Tell 192.168.0.4
   11 1.27302200 ArrisGro_fc:bf:b6    IntelCor_7e:04:6c    ARP      42 192.168.0.1 is at 58:56:e8:fc:bf:b6
```

Buffer Overflow

When programs execute, they write commands into memory, or to a *buffer*. Well-written programs allow a certain location and/or amount of memory space for these commands to execute. If a hacker is able to inject a command that overflows the amount of memory allocated and the command is able to execute with the proper security privileges, the hacker could execute commands that would not normally be allowed. They may be able to take control of the machine and create havoc.

A number of well-known exploits, such as the Code Red worm, employed buffer overflows to create their mayhem. The way to prevent buffer overflows is to include input validation into programs to mitigate the possibility of them occurring.

DNS Poisoning

DNS clients send requests for name to IP address resolution (called queries) to a DNS server. The search for the IP address that goes with a computer or domain name usually starts with a local DNS server that is not authoritative for the DNS domain in which the requested computer or website resides. When this occurs, the local DNS server makes a request of the DNS server that does hold the record in question. After the local DNS server receives the answer, it returns it to the local DNS client. After this, the local DNS server maintains that record in its DNS cache for a period called the Time to Live (TTL), which is usually an hour but can vary.

In a DNS cache poisoning attack, the attacker attempts to refresh or update that record when it expires with a different address than the correct address. If the attacker can convince the DNS server to accept this refresh, the local DNS server will then be responding to client requests for that computer with the address inserted by the attacker. Typically, the address they now receive is for a fake website that appears to look in every way like the site the client is requesting. The hacker can then harvest all the name and password combinations entered on his fake site.

To prevent this type of attack, the DNS servers should be limited in the updates they accept. In most DNS software, you can restrict the DNS servers from which a server will accept updates. This can help prevent the server from accepting these false updates.

Wireless Threats

The proliferation of wireless communication has introduced a number of security challenges that are unique to the wireless environment. Some of these threats even take advantage of the security measures that have been created to protect wireless networks and hosts. Wireless threats such as WEP and WPA cracking (discussed in the following sections) remind us that network attackers never stop evolving their methods and that constant review and adaptation of security measures are required to maintain security in the network.

War Driving

War driving is one of the oldest wireless threats and perhaps one of the easiest to discourage (although you can't defeat it if the hacker is determined). The attacker simply drives around with a high-powered antenna connected to a wireless laptop scanning for networks. The networks will be listed by network name (SSID) in the wireless client software, and depending on the software, the channel and security measures in use will also be displayed.

If the network is not secured, the attacker can connect to it. This is not just a matter of stealing bandwidth for Internet access. Once connected, the attacker may be able to proceed on into your wired network as well. They can then attempt other attacks, such as port scanning and peer-to-peer attacks. The point is that they have completed the first step in the hacking process, which is *penetration*.

War driving cannot be entirely prevented, but you can make it harder for an attacker. One of the simplest things you can do is limit the transmission power on the access point (AP) such that the signal does not go any further than required! Additionally, if you set the access point to not broadcast the SSID, the name of the network will not appear in the display when they scan for networks. This means that to connect, they will have to know the SSID and create a wireless profile specifying it.

If an attacker is determined, however, they can learn the SSID by using a wireless protocol analyzer or sniffer to capture the raw packets. This is something you *cannot prevent* without turning off the AP. When you set the AP to not broadcast the SSID, it will remove the SSID from packets called *beacons* (these are the packets that populate the display when you scan for networks), but the SSID will still be present in many other packet types.

In most cases, hiding the SSID will be sufficient because if an attacker doesn't see your network when scanning, they probably won't be motivated to use the sniffer.

War Chalking

War chalking is really just an extension of war driving. The hacker simply writes the SSID and security employed on the sidewalk or wall somewhere near your facility, sort of like advertising "here's a wireless network" to anyone who recognizes that code. Most of this type of activity has moved online where websites have sprung up that allow hackers to post and share these networks on maps indicating their location.

WEP Cracking

Wired Equivalent Privacy (WEP) is a security protocol created in the early years of 802.11 development that was designed to both authenticate users and encrypt the wireless data they transmitted. It uses the RC4 algorithm in the encryption process. Soon after its adoption as a security measure, it was discovered that due to a weakness in the way the algorithm was employed, programs that became widely available on the Internet could be used to crack the WEP key. Once the key was known, it could be used to decrypt the data. Because of this, WEP is no longer considered to be a sufficient security mechanism in any situation where the data is sensitive.

WPA/WPA2 Cracking

After WEP cracking became an issue, the manufacturers of wireless equipment were faced with a problem. The IEEE was working on creating a new security standard (which became known as 802.11i) but were moving at their usual deliberate pace. In the meantime, companies were not deploying wireless networks because of security concerns. The Wi-Fi Alliance created a temporary solution called Wi-Fi Protected Access (WPA) that was an improvement on WEP.

Soon after WPA was rolled out, it was discovered that it also could be cracked. Cracking WPA required more effort than cracking WEP, and it required what is called a dictionary file (a file of words that could possibly be used as a password). It also required that the passphrase or password be a word in the dictionary. Finally, it required capturing a large number of wireless frames, and the cracking process took a lot of time. Keep in mind that this type of attack is effective on any password-based system, including Wi-Fi Protected Access 2 (WPA2) when it uses passwords.

But the point is that if the hackers had good reason to believe they were capturing valuable data, it could be done. Therefore, WPA is not considered good security unless it is employed as WPA2, which is based in the secure 802.11i architecture.

Deauthentication

A wireless deauthentication attack is a form of a DoS attack in which the attacker sends a large number of management packets called deauthentication frames on the WLAN, causing stations to be disconnected from the access point.

WPS Attacks

Wi-Fi Protected Setup (WPS, originally Wi-Fi Simple Config) is a network security standard that attempts to allow users to easily secure a wireless home network. It works by enabling the user to add a device to the network without typing credentials; all the user needs to do is push the WPS button located on many home wireless access points.

When this function is enabled, which it is by default on many systems, it is possible for a hacker to perform a brute force attack on the password and then later on the network preshared key for WPA or WPA2. Users should disable this feature if the device allows this change.

Rogue Access Points

Rogue access points are access points that you do not control and manage. There are two types: those that are connected to your wired infrastructure and those that are not. The ones that are connected to your wired network present a danger to your wired and wireless network. They may be placed there by your own users without your knowledge, or they may purposefully be put there by a hacker. In either case, they allow access to your wired network. Wireless intrusion prevention system (IPS) devices are usually used to locate them and to alert administrators of their presence.

Rogue access points that are not connected to your wired infrastructure are usually used as part of a hijacking attack, which is discussed in the next section.

Evil Twin

An evil twin is an AP that is not under your control but is used to perform a hijacking attack. A hijacking attack is one in which the hacker connects one or more of your users' computers to their network for the purpose of a peer-to-peer attack.

The attack begins with the introduction of an access point that is under the hacker's control. This access point will be set to use the same network name or SSID your network uses, and it will be set to require no authentication (creating what is called an open network). Moreover, this access point will be set to use a different channel than the access point under your control.

To understand how the attack works, you must understand how wireless stations (laptops, PDAs, and so on) choose an access point with which to connect. It is done by SSID and not by channel. The hacker will "jam" the channel on which your access point is transmitting. When a station gets disconnected from an access point, it scans the area for another access point with the same SSID. The stations will find the hacker's access point and will connect to it.

Once the station is connected to the hacker's access point, it will receive an IP address from a DHCP server running on the access point and the user will now be located on the same network as the hacker. At this point, the hacker is free to commence a peer-to-peer attack.

Bluejacking

Bluejacking is an attack aimed at Bluetooth connections. It sends unsolicited messages to the devices. These messages are typically in the form of a vCard that contains the message in the name field. While these attacks are annoying, they are not serious when compared to the attack in the next section, which is also a Bluetooth attack.

Bluesnarfing

Bluesnarfing is unauthorized access of a Bluetooth-enabled device. These attacks allow access to the data on the device and make use of the pairing function used to connect two devices to transfer data between them. Users should be advised to disable the function that makes their device "discoverable" and enable it manually only when a connection needs to be made.

Attackers and Their Tools

The old adage "Never talk to strangers" applies here because you can't spot a hacker by looking at one. That quiet 15-year-old kid next door or the head of the PTA could secretly be a criminal hacker (or *cracker*, in nerd-speak)—you just never know. But instead of living your life being suspicious of everyone you meet, it's much better to understand the ways and strategies bad guys use to infiltrate your defenses.

The interaction between a hacker and a network administrator can be anything from a harmless game of cat and mouse to a terrorist attack on national security. Either way, there's someone out there trying to break into or crash your system, and it's up to you to track and prevent the attacks.

Network attacks executed by an actual hacker are called *directed attacks*. For instance, a bad guy can use the WinNuke utility, which I'll describe soon, to generate a packet and send it to a specific machine. On the other hand, viruses aren't usually directed attacks—instead they're just blindly copied from user to user.

I'll start by telling you about some common network attacks and then move on to cover the techniques used to prevent them from happening to you.

Real World Scenario

Do We Really Need Firewalls?

Believe it or not, the honor system used to apply to the Internet, and it pretty much worked, so firewalls just weren't needed. Now, nothing could be further from the truth! Today, multitudes of companies have their entire corporate intranets connected to the Internet; plus, a legion of e-commerce sites like eBay and Amazon transfer seriously sensitive personal and financial data over the Internet. Corporate espionage and identity theft are currently the fastest-growing crimes worldwide—evil deeds pulled off by bad guys lurking on the Net. So, we all need to practice "Safe Net," and one popular way to do that is by implementing firewalls on our networks.

Application-Layer Attacks

Application-layer attacks usually zero in on well-known holes in software that's running on our servers. Favorite targets include FTP, sendmail, and HTTP because the permissions level granted to these accounts is often privileged. This means that bad guys who break in not only gain access to your network but also get the added bonus of having privileged status while they're in there—yikes!

ActiveX Attacks

A fairly new form of attack makes its way to your computer through ActiveX and Java programs (applets). These are miniature programs that run on a web server or that you download to your local machine. Most ActiveX and Java applets are safe, but some contain viruses or snoop or spyware programs. Snoop or spyware programs allow a hacker to look at everything on your hard drive from a remote location without you knowing about it, which is really bad, so be sure you properly configure the on-access component of your antivirus software to check and clean for these types of attacks.

Autorooters

You can think of autorooters as a kind of hacker automaton. Hackers use something called a *rootkit* to probe, scan, and then capture data on a strategically positioned computer that's poised to give them "eyes" into entire systems automatically. This is clearly very bad for you and your data. Note that this is typically how a cracker can attack a Mac or Unix box.

Backdoors

Backdoors are simply paths leading into a computer or network. From simple invasions to elaborate Trojan horses, villains can use their previously placed inroads into a specific host or a network whenever they want to—that is, unless you can detect them and stop them in their tracks.

Network Reconnaissance

Before breaking into a network, bad guys gather all the information they can about it because the more they know about the network, the better they can compromise it. This is called *network reconnaissance*. Hackers accomplish their objectives through methods like port scans, Domain Name Service (DNS) queries, and ping sweeps—even social engineering, or *phishing*, which I'll cover in a bit.

Packet Sniffers

A *packet sniffer* is a software tool that can be incredibly effective in troubleshooting a problematic network, but it can also be a hacker's friend. Here's how it works: A network adapter card is set to promiscuous mode so it will send all packets snagged from the network's Physical layer through to a special application to be viewed and sorted out. A packet sniffer can nick some highly valuable, sensitive data, including, but not limited to, passwords and usernames, making such a tool a prize among identity thieves.

Port Scanners

Port scanners are programs that ping every port on the target to identify which ports are open. It does this by pinging the IP address of the target with the port number appended after a colon. If an answer is received, the port is open. Open ports can lead to services the hacker can potentially exploit.

FTP Bounce

This attack is a variation of the port scan in that the attacker uses the `FTP PORT` command to request access to ports indirectly by using the victim machine as a middleman for the request. This cloaks the identity of the device performing the port scan.

Port-Redirection Attacks

A port-redirection attack requires a host machine the hacker has broken into and uses to redirect traffic that normally wouldn't be allowed passage through a firewall. The attacker gains access to a trusted computer that is outside the firewall and installs software on the machine. They then redirect traffic bound for a particular port on the trusted yet now compromised host to their machine.

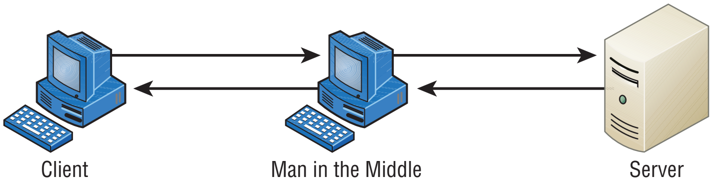
Trust-Exploitation Attacks

Trust-exploitation attacks happen when someone exploits a trust relationship in your network. The attacker gains control of a host that is outside the firewall yet is trusted by hosts that are inside the firewall. Once compromised, the host outside the firewall can be used as a platform to exploit the fact it is trusted by those inside the firewall.

Man-in-the-Middle Attacks

Interception! But it's not a football, it's a bunch of your network's packets—your precious data. A man-in-the-middle attack happens when someone intercepts packets intended for one computer and reads the data. A common guilty party could be someone working for your very own ISP using a packet sniffer and augmenting it with routing and transport protocols. Rogue ATM machines and even credit-card swipers are tools that are also increasingly used for this type of attack. Figure 14.11 shows a man-in-the-middle attack.

FIGURE 14.11 Man-in-the-middle attack



Improper Access/Backdoor Access

A backdoor is a piece of software installed by a hacker that allows them to return later and connect to the computer without going through the normal authentication process. Some commercial applications inadvertently include backdoors because programmers forget to remove them before release to market. In many cases, the program is listening on a specific port, and when attempting to connect to that port, the attacker is allowed to connect without authentication. An example is Back Orifice 2000 (BO2K), an application-level Trojan horse used to give an attacker backdoor network access.

ARP Issues

ARP cache poisoning, usually a part of a man-in-the-middle attack, was discussed earlier in the section "ARP Cache Poisoning."

Banner Grabbing/OUI

Banners are messages that are configured on some devices (routers, switches, servers) and appear under certain conditions, such as when someone is presented with a login screen, upon making a connection or when an error is encountered. These messages can impart information that can be used during the discovery phase of the hacking process. It may reveal the operating system or the version of firmware.

Banner grabbing is the process of connecting to the device using protocols such as Telnet, SMTP, or HTTP and then generating an error displaying the banner. Once the hacker discovers information contained in the banner such as the operating system and its version, they can research weaknesses in the system. For this reason, any service not in use should be disabled to eliminate it as a source of connection.

Domain/Local Group Configurations

In cases where computers are part of a domain, the domain member computers will have both domain accounts and local accounts. Local accounts are thus only effective on the local machine and cannot be used to access the domain.

However, there are default local accounts that exist on these computers that can be used to log on locally to the computer, thereby circumventing the domain login process. It's dangerous to leave some of these enabled, such as the local administrator account. While they cannot be deleted, it is possible to rename them and/or disable them.

Jamming

Jamming is the process of sending out radio waves on the frequency used by a wireless network. It will have the effect of disassociating (disconnecting) all of the stations from the AP, at least while the jam signal is still there. When used for that purpose, jamming could be considered a DoS attack.

However, it is usually part of an evil twin attack, when the hacker is attempting to get your wireless stations to connect to their access point. They will set their AP to the same SSID as your wireless network but in a different channel (frequency). When they jam the real frequency, it causes the stations to seek another frequency with the same SSID, and they will find the hacker's AP all too willing to allow their association.

Misconfiguration Issues

In many cases, security issues arise due to our own mistakes rather than the efforts of hackers. In the following sections, we'll take a look at (and in some cases review) some of the most common misconfiguration errors and omissions.

Misconfigured Firewall

If the access control lists are misconfigured on a firewall, the damage will fall into one of three categories:

- Traffic is allowed that shouldn't be allowed.
- Traffic that should be allowed is blocked.
- No traffic is allowed at all.

The first two problems are a matter of specifying the wrong traffic type in a permit or deny rule. Because in many cases the traffic type is specified in terms of a port number, it is critical to know the port numbers of the traffic you are dealing with.

The last problem can be either a simple omission or a complete misunderstanding of how ACLs work. At the end of every ACL is an implied rule that blocks all traffic that has not been allowed by earlier rules in the rule set. This means that all ACLs should have a rule at the end that allows all traffic that should be allowed. An ACL with no permit statements will block all traffic.

Misconfigured ACLs/Applications

Misconfigured applications can also cause issues. Web applications that do not perform proper input validation can allow for attacks such as buffer overflows. They can also in some cases allow for commands to be executed on the web server. For this reason, web-based applications should undergo strict code review and fuzz testing, and you should ensure that all input is validated before it is accepted by the application.

Open/Closed Ports

As discussed in the section on misconfiguration of firewalls, destination services and applications are specified in a packet in terms of a port number. When a device is open to receiving a connection to a service or application, it is said to be listening on the corresponding port. Therefore, closing or disabling a port eliminates the possibility of a malicious user connecting to that port and leveraging any weakness that may be known to be present with that service.

It is a standard device hardening practice to close any ports not required for the proper functioning of a device based on its role in the network. For example, a DNS server should have no other ports open but port 53, which is used to service DNS.

Unpatched Firmware/OSs

The best defense against the majority of malware types and attack modes is to keep current on all updates. This includes operating system patches, firmware updates, and application updates. Many devices that fall prey to malware and attacks do so needlessly because a patch existed that would have prevented the attack. A formal update system should be in place to ensure that no updates fall through the cracks.

Social Engineering (Phishing)

Hackers are more sophisticated today than they were 10 years ago, but then again, so are network administrators. Because most of today's sys admins have secured their networks well enough to make it pretty tough for an outsider to gain access, hackers decided to try an easier route to gain information: they just asked the network's users for it.

Social engineering, or *phishing*, refers to the act of attempting to illegally obtain sensitive information by pretending to be a credible source. Common phishing tactics include sending emails, making phone calls, or even starting up a conversation in person.

Some email phishing scams have made the news. In one case, bad guys sent out a mass email that was all dressed up to appear as though the message actually came from a real bank. The email said that the bank had an issue with one of its servers, so it now required you to confirm your user-account information to verify that none of your data was lost. All you needed to do was click the link provided in the email, enter your information, and snap—your identity went poof! If you possess a working brain and someone you didn't know phoned and asked for your bank-account number, you certainly wouldn't give it to them, right? No way—but the same request, coming in the form of a really legitimate-looking email, seems more believable for some reason. This has become a popular phishing tool, notoriously used to separate people from anything from a few bucks to their entire identity. Be careful!

Oh, and speaking of phone calls…let's say you get a call to your desk at work from "Joe" in IT. He says he's noticed some unusual activity on your network account and wants to check it out, but for security purposes, he needs your permission first. So he proceeds to confirm your login, and then he tells you he needs to enter your password into the network tracker. He asks, "What's your password?" To protect yourself from this one, all you need to do is confirm *his* information and verify it with your IT department *before* you give him any of your data. You know by now that just because "Joe" knows your login doesn't mean he's on the up-and-up; even if "Joe" hangs up on you, you should still report the call to IT.

How did Joe get your login and telephone number? Remember network reconnaissance? First, because company phone directories are often on the Web, getting your phone number was easy. Even if it isn't published, maybe Joe did some earlier phishing by calling one of your coworkers and, pretending to be a colleague at another site, asking for your phone number. But what about the username? On most networks, your username is the same as your email address because that makes things easier for your sys admin. This means that knowing that information is probably just a good guess on the attacker's part. Maybe Joe the Hacker has gotten an email from someone at your company and knows what your email format is, and he may have some other information to help him figure out your network login. And even if the number on your caller ID when Joe called was an internal phone number, it doesn't mean a thing—remember IP spoofing? Well, you can do that with phone numbers too.

The golden rule is don't ever give any of your information or anyone else's to anyone you're not absolutely sure should have it. And if they are someone who should have it, they probably already do, and they shouldn't be contacting you for it!

Understanding Mitigation Techniques

To be honest, I'm not going to go into detail about how to mitigate each and every one of the security threats I just talked about, not only because that would be outside the scope of this book, but also because the methods I am going to teach you will truly protect you from being attacked in general. You'll learn enough tricks to make all but the most determined bad guys give up on you and search for easier prey. Basically, think of this as a section on how to practice "Safe Net."

Safe networking techniques fall into three major categories: policies and procedures, training, and patches and upgrades. But before we go there, let's cover some of those general defense techniques I just referred to.

Okay—first know that there are three main ways to detect an intruder and defend yourself against one:

- Active detection, which involves constantly scanning the network for possible break-ins
- Passive detection, which involves logging all network events to a file
- Proactive defense methods, which involve using tools to shore up your network walls against attack

Active Detection

Active detection is analogous to a security guard walking the premises, rattling doors to make sure they're locked, and checking for intruders and any unusual activity. Similarly, there's special network software that searches for hackers attempting known attack methods and scans for the kind of suspicious activity and weird network traffic that hackers leave behind as they travel over the network. Some sophisticated active systems go a step further and take action by doing things like shutting down the communications sessions a bad guy is using as well as emailing or paging you. Some security packages will even go as far as trying to cripple the computer from which the hacker is attacking! Cisco's NetRanger, Memco's Session Wall, and Snort are all forms of active intrusion-detection software.

Passive Detection

Using video cameras is a good example of using a passive intrusion detection system. Their counterparts in networking are files that log events that occur on the network. Tripwire for Unix systems is one of the earliest programs of this variety. It identifies changes in files using checksums. Changes in files indicate that someone has accessed them. Passive detection systems work by examining files and data and then calculating the checksums for each. The checksums are stored in a log file so that if the sys admin notices that a security breach has occurred on the network, they can access the log files to find clues about it.

Proactive Defense

A proactive defense is something you do or implement to ensure that your network is impenetrable. You can accomplish a lot through solid research and vigilant maintenance—you absolutely must stay current regarding any known security holes relevant to your type of network and the devices that populate it. You can also use tools like the unfortunately dubbed Security Administrator Tool for Analyzing Networks (SATAN) to find the holes in your security walls and plug them with software patches.

Clearly, before you can patch a hole, you've got to know it's there, right? This is why I said it's so important to stay current. Even better, stay a step ahead of bad guys by knowing your enemy's strategies because the war against attackers is ever evolving—as soon as one hole is patched, bad guys will search for and find another vulnerability to exploit. And because patches usually take some time to develop, you can lose your shirt to a hacker in the interim. This is a big reason I'm saying it's a better idea for you to know thy enemy than to rely on patches and the like.

Incident Response

Often when an attack or security breach occurs in the network, valuable time and information are lost in the critical first minutes and hours after the incident occurs. In some cases, evidence is inadvertently destroyed, making prosecution of the offending party impossible. In other cases, attacks that could have been interrupted and prevented before damage occurs are allowed to continue.

An incident response policy is designed to prevent this by establishing in advance the procedures that should be followed when an attack occurs. It may categorize incidents in such a way that certain event types (such as an active port scan) may require a response (such as disabling certain services) within 10 minutes while other events (such as an attempt to access a file without proper credentials) may only require a notation and follow-up in the next few days. The point is to establish these rules ahead of time to ensure that events are handled in a way that minimizes damage and preserves evidence.

NOTE There is a host of great shareware and freeware available on the Internet today, including Windows Defender, Spybot Search & Destroy, and Ad-Aware as well as Windows Update.

Basic Forensic Concepts

When security incidents occur in a network, a proper response is key, especially in the early stages. Computer forensics principles must be applied. These principles are specific to the nature of digital devices and the environment in which security incidents occur. From a high level, the steps in incident response are as follows:

1. Detect the incident.
2. Respond to the incident.
3. Report the incident to the appropriate personnel.
4. Recover from the incident.
5. Remediate all components affected by the incident to ensure that all traces of the incident have been removed.
6. Review the incident, and document all findings.

In the following sections, we'll take a look at some of the salient details of these six steps.

First Responder

The first responder is responsible for securing the crime scene and protecting the evidence from corruption. This requires addressing the evidence in the order of volatility. Some types of data may be fragile and therefore need to be collected before other types. For example, a Polaroid photo (not a digital photo) should be taken of anything showing on the computer screen since that could go away at any time if the system goes off.

Secure the Area

The area should be sealed off to prevent anyone from touching or tampering with anything. Access to the crime scene should be tightly controlled and limited only to individuals who are vital to the investigation. As part of the documentation process, make sure to note anyone who has access to the crime scene. Once a crime scene is contaminated, there is no way to restore it to the original condition.

Escalate When Necessary

In any case where the first responder is not trained in forensics, the issue should be escalated to other personnel. In some cases it may involve calling the police, but be aware that when you do that you may lose control of the crime scene because they will take over the investigation. All users should be trained in basic crime scene concepts, such as don't turn the machine off and don't touch anything.

Document the Scene

Everything about the crime scene should be recorded and documented. Polaroid pictures should be taken to show the position of everything in the scene. Diagrams can be drawn to indicate positioning as well. Interviews of witnesses and first responders should be conducted as soon as possible because memory of details fades quickly.

eDiscovery

In the United States, discovery is the exchange of evidence by both sides in a lawsuit. eDiscovery is simply the application of this principle to electronic documents, such as emails, chat records, and other electronic forms of data. When this data is identified as potentially relevant to a case, it is placed on legal hold. Then it is gathered using digital forensic procedures to prevent its contamination as evidence.

Evidence/Data Collection

When you're collecting evidence, the order of volatility is critical. Collecting it in the following order ensures that investigators get evidence from the components that are most volatile first. The order of volatility is as follows:

1. Memory contents
2. Swap files
3. Network processes
4. System processes
5. File system information
6. Raw disk blocks

You should create a bit-level copy of the system image and isolate the system from the network when you do this. Keep two copies of this image, one to be stored as an accurate backup copy of the evidence and the other to use to examine the image. You should create message digests (hashes) of the images to ensure that you can later prove that the images have not been tampered with.

Chain of Custody

Chain of custody records document who controlled the evidence, who secured the evidence, and who obtained the evidence. To successfully prosecute a suspect, a proper chain of custody must be preserved and the evidence must be collected following predefined procedures in accordance with all laws and regulations. Proper chain of custody ensures that all evidence is admissible in court.

Data Transport

When the data or evidence is being transported in any way, the process must be recorded and documented in detail. All physical evidence must be tagged, and the evidence tags must document the mode and means of transportation, a complete description of the evidence (including quality), who received the evidence, and who had access to the evidence. Any transmission of evidence should include a hash so the integrity of the evidence can be maintained.

Forensics Report

A forensics report should be created based on the findings. While evidence is being examined, any characteristics, such as time stamps and identification properties, should be determined and documented. Once the evidence has been fully analyzed using scientific methods, the full incident should be reconstructed and documented.

Legal Hold

During the eDiscovery process, evidence that is deemed to be possibly relevant will be placed on legal hold. This process may be initiated by a notice or communication from legal counsel to an organization. It requires suspension of normal processing of the data, such as backup tape recycling, archiving media, and using other forms of document and information storage and management.

Policies and Procedures

Every company should have written policies to effectively enable security on their computer networks. The policies should have the approval of the highest-ranking security or IT officer within the company, and they should address all aspects of the company network.

Procedures should also be in place to determine the appropriate course of action if there is a security breach. And all network administrators absolutely need to be thoroughly trained on all policies and procedures—no weak links.

All of this might sound a bit militaristic in nature, but it's truly necessary. Speaking of the military, though, the U.S. Department of Defense (DoD) has some really good standards; it wouldn't hurt to keep them in mind when you're setting up the security policies for your own network.

NOTE

You can find the evaluation criteria for the DoD computer standards at `https://csrc.nist.gov/csrc/media/publications/conference-paper/1998/10/08/proceedings-of-the-21st-nissc-1998/documents/early-cs-papers/dod85.pdf`

In the past, this was known as the Rainbow Series because of the color of the books, but that's been replaced by the much less colorful Common Criteria Evaluation and Validation Scheme (CCEVS).

Security Policies

So what, exactly, is a *security policy*? Ideally, it should precisely define how security is to be implemented within an organization and include physical security, document security, and network security. Plus, you have to make sure these forms of security are implemented completely and solidly because if they aren't, your security policy will be a lot like a block of Swiss cheese—some areas are covered, but others are full of holes.

Before a network can be truly secure, the network support staff should post the part of the security policy that applies to employee conduct on bulletin boards. It should, for example, forbid posting any company and/or employee information that's not absolutely necessary—like, believe it or not, sticking Post-its with usernames and passwords on computer screens. Really clean desks, audits, and recording email communications and, in some cases, phone calls should also be requirements. And don't forget to also post the consequences of not complying with the security policy.

Security Audit

Let me take a minute to explain all this a little more, beginning with security audits. A *security audit* is a thorough examination of your network that includes testing all its components to make sure everything is secure. You can do this internally, but you can also contract an audit with a third party if you want the level of security to be certified. A valid and verified consultant's audit is a good follow-up to an internal audit. One reason for having your network's security certified like this is that government agencies usually require it before they'll grant you contract work, especially if that work is considered Confidential, Secret, or Top Secret.

Clean-Desk Policy

That clean-desk policy doesn't mean just "get rid of the crumbs from your last snack." It means requiring that all potentially important documents like books, schematics, confidential letters, notes to self, and so on aren't left out in the open when someone's away from their desk. Instead, they're locked away, securely out of sight. And make sure it's clear that this rule applies to users' PC desktops too. Policies like this apply to offices, laboratories, and workbenches as well as desks, and it's really important for employees who share workspaces and/or workstations.

It's super easy to nick something off someone's desk or screen. Because most security problems involve people on the inside, implementing and enforcing a clean-desk policy is a simple way to guard against security breaches.

NOTE The International Computer Security Association (ICSA, `www.icsa.net`) reports that as many as 80 percent of all network break-ins occur from within the company and are carried out by employees, so protecting your data with a firewall is just the beginning of establishing network security.

It might sound really nitpicky, but for a clean-desk policy to be effective, users have to clean up their desks every time they walk away from them—without exception. The day someone doesn't will be the very day some prospective tenant is being shown the building's layout and a sensitive document suddenly disappears. You should make sure workstations are locked to desks and do random spot checks once in a while to help enforce the policy. For obvious reasons, before company picnics and parties and before "bring your child to work day" are good times to do this.

NOTE The ICSA is a vendor-neutral organization that certifies the functionality of security products as well as makes recommendations on security in general.

Recording Equipment

Recording equipment—such as tape recorders, cell phones, and small memory devices like USB flash memory keychains—can contain sensitive, confidential information, so a good security policy should prohibit their unauthorized presence and use.

Just walk into almost any large technology company and you'll be immediately confronted with signs. A really common one is a camera with a circle surrounding it and a slash through the center of the circle. Read the text below the sign and you'll be informed that you can't bring any recording devices onto the premises.

Here's a good example. The NSA has updated its policy to include prohibiting Furby dolls on government premises because they have reasonably sophisticated computers inside them, complete with a digital recording device. The doll repeats what it hears at a certain interval of time, which is either cute or creepy but pretty much harmless—maybe even protective—in a children's daycare center. Not so much at the NSA, though—no recording conversations there. Maybe, at least in some locations, it's not such a good idea for your company either.

Licensing Restrictions

Software piracy is the unauthorized reproduction or distribution of copyrighted software. Although software piracy is a worldwide issue, it is much more prevalent in Asia, Europe, Latin America, and Africa/Middle East.

Security professionals and the organizations they work with must ensure that the organizations take measures to ensure that employees understand the implications of installing pirated software. They also need to ensure that these issues are covered specifically in the security policy.

In addition, large organizations might need to utilize an enterprise software inventory application that will provide administrators with a report on the software that is installed.

International Export Controls

Many organizations today develop trade relationships with organizations that are in other countries. Organizations must be aware of the export and import laws of both the source and destination countries. Encryption technologies are some of the most restricted technologies when it comes to import and export laws. Although the United States does limit the export of encryption technologies for national security reasons, other countries, such as China and Russia, limit the import of these same technologies because they do not want their citizens to have access to them. Publicly available technology, including software, is exempt from most export laws, except for encryption technologies.

Any organization that engages in export and import activities with entities based in other countries should ensure that legal counsel is involved in the process so that all laws and regulations are followed. In addition, the organization should implement the appropriate controls to ensure that personnel do not inadvertently violate any import and export laws, regulations, or internal corporate policies.

Other Common Security Policies

So you get the idea—security policies can cover literally hundreds of items. Here are some common ones:

Notification Security policies aren't much good if no one knows about them, right? So make sure you give users a copy of the security policy when you give them their usernames and passwords. It's also a good idea to have computers display a summarized version of the policy when any user attempts to connect. Here's an example: "Unauthorized access is prohibited and will be prosecuted to the fullest extent of the law." Remember—your goal is to close loopholes. One hacker actually argued that because a computer didn't tell him otherwise, anyone was free to connect to and use the system!

Equipment Access Disable all unused network ports so that any nonemployees who happen to be in the building can't connect a laptop to an unused port and gain access to the network. And don't forget to place all network equipment under lock and key.

Wiring Your network's wires should never run along the floor where they can be easily accessed (or tripped over, getting you sued). Routers, switches, and concentrators should live in locked closets or rooms, with access to those rooms controlled by anything ranging from a good lock to a biometric access system, depending on the level of security your specific network and data require.

Door Locks/Swipe Mechanisms Be sure that only authorized people know the combination to the cipher lock on your data-center doors or that only the appropriate people have badges that allow access to the data center. Change lock combinations often, and never ever leave server room doors open or unlocked.

Badges Require everyone to wear an ID badge, including contractors and visitors, and assign appropriate access levels to everyone.

Tracking Require badge access to all entrances to buildings and internal computer rooms. Track and record all entry to and exits from these rooms.

Passwords Reset passwords at least every month. Train everyone on how to create strong passwords. Set BIOS passwords on every client and server computer to prevent BIOS changes.

Monitor Viewing Place computer monitors strategically so that visitors or people looking through windows can't see them, and make sure unauthorized users/persons can't see security-guard stations and server monitors. Use monitor privacy screens if necessary.

Accounts Each user should have their own, unique user account, and employees should never share user accounts. Even temporary employees should have their own account. Otherwise, you won't be able to isolate a security breach.

Testing Review and audit your network security at least once a year.

Background Checks Do background checks on all network support staff. This may include calling their previous employers, verifying their college degrees, requiring a drug test, and checking for a criminal background.

Firewalls Use a firewall to protect all Internet connections, and use the appropriate proxies and dynamic-packet-filtering equipment to control access to the network. Your firewall should provide as much security as your company requires and your budget allows.

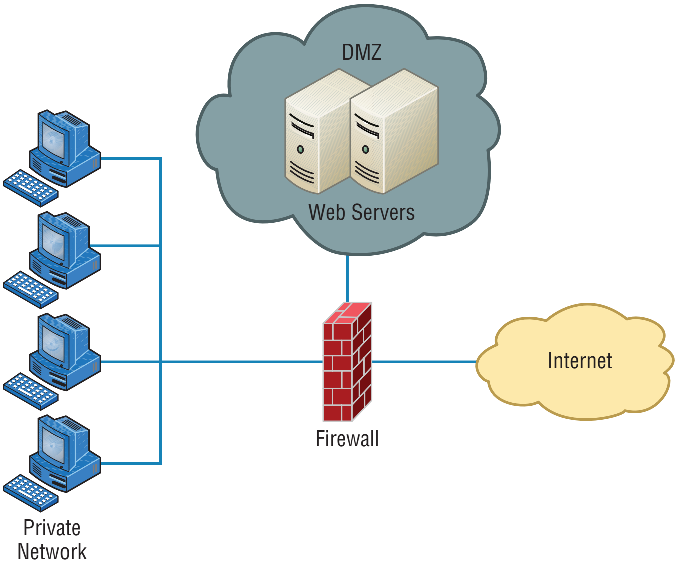
Intrusion Detection Use intrusion detection and logging software to discover security breaches, and be sure you're logging the events you want to monitor.

Cameras Cameras should cover all entrances to the building and the entire parking lot. Be sure that cameras are in weather-proof and tamper-proof housings, and review the output at a security-monitoring office. Record everything on extended-length tape recorders.

Mail Servers Provide each person with their own email mailbox, and attach an individual network account to each mailbox. If several people need to access a mailbox, don't give all of them the password to a single network account. Instead, assign individual privileges to each person's network account so you can track activity down to a single person, even with a generic address like `info@mycompany.com`.

DMZ Use a demilitarized zone (DMZ) for all publicly viewable servers, including web servers, FTP servers, and email relay servers. Figure 14.12 shows a common DMZ setup.

FIGURE 14.12 A common DMZ configuration



It is not advisable to put a DMZ outside the firewall because any servers outside your firewall defeat the whole purpose of having one. However, it is possible that you may see a DMZ outside the firewall in some networks.

Mail Relay Mail servers relay to other email servers by design. When the email server relays from any server that requests it, it is called *open relay*. Hackers use this feature to forward spam. Modern email systems allow you to control which servers your email server will relay for, which helps to prevent this.

Patches Make sure the latest security updates are installed after being properly tested on a nonproduction computer.

Backups Store backup tape cartridges securely, not on a shelf or table within reach of someone working at the server. Lock tapes in a waterproof, fireproof safe, and keep at least some of your backups off site.

Modems Do not ever allow desktop modems because they can be used to get to the Internet without your knowledge. Restrict modem access to approved server-based modem pools.

Guards If you need security guards, they shouldn't patrol the same station all the time. As people become familiar with an environment and situation, they tend to become less observant about that environment, so rotating guards to keep their concentration at the highest possible level makes a lot of sense. Clearly, guards are people who need breaks to ensure alertness, but make sure that all patrol areas are covered during shift changes, rotations, and breaks. Guards should also receive periodic training and testing to make sure they can recognize a threat and take appropriate action.

NOTE

Believe it or not, covering all these bases still won't guarantee that your network or facility is secure. All of this is really just a starting point that's meant to point you in the right direction.

Breaking Policy

You know that for your policy to be effective it's got to be enforced consistently and completely. Nobody is so special that they don't have to adhere to it. And people have to understand the consequences of breaking policy too. Your network users need to have a clearly written document, called a *security policy*, that fully identifies and explains what's expected of them and what they can and can't do. Plus, people must be made completely aware of the consequences of breaking the rules, and penalties have to match the severity of the offense and be carried out quickly, if not immediately, to be effective.

Let's take a minute and talk about those penalties. As far back as the mid-1980s, employees were immediately terminated for major technology policy infractions. For example, one guy from a large computer company immediately got his pink slip when pornography was found on his computer's hard drive. The situation was handled decisively—his manager informed him that he was being immediately terminated and that he had one hour to vacate the premises. A security guard stood watch while he cleaned out his desk to make sure the employee touched only personal items—no computer equipment, including storage media—and when he had finished gathering his personal things, the guard then escorted him from the building.

Downloading and installing software from the Internet to your PC at work is not as major (depending on where you work), but from the things we've been over so far, you know that doing that can compromise security. Beta products, new software, and patches need to be tested by the IT department before anyone can use them, period! Here's an example: After an employee installed the untested beta release of a web browser and rebooted their PC, the production Windows NT server at a national telephone company crashed. The resulting action was to revoke that employee's Internet FTP privileges for three months.

Real World Scenario

Implement the Appropriate Policies or Procedures

You operate a mid-sized network for Acme Inc. Recently a rogue access point was discovered in the network, which constituted a security breach. While the original fear was that it was installed as an evil twin, further investigation revealed it was placed there by an employee so his department could have wireless access. It has now been removed. What two actions do you need to take and what security policy document do you need to access?

Answer

Remind/inform the employee of the security policy prohibiting this activity and discipline the employee. This will require access to an acceptable use policy, specifically the one that the employee signed when hired.

To prevent this in the future, you should schedule a training session for employees that reinforces the rules contained in the acceptable use policy and explains the motivation behind each.

The Exit Interview

Sometimes, the importance of an employee's position and the amount of knowledge they have about the company and its systems justifies requiring an exit interview when they're terminated. It's done to minimize the risk of that employee being disgruntled and to attempt to ensure that they're leaving under the most favorable circumstances possible. The interview can include the IT manager, a human resources representative, a sys admin, and sometimes even security personnel.

When an employee leaves the company—whether they're quitting to move on to another job or being terminated—all company property needs to be turned in and logged. This includes things like company cell phones, pagers, toolkits, keys, badges, security tokens, models, and, obviously, all company documents.

And clearly, IT needs to disable all accounts immediately, including those for network access and voicemail, and remaining employees should be informed that the employee is leaving at this time. This is especially important when that employee has access to sensitive documents because even if they're leaving under favorable conditions, they could still log in and copy data to take with them for their own use. For instance, salespeople can easily hurt a company by taking client information with them, and it has happened, as in the case of a salesperson who accessed their former company's voicemail system and stole sales leads. So it's not just the obviously disgruntled ex–network administrator who could demolish your website after leaving that you need to be concerned about.

Security Procedures

A *security procedure* defines how to respond to any security event that happens on your network. Here's a short list of items you might include:

- What to do when someone has locked themselves out of their account
- How to properly install or remove software on servers
- What to do if files on the servers suddenly appear to be "missing" or altered
- How to respond when a network computer has a virus
- Actions to take if it appears that a hacker has broken into the network
- Actions to take if there is a physical emergency such as a fire or flood

Privileged User Accounts

Privileged user accounts represent those that have been provided rights normally reserved for the administrator. For example, if Jeff is granted the right to manage a printer, he now possesses a privileged account. Privileged accounts represent a potential security vulnerability, and their use should be monitored continually to ensure that they are used responsibly. When implementing them, you should always follow the principle of least privilege, which specifies that users should only be granted privileges required to do their job.

File Integrity Monitoring

File integrity refers to the prevention of unauthorized alteration. File hashing can be used to verify that changes to files have not occurred. See the section "File Hashing" later in this chapter for more details.

Role Separation

Separation of duties is a concept that specifies that any operation that is susceptible to fraud or abuse by employees should be broken into two tasks and then these two tasks should be assigned to different individuals. While there is no guarantee that these two individuals don't collude, the chance of that occurring are much less than the chance of a single individual committing fraud.

Restricting Access via ACLs

Access control lists identify those who have access to resources and what type of access they have. ACLs are attached to the resource and are consulted whenever access is requested by an entity. These ACLs are your primary means of preventing access to unauthorized individuals. When implementing them you should always follow the principle of need to know, which specifies that users should only be granted access to information required to do their job.

Security Training

This brings us to the human element of network security. It's true that most of your users want to do the right thing to protect the company—and their jobs—from the prying eyes of hackers, but the problem is that people don't always know the right thing to do. That's why training is so vital. It can include classroom sessions and/or web-based training, but experience has shown me that actual classroom-based instruction works the best. It's also a good idea to have separate training classes for IT personnel and end users.

End-User Training

End-user training is pretty easy—it can take just an hour or so to bring employees up to speed. The "keep it short and simple" rule applies here or you'll just end up with nap time. This is a great time to include detailed security protocol training. But if you see eyes beginning to glaze over or hear anyone snoring, you might want to make security protocol training a separate session because, as I said, it's really important to the effectiveness of your security policy for everyone to know about and understand it. You can even use a year-end bonus or something else cool as a motivational reward for the employees who complete their training and test well on it.

And you have to back up your training by providing your end users with hard-copy, printed reference manuals in case they forget something (which they will). Include things like the following items:

- Recommended policies for creating safe passwords
- The number to call if they've locked themselves out of their accounts
- What to do if they think someone is phishing for information
- What to do if they think their computer has a virus

Clearly, new employees to the company or division should be required to go through training, but requiring that everybody attend refresher courses is also a good idea. And don't hesitate to call a meeting if new threats arise or any sudden changes occur to keep everyone up-to-date.

Administrator Training

Obviously, training sessions for your IT personnel have to be a lot more in depth because they'll be the ones who set up and configure policies, and they'll also be the first responders to any security emergency.

It's important to cover every aspect of your security policy with these people. And be sure they understand the correct ways to escalate issues in case of an emergency. Reacting to a security emergency is pretty stressful, and you don't want your administrators to panic or feel isolated if one occurs. Making sure they know where their lifelines are and how to reach them quickly if they need backup will relieve a lot of pressure when something nasty happens.

Patches and Upgrades

The operating systems and applications we use today are really just gigantic collections of computer code. Windows Vista has about 50 million lines of code, and Windows XP has 35 to 40 million lines of code, whereas they shaved down Windows 7 to 40 million lines of code, Windows 8 is rumored to be between 50 and 80 million lines of code. And if you look at the subsystems within Windows, you'll find that there are more than 50 dependency layers—processes that depend on other processes. Experts who work on developing Windows say that it typically takes someone about five years to fully learn two or three of these layers. So it's pretty easy to imagine that with that much code being created by a couple of thousand different people, sometimes a few things get mixed up—and that's the reason there always seems to be a few holes, glitches, and bugs to fix.

The good news is, as operating systems and applications are released, their developers have a chance to catch and repair the problems they uncover. In addition, as hackers find and take advantage of vulnerabilities, software developers work to plug those holes. The repairs are usually released to the public as *patches* or *hotfixes*. To address large-scale issues or add major features and components to a program, companies release complete upgrades instead.

Here's where we get into the software side of security, which includes things like applying patches, hotfixes, and upgrades, plus how to choose and install the right third-party software to protect yourself against viruses.

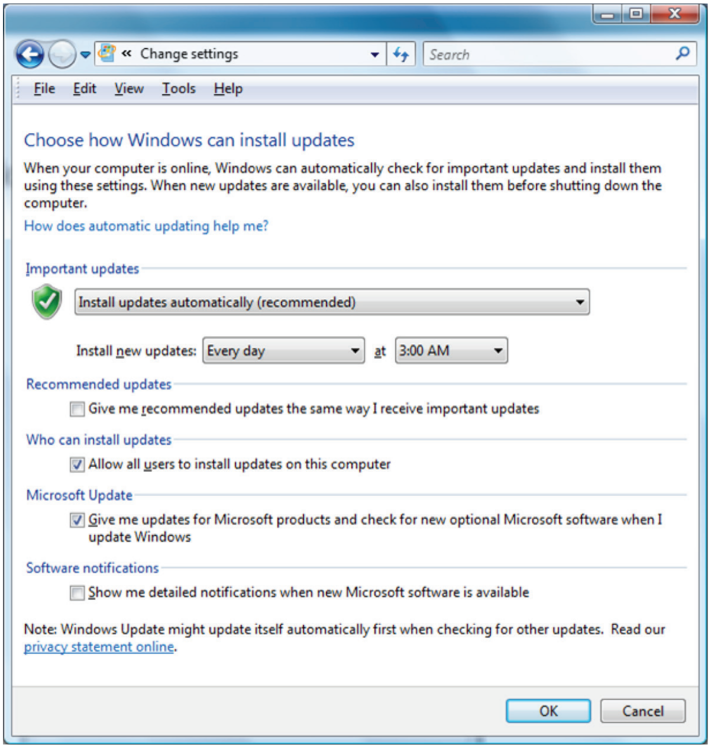
Ensuring that your software is up-to-date is one of the best ways to protect against bad guys exploiting the security holes on your network.

Automatic Updates Through Windows Update

It's really easy to get updates for Windows-based operating systems from Windows via Windows Update—a utility that's usually automatically installed when you install Windows. If you need to get more information, go to `www.microsoft.com`.

To ensure that Windows Update is enabled, open your System Properties dialog (right-click My Computer and then choose Properties). You will see a screen similar to the one shown in Figure 14.13.

FIGURE 14.13 Automating Windows Update



Choose how Windows can install updates

When your computer is online, Windows can automatically check for important updates and install them using these settings. When new updates are available, you can also install them before shutting down the computer.

How does automatic updating help me?

Important updates

Install updates automatically (recommended)

Install new updates: Every day at 3:00 AM

Recommended updates

□ Give me recommended updates the same way I receive important updates

Who can install updates

☑ Allow all users to install updates on this computer

Microsoft Update

☑ Give me updates for Microsoft products and check for new optional Microsoft software when I update Windows

Software notifications

□ Show me detailed notifications when new Microsoft software is available

Note: Windows Update might update itself automatically first when checking for other updates. Read our privacy statement online.

If you have Windows Update installed, it will periodically scan your system for the version of Windows components you already have installed and compare them to the most current versions available from Microsoft. If your software is out-of-date, a Windows Update dialog box will appear, asking if you want to install the software updates. If you click Continue, the installation will proceed in the background; you'll still be able to work in the foreground without skipping a beat.

Downloading Patches and Hotfixes

If you don't have automatic updates set up, you can download patches and hotfixes manually. A hotfix is just like a patch that updates software, but this term is reserved for a solution to potentially serious issues that could compromise your network and hosts. When a company like Microsoft has created a whole bunch of patches, hotfixes, and upgrades, it will put them together in a larger bundle called a *service pack*. For instance, you can download Windows 7 Service Pack 1 (SP1) or Windows Server 2008 Service Pack 2 (SP2), which will update lots of components and address security, performance, and stability issues all at the same time. For the latest service pack for your Windows-based operating system or application, visit `support.microsoft.com`.

But let's say you think you have a smaller, specific issue and you only want to download a patch for that particular problem. Maybe you're dealing with an issue with IPSec and you want to know about creating IPSec security filters in Windows XP. After surfing Microsoft's support site, you come across article KB914841 (`https://www.microsoft.com/en-us/download/details.aspx?id=735`). (KB stands for Knowledge Base, and it's one way Microsoft organizes its support documents.) This article will give you background information as well as allow you to download hotfixes for the operating system you're running.

Firmware Updates

While keeping operating system and application patches up-to-date gets most of the attention, there are devices on your network that may require firmware updates from time to time. Firmware is a form of program code and related data that is stored in persistent memory of some sort, such as non-volatile RAM (NVRAM).

In many cases firmware updates are designed to increase the functionality of a device. In other cases it may correct a bug or flaw in the system. Firmware updates are much more infrequent than other types of updates, so it's easy to forget about them. You should always agree to be contacted by manufacturers regarding these updates because they are not as widely publicized as other types of updates.

Updating firmware is a process sometimes called flashing, in which the old firmware instructions are overwritten by the new ones. You should carefully follow the process described in the manufacturer's documentation because failure to do so can lead to the device being made useless (sometimes called bricking the device).

Driver Updates

Drivers are files that allow a peripheral or component to talk to the hardware layer of the hosting device. In most cases, the drivers you need for a device will already be present in the drive cache that is installed with the operating system, but in some cases, especially with new devices, this will not be the case. In those instances, you will have to allow the system to locate the driver file from the CD that came with the device, or in extreme instances, you may have to search for it on the Internet. You should always start your search on the website of the manufacturer. Drivers found elsewhere may be problematic and in some cases may introduce malware.

Drivers also need to be updated from time to time. If you have computers set to receive updates automatically, updated drivers can be among the items you select to receive. Not all devices can benefit from automatic updating, and you may be required to check manually from time to time for driver updates for other devices, such as printers, scanners, and cameras.

File Hashing

Another security feature that can be utilized to prevent issues caused when malware attempts to alter or delete system files is file hashing. A hash function takes a message of variable length and produces a fixed-length hash value. Hash values, also referred to as message digests, are calculated using the original message. If the receiver calculates a hash value that is the same as the hash value of the original message, the original message is intact. If the receiver calculates a hash value that is different, then the original message has been altered.

Using a given function H, the following equation must be true to ensure that the original message, M1, has not been altered or replaced with a new message, M2: H(M1)<>H(M2)

By using software that computes hash values for all system files, and continually verifying these values, you can detect changes to system files.

Generating New Keys

Devices can use keys, which are long, randomly generated character streams, as input to encryption algorithms when encrypting data either in transit or at rest. At specified intervals, these keys must be renewed. While it is possible to renew the use of the same key (or key pair), generating a new key or key pair is advised. The longer a key is in use, the more likely the key will be compromised. Generating new keys at renewal time increases security.

Upgrading vs. Downgrading

Whenever a new version of an operating system or application is released, it usually generates a debate over whether the upgrade should be implemented. This is because experience has taught many IT technicians that there are often problems with a new release that they would prefer to avoid until someone else locates and corrects them.

Waiting until “all the bugs are ironed out” in an upgraded release is probably not a bad idea unless the upgrade addresses a security issue. In those cases, the risk is probably worth taking to close the security hole.

In some cases it may be necessary to reverse or downgrade a system to the old version if the new version causes substantial issues in the production environment. You can save yourself a lot of grief and possible downtime in the production environment by testing all new versions of applications, operating systems, and firmware before deploying them.

Real World Scenario

Applying Your Knowledge

In your new position at ABB Tech Inc., one of your responsibilities is to maintain all software and firmware updates for the Sales department, which contains the following devices:

- 38 Windows 8.1 desktop systems
- 4 Red Hat Linux servers
- 1 Cisco 3550 switch
- 2 HP printers
- 1 Windows Server 2012 R2

Your latest assignment is to develop a plan for maintaining the updates on all of these machines. Complete the following table to provide the data required to create the plan. Research your answers using the websites of the vendors listed. You can check your answers in the following chart.

Device	Update types (OS, firmware, driver)	Most efficient method	Schedule
Windows 8.1	OS, driver	WSUS	Weekly
Red Hat Linux	OS, driver	Individual application	As notified by errata advisories through the Red Hat Customer Portal
Cisco 3550	Firmware	Individual application	As notified by subscribing to field advisories and security emails from Cisco
HP printers	Driver	Individual application	As notified by subscribing to HP
Windows Server 2012 R2	OS, driver	WSUS	Weekly

Asset Disposal

When the time comes to decommission an asset such as a server or a hard drive, the handling of any data that remains is a big security issue. Whenever data is erased or removed from a storage media, residual data can be left behind. This can allow data to be reconstructed when the organization disposes of the media, resulting in unauthorized individuals or groups gaining access to data. Media that security professionals must consider include magnetic hard disk drives, solid-state drives, magnetic tapes, and optical media, such as CDs and DVDs. When considering data remanence, security professionals must understand three countermeasures: clearing, purging, and destruction.

- **Clearing** includes removing data from the media so that the data cannot be reconstructed using normal file recovery techniques and tools. With this method, the data is only recoverable using special forensic techniques.
- **Purging,** also referred to as sanitization, makes the data unreadable even with advanced forensic techniques. With this technique, data should be unrecoverable.
- **Destruction** involves destroying the media on which the data resides.
  - *Overwriting* is a destruction technique that writes data patterns over the entire media, thereby eliminating any trace data.
  - *Degaussing*, another destruction technique, exposes the media to a powerful, alternating magnetic field, removing any previously written data and leaving the media in a magnetically randomized (blank) state.
  - *Encryption* scrambles the data on the media, thereby rendering it unreadable without the encryption key.
  - *Physical destruction* involves physically breaking the media apart or chemically altering it. For magnetic media, physical destruction can also involve exposure to high temperatures.

Most of the countermeasures given work for magnetic media. However, solid-state drives present unique challenges because they cannot be overwritten. Most solid-state drive vendors provide sanitization commands that can be used to erase the data on the drive. Security professionals should research these commands to ensure that they are effective. Another option for these drives is to erase the cryptographic key. Often a combination of these methods must be used to fully ensure that the data is removed.

Data remanence is also a consideration when using any cloud-based solution for an organization. Security professionals should work with their organization when negotiating any contract with a cloud-based provider to ensure that the contract covers data remanence issues, although it is difficult to determine that the data is properly removed. Using data encryption is a great way to ensure that data remanence is not a concern when dealing with the cloud.

Detection

Certain devices and the features they offer can help us to detect when something is awry. Technicians shield make use of these tools and features to apprise themselves of issues that require their attention.

Motion detection

In areas that require constant attention to security it may be advisable to install motion detectors of some sort. Server rooms, wiring closets and other critical areas may need these. Let's look at a few types

Infrared Sensors

Passive infrared systems (PIR) operate by identifying changes in heat waves in an area. Because the presence of an intruder would raise the temperature of the surrounding air particles, this system alerts or sounds an alarm when this occurs.

Electromechanical Systems

Electromechanical systems operate by detecting a break in an electrical circuit. For example, the circuit might cross a window or door and when the window or door is opened the circuit is broken, setting off an alarm of some sort. Another example might be a pressure pad placed under the carpet to detect the presence of individuals.

Photoelectric Systems

Photometric or photoelectric systems operate by detecting changes in the light and thus are used in windowless areas. They send a beam of light across the area and if the beam is interrupted (by a person, for example) the alarm is triggered.

Acoustical Detection Systems

Acoustical systems use strategically placed microphones to detect any sound made during a forced entry. These systems only work well in areas where there is not a lot of surrounding noise. They are typically very sensitive, which would cause many false alarms in a loud area, such as a door next to a busy street.

Wave Motion Detector

These devices generate a wave pattern in the area and detect any motion that disturbs the wave pattern. When the pattern is disturbed, an alarm sounds.

Capacitance Detector

These devices emit a magnetic field and monitor that field. If the field is disrupted, which will occur when a person enters the area, the alarm will sound.

Asset tracking tags

Proper asset management is not rocket science. It boils down to knowing exactly what you have, when you got it, where it is and where the license to use it is. The devil as they say is in the details. Most server administrators don't set out to intentionally exercise poor asset management; they simply don't give the importance it requires to be done correctly.

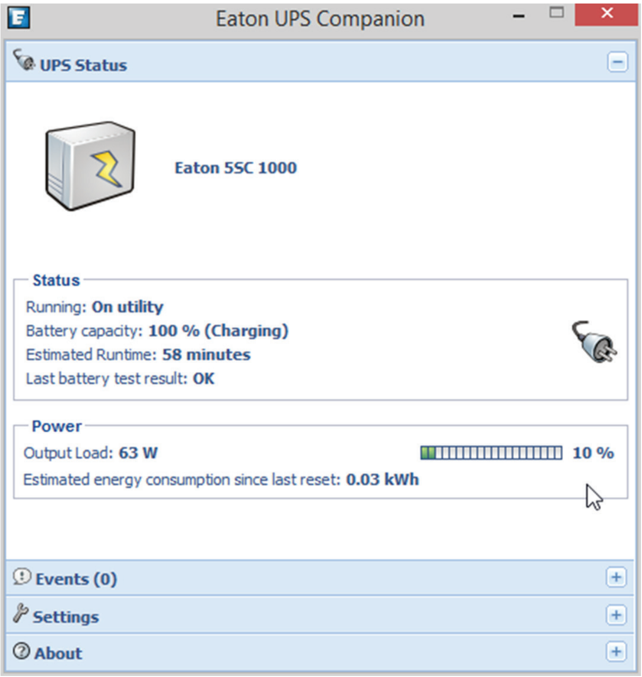
Labeling or tagging servers, workstations, printers, ports on infrastructure devices (routers and switches) and other items is another form of asset documentation that often doesn't receive enough attention. Not only does this make your day to day duties easier, it makes the process of maintaining accurate records simpler and supports a proper asset management plan. When periodic inventories are taken (you are doing that, right?) having these items labeled makes the process so much quicker. This goes for cables in the server room as well

Tamper detection

Tamper detection refers to any method that alerts you when a device or the enclosure in which it resides has been opened or an attempt has been made to open it. A good example is chassis intrusion detection.

You should use settings in the BIOS to alert you when the case has been opened. These settings are shown in Figure 14.14. In this case the open case warning has not been enabled yet.

FIGURE 14.14 Open case warning in the BIOS



Eaton 5SC 1000

Status

Running: On utility
Battery capacity: 100 % (Charging)
Estimated Runtime: 58 minutes
Last battery test result: OK

Power

Output Load: 63 W 10 %
Estimated energy consumption since last reset: 0.03 kWh

Anti-malware Software

Of all the update types that need to be maintained, anti-malware updates are the most critical to the organization. You must maintain updates to the malware definitions as well the updates to the malware engine itself. When choosing an anti-malware solution, there are two approaches, host based (also called premises based) and cloud based. In the following sections, we will examine both.

Host Based

Host- or premises-based anti-malware is a solution that you install and run inside your network. It has the advantage of giving you total control over the process but also requires you to stay on top of updates. It also requires the deployment of some hardware to hold the engine and the definition files.

Cloud/Server Based

Cloud antivirus products run not on local computers but in the cloud, creating a smaller footprint on the client and utilizing processing power in the cloud. They have the following advantages:

- They allow access to the latest malware data within minutes of the cloud antivirus service learning about it.
- They eliminate the need to continually update your antivirus software.
- The client is small, and it requires little processing power.

Cloud antivirus products have the following disadvantages:

- There is a client-to-cloud relationship, which means they cannot run in the background.
- They may scan only the core Windows files for viruses and not the whole computer.
- They are highly dependent on an Internet connection.

Real World Scenario

Should I Install Host-Based or Cloud/Server-Based Anti-malware for My Network?

You manage a very large enterprise network and need to keep a close eye on the most common attacks today: malware. You should install a next-generation IPS device, but you don't have the money for that type of equipment and the necessary training. You need something that will stop zero-day attacks if possible and don't want to add much processing or even more software on the hosts in the network than you already have. You don't want to install any new hardware, if possible, to get this done. With all this in mind, cloud/server-based anti-malware is your answer! It allows access to the latest malware data within minutes of the cloud antivirus service learning about it, and you don't need to install any new hardware at your location. You just need a good, solid Internet connection.

Configuration Backups

We create device configurations over time that can be quite complicated, and in some cases where multiple technicians have played a role, no single person has a complete understanding of the configuration. For this reason, configurations should be backed up.

Configurations may sometimes exist as text files, such as in a router or switch. Other times, such as with a Microsoft server, you will back up what is called the *system state*. This backs up only the configuration of the server and *not* the data. In this case, a system state backup *and* a data backup should be performed. It is also possible to back up the entire computer, which would include both data sets.

Considering the time it takes to set up a new device, install the operating system, and reconfigure it to replace a defective device, it makes great sense to keep backups of configurations so that if a device fails, you can quickly reimage a new machine and simply apply the system state to it or apply the configuration file (in the case of routers and switches).

Updating Antivirus Components

A typical antivirus program consists of two components:

- The definition files
- The engine

The definition files list the various viruses, their types, and their footprints and tell you how to remove them. More than 100 new viruses are found in the wild each month, so it's easy to see that an antivirus program would be totally useless if it didn't keep up with all those emerging viruses.

The engine accesses the definition files (or database), runs virus scans, cleans the files, and notifies the appropriate people and accounts. Eventually, viruses become so sophisticated that a new engine, or even a whole new technology, is required to combat them effectively.

NOTE

Heuristic scanning is a technology that allows an antivirus program to search for a virus even if there's no definition for it yet. The engine looks for suspicious activity of the kind that usually indicates the presence of a virus. But use such a tool with caution—if it's turned on, this scanning technique can mistake harmless or even necessary code for suspicious code, and that can give you some major grief.

For your antivirus program to work for you, you have to upgrade, update, and scan in a specific order:

1. Upgrade the antivirus engine.
2. Update the definition files.
3. Create an antivirus emergency boot disk.

4. Configure and run a full on-demand scan.
5. Schedule monthly full on-demand scans.
6. Configure and activate on-access scans.
7. Make a new antivirus emergency boot disk monthly.
8. Get the latest update when fighting a virus outbreak.
9. Repeat all steps when you get a new engine.

I'm going to cover only the steps in this list that map to objectives of the Network+ exam, but looking into the others on your own won't hurt and will give you some worthwhile knowledge.

Upgrading an Antivirus Engine

An antivirus engine is the core program that runs the scanning process, and virus definitions are keyed to an engine version number. For example, a 3.*x* engine won't work with 4.*x* definition files. When the manufacturer releases a new engine, consider both the cost to upgrade and how much you'll benefit before buying it.

NOTE Before installing new or upgraded software, back up your entire computer system, including all your data.

Updating Definition Files

I recommend that you update your list of known viruses—called the *virus definition files*—no less than weekly. You can do this manually or automatically through the manufacturer's website, and you can use a staging server within your company to download and distribute the updates or set up each computer to download updates individually.

Scanning for Viruses

An *antivirus scan* is the process that an antivirus program deploys to examine a computer suspected of having a virus, identify the virus, and then get rid of it. There are three types of antivirus scans, and to really make sure your system is clean, you should use a combination of the types I'm covering in this section:

On-Demand Scan An *on-demand scan* is a virus scan initiated by you or an administrator that searches a file, a directory, a drive, or an entire computer but only checks the files you're currently accessing. I recommend doing this at least monthly, but you'll also want to do an on-demand scan when the following occurs:

- You first install the antivirus software.
- You upgrade the antivirus software engine.
- You suspect a virus outbreak.

NOTE Before you initiate an on-demand scan, be sure you have the latest virus definitions.

On-Access Scan An on-access scan runs in the background when you open a file or use a program in situations like these:

- Inserting a floppy disk or thumb drive
- Downloading a file with FTP
- Receiving email messages and attachments
- Viewing a web page

This kind of scan slows down the processing speed of other programs, but it's worth the inconvenience.

Emergency Scan During an emergency scan, only the operating system and the antivirus program are running. You initiate one of these scans when a virus has totally invaded your system and taken control of the machine. In this situation, insert your antivirus emergency boot disk and boot the infected computer from it. Then, scan and clean the entire computer. If you don't have your boot disk, go to another, uninfected machine and create one from it. Another possibility is to use an emergency scan website like `https://housecall.trendmicro.com`, which allows you to scan your computer via high-speed Internet access without using an emergency disk.

Fixing an Infected Computer

So what do you do if you know you have a virus? First, you want to make sure to scan all potentially affected hard disks plus any external disks that could be infected. Establish a cleaning station, and quarantine the infected area. You'll have a really hard time doing this if anyone continues to use the computer while it is infected, so make sure all users in the infected area stop using their computers.

Then, remove all external memory devices from all disk drives and perform a scan and clean at the cleaning station. Update the virus definitions of any computers that are still operational. For the ones that aren't, or the ones that are still working but are infected, boot to an antivirus emergency boot disk. After you've done that, run a full scan and clean the entire system on all computers in the office space. With luck, you will be done before your users return from lunch.

NOTE It's frustrating, but a lot of programs won't install unless you disable the on-access portion of your antivirus software. Clearly, this is dangerous if the program has a virus. If you want to be really safe, do an on-demand scan of the software before installing it. If things are all good, go ahead and disable on-access scanning during installation, and then reactivate it when the installation is complete.

Summary

Whew—this was a long chapter with a lot of good information in it. We talked about the dark side of computer networking: bad guys and the threats and attacks they use to victimize our systems and networks. You learned a lot about tactics like denial of service attacks, viruses, worms, social engineering, and other devious methods that hackers use. After that, you learned about ways to mitigate these threats and protect yourself by establishing policies and procedures, providing training, and ensuring that all your software is up-to-date. You also learned what to do about the ubiquitous problem of viruses. It's a lot to remember, I know, but believe me, you'll be really glad you're armed with this knowledge because unfortunately, you'll probably deal with these threats sooner or later.

Exam Essentials

Recognize vulnerabilities that may exist in your network. These vulnerabilities include unnecessary running services, open ports, unpatched systems, unencrypted channels, and the transmission of clear-text authentication credentials.

Know what types of threats can adversely affect your network. Threats include denial of service attacks, viruses, worms, rogue access points, phishing, and various other attack methods employed by hackers.

Understand how attackers attempt to get information about your network. Attackers have various methods they can use to gather information. Some of the most common reconnaissance tools are packet sniffers and social engineering.

Know how to keep your systems automatically updated. Programs such as Windows Update can keep your operating systems current, which will reduce opportunities for attackers to exploit your computers and network.

Know where to go to find downloadable software updates. Check the manufacturer's website for the most current security information, patches, and updates.

Understand and implement proper forensic concepts. This includes following the six steps in the incident response process.

Written Lab

Write the answers to the following questions. You can find the answers in Appendix A.

1. A __________ is a group of computers connected on the Internet for the purpose of performing a task in a coordinated manner.
2. How often should you update your virus definitions in your antivirus software?

3. What type of attack injects a command that overflows the amount of memory allocated and executes commands that would not normally be allowed?

4. __________ attacks are those that increase the effectiveness of a DoS attack.

5. What kind of tool could a hacker use to intercept traffic on your network?

6. What type of virus uses Microsoft's Visual Basic scripting language?

7. What is it called when someone intercepts traffic on your network that's intended for a different destination computer?

8. If someone installed a wireless router on your network without your knowledge, the WAP would be called __________ .

9. What software application can automatically ensure that your Windows-based computers have the most current security patches?

10. The two different types of virus scans are __________ .

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following is a type of denial of service attack?
   A. Ping of Death
   B. Stacheldraht
   C. SYN flood
   D. All of the above

2. In which attack does the attacker set the session ID ahead of time by sending a link to the victim with the ID preset?
   A. Session fixation
   B. Cross-site scripting
   C. Session sidejacking
   D. Session seeding

3. Which type of virus impacts files with the filename extensions `.com`, `.exe`, and `.dll`?
   A. File viruses
   B. SYN flood
   C. Smurf
   D. Tribe Flood Network

4. In which type of attack does the attacker scan for networks using a high-powered antenna connected to a wireless laptop?
   A. War driving
   B. Evil twin
   C. WEP cracking
   D. WPA cracking

5. Monkey B, Michelangelo, Stoned, and Stealth Boot are examples of which type of virus?
   A. IP spoofing
   B. Multipartite
   C. Macro
   D. Boot sector

6. Which type of virus affects both the boot sector and files on a computer?
   A. Mulipartite
   B. Macro
   C. Tribe Flood Network 2000 (TFN2K)
   D. Smurf

7. What is the main difference between a worm and a virus?
   - **A.** Worms require user action for replication; viruses do not.
   - **B.** Worms can be spread by email and viruses cannot.
   - **C.** Worms can replicate without user intervention; viruses cannot.
   - **D.** None of the above.

8. What kind of attack involves the hacker attempting all combinations of characters for a password to gain access?
   - **A.** Packet sniffers
   - **B.** Brute force attack
   - **C.** Worm
   - **D.** Backdoor

9. What type of security threat allows an attacker to learn your password through the use of an email or phone call?
   - **A.** Phishing
   - **B.** Trust-exploration attack
   - **C.** Man-in-the-middle attack
   - **D.** Rogue access point

10. Which type of policy should be implemented to secure important company documents and materials when employees leave their workstations?
   - **A.** Clean housekeeping
   - **B.** Clean desk
   - **C.** Security audit
   - **D.** Proactive defense

11. If you implement a set of policies and procedures that define corporate information as confidential and then train employees on these procedures, what type of attack can you prevent?
   - **A.** DoS
   - **B.** Man-in-the-middle attacks
   - **C.** Smurf
   - **D.** Social engineering

12. What type of wireless frame populates the display when someone is scanning for wireless networks?
   - **A.** Probe response
   - **B.** Beacon

C. SSID

D. Discovery

13. What defines the appropriate response to a security event on a network?

A. Implementing security procedures

B. Installing a new router

C. Turning off the network

D. Implementing an HR policy for dress code

14. Which of the following security mechanisms has been compromised?

A. WEP

B. 802.11i

C. WPA2 Enterprise

D. RADIUS

15. What process allows you to update your Windows-based operating system?

A. Technet

B. Windows Update

C. Text message

D. Hotfix

16. Why is it important to keep your system patched and up-to-date?

A. To completely stop your need for security

B. To increase the functionality of your applications

C. To fix system vulnerabilities

D. To make Windows completely safe and worry free

17. Who is responsible for securing a crime scene and protecting the evidence from corruption?

A. First responder

B. CIO

C. Police

D. User

18. Which type of scanning allows an antivirus program to search for a virus even if there is no definition for it?

A. Update scan

B. Signature-file scan

C. Database scan

D. Heuristic scan

19. What type of files need to be updated in order for your antivirus program to have the latest information about attacks and viruses?

    A. Definition files

    B. Email files

    C. DOC (`.doc`) files

    D. EXE (`.exe`) files

20. What type of scan can be done by an antivirus program?

    A. Emergency

    B. On-demand

    C. On-access

    D. All of the above

Chapter 15

Physical Security and Risk

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching**

  - ACL
- Segmentation and interface properties
  - DMZ

✓ **2.2 Given a scenario, determine the appropriate placement of networking devices on a network and install/configure them**

- Firewall

✓ **2.3 Explain the purposes and use cases for advanced networking devices**

- UTM appliance
- NGFW/Layer7 Firewall

✓ **3.2 Compare and contrast business continuity and disaster recovery concepts**

- Power management
- Battery backups/UPS
- Power generators
- Dual power supplies
- Redundant circuits
- Recovery
  - Cold sites
  - Warm sites
  - Hot sites

✓ **4.1 Summarize the purposes of physical security devices**

- Prevention
  - Biometrics
  - Key fob

✓ **4.2 Explain authentication and access controls**

- Multifactor authentication
  - Something you know
  - Something you have
  - Something you are
  - Somewhere you are
  - Something you do
- Access control
  - Access control lists

✓ **4.6 Explain common mitigation techniques and their purposes**

- Signature management
- Network segmentation
  - DMZ
  - VLAN
- Restricting access via ACLs
- Honeypot/honeynet
- Penetration testing

Finding a corporate network that isn't connected to the Internet would be pretty tough these days. Being connected allows for a huge increase in productivity, and not having an online presence is akin to sheer oblivion in today's business environment. But as is often the case, advantages, even big ones, have a downside to them, and being hooked up to the Internet is no exception. Connecting our private networks to a huge public one exposes us to some really major security risks, so we absolutely have to protect our networks from the very real threats of intrusion, corporate espionage, data and identity theft, and exploitation in general. To succeed, we need to make sure our networks have one or more security devices to control any traffic coming into and flowing out from them. We need things like firewalls and intrusion detection and/or prevention systems as much as we need any other form of security in our businesses and daily lives today—period.

These vital security methods are going to be the focus of this chapter. In it, I'll be covering the ins and outs of the protective networking measures and devices designed to shield and secure our network traffic, zooming in on the all-important firewalls because they're a ubiquitous and critical line of defense against the exploits of the all-too-common hackers who seek to compromise our corporate and personal network security.

I'll end this important chapter by going over the specific issues that can and do affect device security on your network. I'll discuss things you can do physically and logically to implement tight security, right down to choosing the best protocols to use for safe communication to the outside world.

NOTE

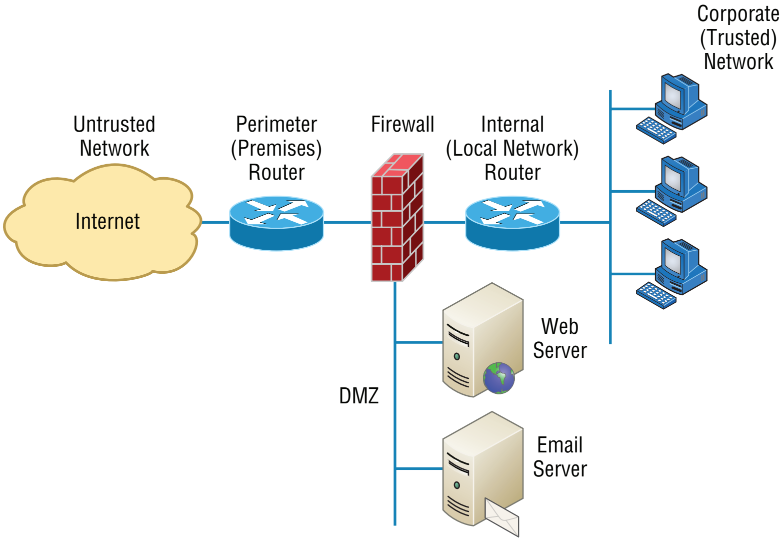
To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Using Hardware and Software Security Devices

This heading may be a little misleading because it makes it sound like I'm going to discuss the differences between hardware and software security devices. But I'm not, because even though many firewalls and routers that contain proxy and/or firewall services brand themselves as hardware or software solutions, the fact is, most of these devices are really a combination of the two. For instance, there's software embedded within a hardware ROM chip to make the software harder to attack, but it still actually functions as software. So instead of focusing on the type of device, it makes a lot more sense to delve into exactly what it is that a device does and how it does it.

In medium to large enterprise networks, strategies for security usually include some combination of internal and perimeter routers plus firewall devices. Internal routers provide added security by screening traffic to the more vulnerable parts of a corporate network through a wide array of strategic access lists. You can see where each of these devices is found within a typical network in Figure 15.1.

FIGURE 15.1 A typical secured network


Corporate (Trusted) Network
Untrusted Network
Internet
Perimeter (Premises) Router
Firewall
Internal (Local Network) Router
Web Server
DMZ
Email Server

I'll use the terms *trusted network* and *untrusted network* throughout this chapter, so it's important that you can see where they are found in a typical secured network. The demilitarized zone (DMZ) can be global (real) Internet addresses or private addresses, depending on how you configure your firewall, but this is typically where you'll find the HTTP, Domain Name Service (DNS), email, and other Internet-type corporate servers. The DMZ is used to create a security zone that allows public traffic but the traffic is isolated from the company private network.

Instead of having routers, we can also use virtual local area networks (VLANs) with switches on the inside trusted network. Multilayer switches containing their own security features can sometimes replace internal (LAN) routers to provide higher performance in VLAN architectures.

Next, I'll show you how these devices go about directing traffic between your *private network*, that only authorized users have access to, and your *public network* that everyone connects to.

Defining Firewalls

Firewalls are usually a combination of hardware and software. The hardware part is usually a router, but it can also be a computer or a dedicated piece of hardware called a *black box* that has two network interface cards (NICs) in it. One of the NICs connects to the public side, and the other one connects to the private side. The software part is configured to control how the firewall actually works to protect your network by scrutinizing each incoming and outgoing packet and rejecting any suspicious ones.

Firewalls generally allow only packets that pass specific security restrictions to get through; they can also permit, deny, encrypt, decrypt, and proxy all traffic that flows through, either between the public and private parts of a network or between different security domains, or zones, on a private network. The system administrator decides on and sets up the rules a firewall follows when deciding to forward data packets or reject them.

NOTE Just so you know, a Network+ certified system administrator rarely has the sophisticated knowledge required to design, install, and manage a firewall. The information I'm imparting to you here will give you the tools you need to understand the basic ways firewalls work and to help you to work effectively in an environment where a firewall is already installed.

Firewalls can be placed on top of an existing operating system or be self-contained. Conversely, black-box systems are proprietary and have external controls that aren't controlled by the operating system itself. If you opt to use a general-purpose server operating system to run your firewall, you can do that with Unix and Windows because both support third-party firewall products.

NOTE For networks with multiple Windows-based computers, firewalls should be installed on a router that connects the private network to the Internet or to a Windows server like Windows Server 2008 or newer rather than on clients like Windows 7 or 8.

Clearly, if your firewalls aren't configured properly, they're not going to do you much good. Most of them are configured as default-deny, meaning that the only network connections allowed are the ones that have been specified to be permitted. A proficient system administrator has to do this, and trust me, with the multitude of applications and ports involved in internal-external network communication, it's not all that easy! To make life easier, some people resort to trusting the default-allow option, where all traffic is allowed to pass through unless it's been specifically blocked. But doing this isn't exactly tight because it makes inadvertent network connections and security breaches much more likely to happen. Even though it might ease a little administrative pain, I don't recommend going with this method—ever.

Network-Based Firewalls

A *network-based firewall* is what companies use to protect their private network from public networks. The defining characteristic of this type of firewall is that it's designed to protect an entire network of computers instead of just one system, and it's usually a combination of hardware and software.

As you can imagine, protecting an entire network of computers from malicious attacks is quite the challenge. Most of the firewall features that I'm going to cover in this chapter are designed with this goal in mind, although the technology is certainly applicable to host-based firewalls too.

NOTE

In many small office, home office (SOHO) networks, a firewall with somewhat less sophistication may be used. While not providing all of the functionality of an enterprise firewall, these devices may be easier to configure and can still be deployed safely.

Host-Based Firewalls

In contrast to a network-based firewall, a *host-based firewall* is implemented on a single machine, so it protects only that one machine. This type of firewall is usually a software implementation because you don't need any additional hardware in your personal computer to run it. All current Windows client operating systems come with Windows Firewall, which is a great example of a host-based solution.

If you hear someone say that host-based software solutions just aren't as secure as a separate hardware-based solution, they're pretty much right. This is because if you're running a dedicated black-box firewall and someone manages to hack in and disable it, your best-case scenario is a blown black box and a ruined firewall. Believe it or not, even if that happens, all the data on your internal network may still be safe if the bad guy wasn't able to get past everything. But if they were able to get all the way in, you could have some ugly consequences to deal with; if the hacker makes it through the often relatively flimsy software firewall running on your local computer, they could not only view and/or nick your files but also trash your entire system—yikes!

Still, it all comes down to how much security you really require. Unless you're the director of the CIA or something, you probably don't need to go the extra mile and shell out for a dedicated black box if all you want to do is protect your personal computer from someone who's trying to hack their way in through your high-speed Internet connection.

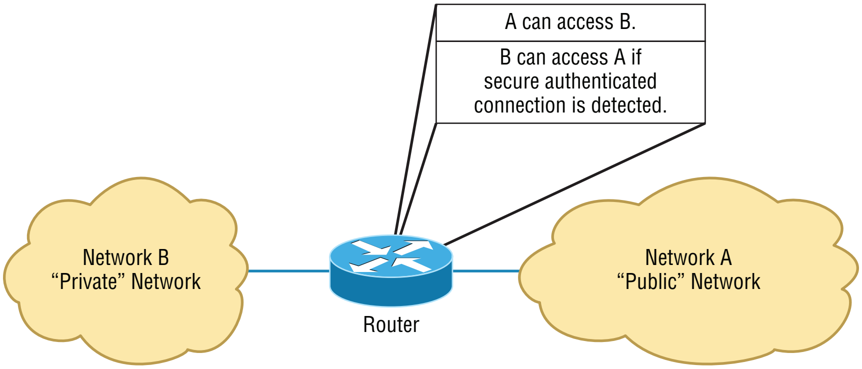
Firewall Technologies

There are a whole bunch of firewall technologies, and they all differ in the way that they restrict information flow. Things like access control lists and dynamic packet filtering are often used as firewalls in their own right, or they can be implemented along with proxies, DMZs, and other firewall technologies to build a serious, formidable system fortress.

Access Control Lists

The first line of defense for any network that's connected to the Internet is what we call *access control lists (ACLs)*. These reside on your routers and determine by IP addresses which machines are allowed to use those routers and in what direction. ACLs have been around for decades and have some other really cool uses apart from being used as firewalls. Figure 15.2 gives you a great demonstration of how ACLs can work to prevent users on Network B from accessing Network A. However, hosts from Network B and can access Network A if a secure authenticated connection is used.

FIGURE 15.2 Two networks with an ACL-enabled router


A can access B.
B can access A if secure authenticated connection is detected.
Network B "Private" Network
Router
Network A "Public" Network

An important thing to note here is that data from users in Network A can still pass through the router into Network B. This means that a hacker executing an IP spoofing attack that makes it appear as though they're an IP address originating from inside the firewall can still gain access to Network B by pretending to be a valid user in Network A.

ACLs are essentially lists of conditions that categorize packets, so you can imagine how helpful they can be in helping you gain control over the network's traffic. One of the most common and easiest-to-understand ways that ACLs are used is for filtering unwanted packets when you're implementing security policies. You can set up the ACLs to make very specific decisions about regulating traffic patterns so that they'll allow only certain hosts to access web resources on the Internet while restricting others. With a solid combination of ACLs, network managers can arm themselves like Rambo and powerfully enforce pretty much any security policy they need to.

Chapter 14 discussed some of the security threats that ACLs can help mitigate:

- IP address spoofing, inbound
- IP address spoofing, outbound
- Denial of service (DoS) TCP SYN attacks
- DoS Smurf attacks

The following techniques can be used to mitigate these security threats:

- Using TCP intercept to address DoS TCP SYN attacks
- Filtering ICMP messages, inbound
- Filtering ICMP messages, outbound
- Filtering Traceroute

You can even employ ACLs for situations that don't necessarily involve blocking packets—like using them to control which networks will or won't be advertised by dynamic routing protocols. The way you configure your ACL to do that is the same; you just apply it to a routing protocol instead of an interface. The only other difference here is that an ACL applied to a protocol is referred to as a *distribution list*, and it doesn't stop routing advertisements, it just controls their content. You can also use ACLs to categorize and queue packets for applications that require Quality of Service (QoS) and for controlling the types of traffic that can activate a pricey backup link.

So, how do you go about creating an ACL? Well, it's really a lot like programming a series of `if-then` statements: If a given condition is met, then a specific action happens; but if that explicit condition isn't met, nothing happens except that the next statement in the list is evaluated. Access-list statements are basically packet filters that packets are compared against, categorized by, and then acted on accordingly as directed. Once your list is built, it can be applied to either inbound or outbound traffic on any interface, causing the router to analyze every packet crossing that interface in the specified direction and take the appropriate action.

There are a few important rules by which packets are processed when being compared with an ACL:

- They're always compared with each line of the ACL in sequential order, always beginning with the first line, then proceeding to line 2, then line 3, and so on.
- They'll be compared with subsequent lines of the list until a match is made. Once the packet matches the condition on a line of the ACL, the packet is acted upon and no further comparisons take place.
- There is an implicit "deny" at the end of each ACL that says that if a packet doesn't match the condition on any of the lines in the ACL, it will be discarded.

Each of these rules has some powerful implications for filtering IP packets with ACLs, which is why creating effective ACLs truly takes some practice!

There are two main types of ACLs:

Standard ACLs These use only the source IP address in an IP packet as the condition test, so all decisions regarding a packet will be based on the source IP address. This means that standard ACLs basically permit or deny an entire suite of protocols without distinguishing between any of the myriad types of IP traffic like web, Telnet, UDP, and so on.

Extended ACLs Extended ACLs go the distance and evaluate lots of the other fields in the Layer 3 and 4 headers of an IP packet. They can evaluate source and destination IP addresses, the protocol field in the Network layer header, and the port number at the Transport layer header. This gives extended ACLs the ability to enforce highly specific network traffic control conditions.

Once you create an ACL, it doesn't do much of anything until you apply it. Yes, it's there on the router, but it's inactive until you tell that router what to do with it. To use an ACL as a packet filter, you've got to apply it to the interface on the router exactly where you want the traffic filtered, and you've also got to specify the traffic's direction—inbound or outbound. This is because you probably want different controls in place for traffic leaving your network that's destined for the Internet than you want for traffic coming into your network from the Internet. Here's the difference:

Inbound ACLs When an ACL is applied to inbound packets on an interface, those packets are processed through the ACL before being routed to the outbound interface. Any packets that are denied won't be routed because they'll be discarded before the routing process is completed.

Outbound ACLs When an ACL is applied to outbound packets on an interface, those packets are routed to the outbound interface and then processed through the ACL before being queued.

Creating ACLs is great, but don't forget to apply them to an interface or they're not going to filter traffic. With that in mind, here's a list of rules to live by when configuring ACLs on interfaces from the Internet into your production network:

- Deny any addresses from your internal networks.
- Deny any local host addresses (127.0.0.0/8).
- Deny any reserved private addresses.
- Deny any addresses in the IP multicast address range (224.0.0.0/4).

These addresses should never, ever be allowed to enter your internetwork.

Port Security

While firewalls can be used to protect access to the network at Layer 3 (IP addresses), there are cases where security needs to be maintained between users within the network. This can be done by implementing port security on the switches in the network. When you do this, you are enforcing security at Layer 2 (MAC addresses).

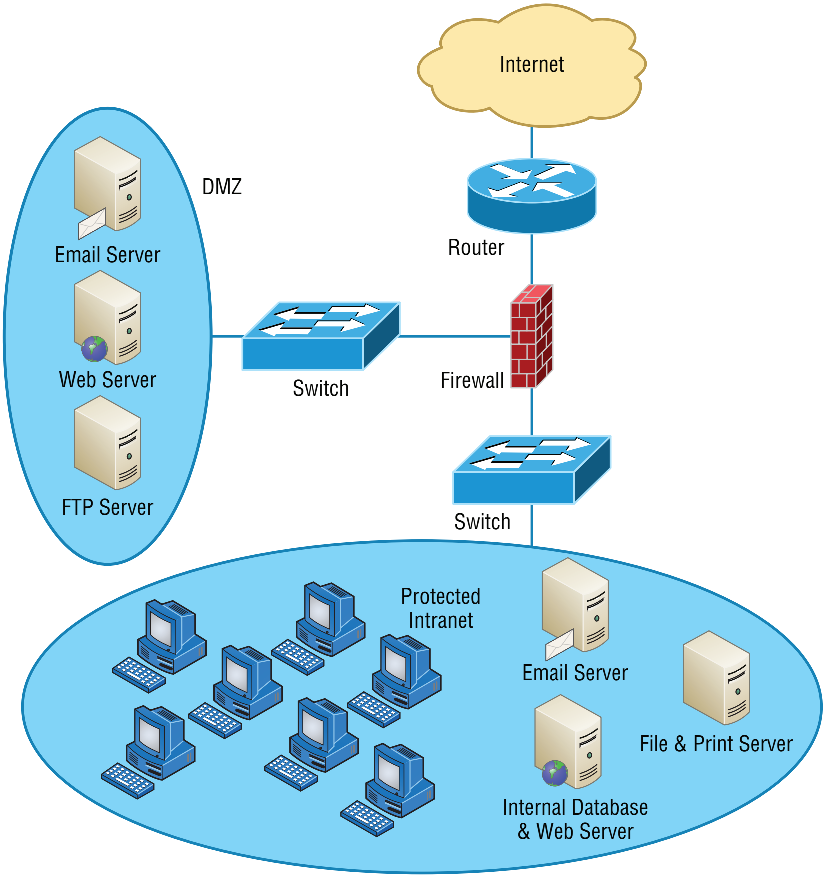
This can be used in several ways. First, you can use port security to define a set of MAC addresses that are allowed to access a port where a sensitive device is located. Another use is to set unused ports to be available to only a preconfigured set of MAC addresses. The second example could help to prevent unauthorized persons from plugging into a wall outlet (connected to a secured switch port) and accessing the network.

Demilitarized Zone

Most firewalls in use today implement something called a *demilitarized zone (DMZ)*, which, as its name implies, is a network segment that isn't public or local but halfway between the two. People outside your network primarily access your web servers, File Transfer Protocol (FTP) servers, and mail relay servers, and because bad guys tend to go after these servers first, it's a good idea to place them in the DMZ.

A standard DMZ setup typically (but not always) has two or three network cards in the firewall computer. The first goes to the Internet, the second one goes to the network segment where the commonly targeted servers exist (the servers I recommended be placed in the DMZ), and the third connects to your intranet. As you can see in Figure 15.3, the email server, the FTP server, and the web server are all in the DMZ, so all critical servers live inside the firewall.

FIGURE 15.3 A firewall with a DMZ



Understand that it is very possible to have a DMZ outside the firewall. Figure 15.3 shows an example of having the DMZ inside the firewall. Both options are available when building your intranets.

If you set things up like this, hackers who break into servers in the DMZ will only get to see public information—meaning your entire corporate network won't be compromised. Understand that email messages are still fairly vulnerable, but only the email relay server (the one in the DMZ) can be accessed because all messages are stored and viewed on email servers inside the network.

It is important to understand and remember that you need to administer your DMZ. This is not a device you buy at the store and just connect, turn on, and forget—you need to permit and deny the ports you want. If your company uses custom port numbers, you need to verify that the DMZ is allowing these ports through your server. This is easy to do by telnetting to the DMZ server using the custom port number. If the server responds, you're good!

Protocol Switching

Protocol switching protects data on the inside of a firewall, and because Transmission Control Protocol/Internet Protocol (TCP/IP) is what the Internet runs on, most external attacks take direct aim at this protocol stack. In days gone by, protocol switching used to be pretty popular, but not so much anymore due to the greatly intensified power of firewall technology and the fact that TCP/IP is now the protocol of choice for all network communications. But if you did want to implement protocol switching, here are the two best ways to do it:

- Use a protocol other than TCP/IP on the internal network inside the firewall. IP-based attacks aimed at your development server just can't work if you use Internetwork Packet Exchange (IPX) on the internal-network side of a router, which gives you an automatic firewall.
- Use TCP/IP on the internal network and use a different protocol like IPX in a dead zone between the internal network and the Internet. Basically, you'll have things set up to switch from IP to IPX in that dead zone and switch back to IP again once inside your network (IPv6 would work in this example as well, but IPX is a good example because no one would expect it).

Real World Scenario

Applying Your Knowledge

Your new role with ABB Tech Inc. requires you to manage the firewall leading into the Sales department. Your predecessor configured the following ruleset on the firewall.

Source	Destination	Port	Protocol	Action
192.168.2.0/24	192.168.10.0/24	23	TCP	Drop
192.168.2.1/24	ANY	23	TCP	Allow
192.168.10.0/24	192.168.3.0/24	FTP	UDP	Allow
All	All	All	All	Allow

The following issues have been identified with the functioning of the firewall.

- Joe Smith, an IT tech with an IP address of 192.168.2.1, should be able to use Telnet to any devices in the network, but he cannot use it with any devices.
- All users in the Marketing department, which uses the 192.168.10.0 subnet, should be able to use FTP to upload images to a server at 192.168.3.10 but cannot do so.

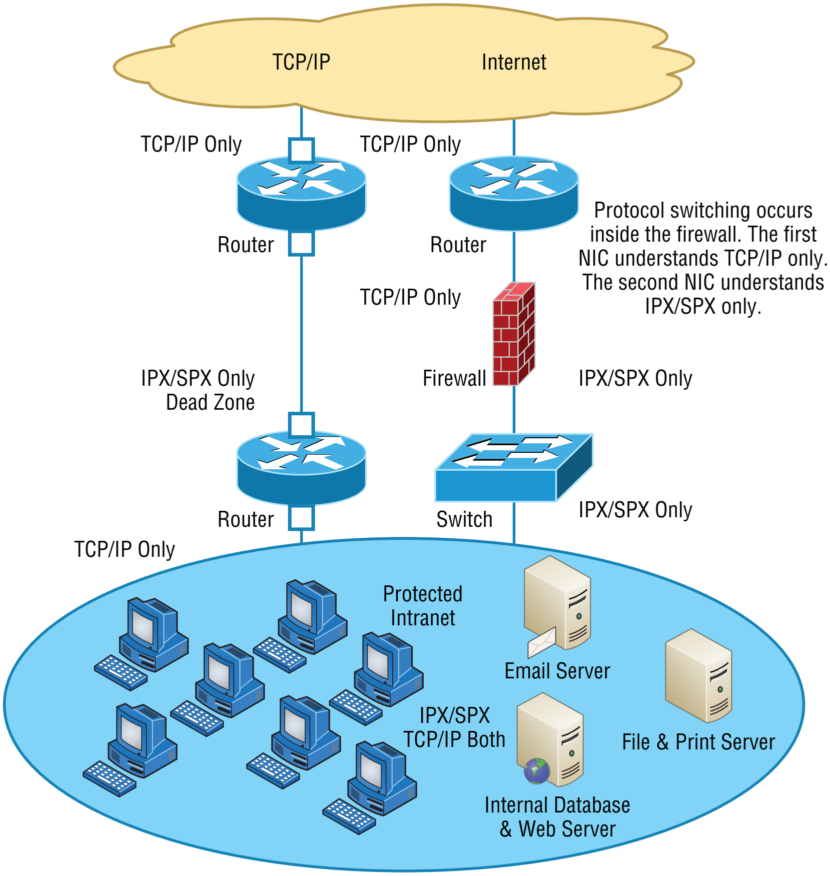
Your assignment is to correct the rule list. The corrected list is shown here.

Source	Destination	Port	Protocol	Action
192.168.2.1/24	ANY	23	TCP	Allow
192.168.2.0/24	192.168.10.0/24	23	TCP	Drop
192.168.10.0/24	192.168.3.0/24	FTP	TCP	Allow
All	All	All	All	Allow

Note: The rule designed to allow Joe at 192.168.2.1 should be moved to the top of the list. As it is now positioned, the first rule will match his address as well and prevent him from using Telnet to any devices. The rule designed to allow users in the Marketing department, which uses the 192.168.10.0 subnet, to use FTP to upload images to a server at 192.168.3.10 is set with an incorrect protocol type. FTP uses TCP and not UDP, so changing that in the ruleset will solve that issue.

Figure 15.4 demonstrates both of these strategies. Focus on the dead zone between two of the routers, and also notice that the only protocol on the inside of either router is IPX. This means that any TCP/IP packets coming in from the Internet can't pass through into the local network because of the difference in protocols used by each network.

FIGURE 15.4 Protocol switching with and without a dead zone



NOTE

Both of these methods protect only the internal network. You still need a firewall to guard against attacks on your network's access point and protocol-switching device.

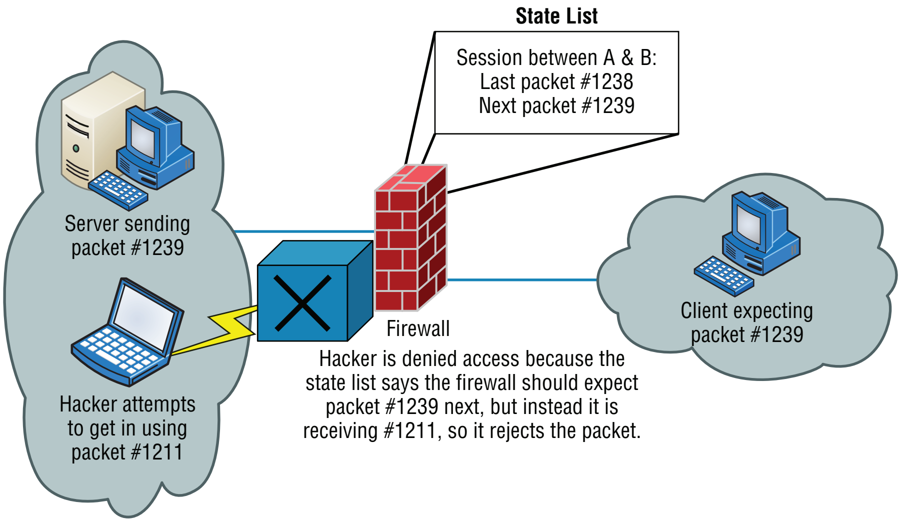
Dynamic Packet Filtering

Packet filtering refers to the ability of a router or a firewall to discard packets that don't meet the right criteria. Firewalls use *dynamic packet filtering* to ensure that the packets they forward match sessions initiated on their private side by something called a *dynamic state list* or *state table*, which keeps track of all communication sessions between stations from inside and outside the firewall. This list changes dynamically as sessions are added and deleted.

So with dynamic packet filtering, only packets for valid and current sessions are allowed to pass. Anyone trying to play back a communication session—for instance, a login to gain access—won't be able to do that if your firewall is using dynamic packet filtering with a dynamic state list because the data they send isn't part of a currently valid session. The firewall will respond to an event like this by dropping all packets that don't correspond to a current session via the information in the dynamic state list. Let me clarify this: Say a computer in Network A requests a Telnet session with a server in Network B. The firewall in between the two keeps a log of the communication packets that are sent each way, and only packets that belong to the current session will be allowed back into Network A through that firewall.

Figure 15.5 depicts a failed attempt to infiltrate a network protected with a dynamic state list. Can you see that the hacker attempts to insert a packet into the communication stream but can't because they don't have the correct packet number? This is because the firewall was waiting for a specific order of packets and the hacker's packet is out of sequence.

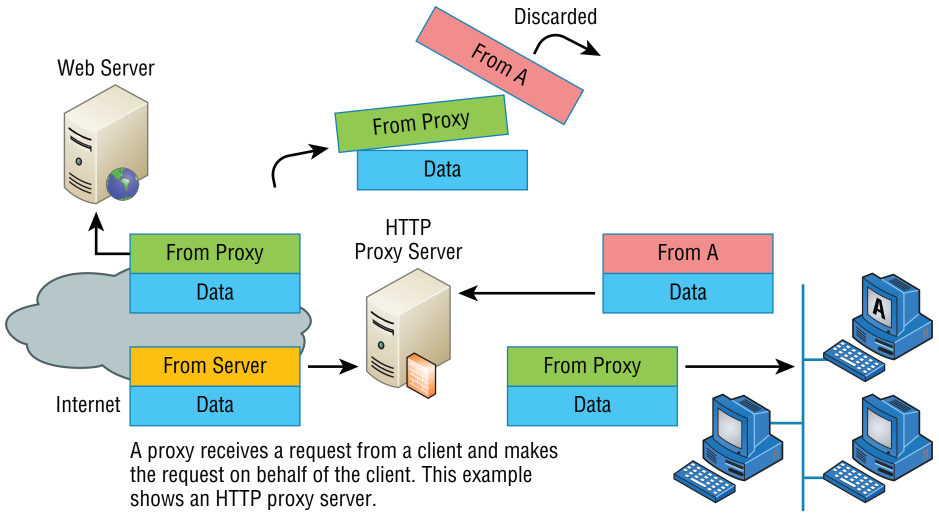
FIGURE 15.5 A hacker denied by a dynamic state list


State List
Session between A & B:
Last packet #1238
Next packet #1239
Server sending packet #1239
Hacker attempts to get in using packet #1211
Firewall
Hacker is denied access because the state list says the firewall should expect packet #1239 next, but instead it is receiving #1211, so it rejects the packet.
Client expecting packet #1239

Proxy Services

Firewalls can also implement something called *proxy services*, which actually makes them *proxy servers*, or proxies for short. Proxies act on behalf of the whole network to completely separate packets from internal hosts and external hosts. Let's say an internal client sends a request to an external host on the Internet. That request will get to the proxy server first, where it will be examined, broken down, and handled by an application that will create a new packet requesting information from the external server. Figure 15.6 demonstrates this process. Make a note to yourself that this exchange occurs between applications at the Application layer of the OSI model.

FIGURE 15.6 A packet going to a proxy


Discarded
From A
Web Server
From Proxy
Data
HTTP
Proxy Server
From Proxy
Data
From A
Data
A
From Server
Data
From Proxy
Data
Internet
A proxy receives a request from a client and makes the request on behalf of the client. This example shows an HTTP proxy server.

Proxies make good firewalls because they dissect the entire packet so that each section of it can be scrutinized for invalid data at each and every layer of the OSI model; proxies look at everything from information in the packet header to the actual contents of the message. They can even examine attachments for viruses. As if all that isn't cool enough, proxies can also search messages for keywords that can indicate the source of a packet. That last little goodie is vital because you can use this type of searching to prevent sensitive information from escaping your organization along with the outbound data stream. If your sensitive documents contain a header or footer that includes something like MyCompanyName *Confidential*, you can set up your proxy server software to search for it. The only downside is that all that analysis will definitely degrade overall performance because it requires a lot more time than just checking state lists.

There are many types of proxy servers:

IP Proxy An *IP proxy* hides the IP addresses of all the devices on the internal network by exchanging its IP address for the address of any requesting station. This is good because you definitely don't want a hacker to know any IP addresses specific to your internal network, right? Even Internet web servers won't be able to determine the specific IP address from which they receive a request because any and all communications appear to have originated from the proxy server—nice! These proxies are sometimes called *Network Address Translation (NAT)* proxies.

Web (HTTP) Proxy *Web proxies*, also called HTTP proxies, handle HTTP requests on behalf of the sending workstation. When these are implemented correctly, a client's web browser asks a web server on the Internet for a web page using an HTTP request. Because the browser is configured to make HTTP requests using an HTTP proxy, the browser sends the request to the proxy server. The proxy server changes the From address of the HTTP request to its own network address and sends it to the Internet web server. The response to the HTTP request goes directly to the proxy (because it replaced the sender's address with its own). The proxy server then replaces its address with the address of the original sender, and the response is delivered to the original sender.

The most popular implementation of a web proxy is a *proxy cache server*. This server receives an HTTP request from a web browser and then makes the request on behalf of the sending workstation. When the requested page is returned, the proxy server caches a copy of the page locally. The next time someone requests the same web page or Internet information, the page can be delivered from the local cache instead of the proxy server having to formulate a new request to the web server on the Internet. This speeds up web surfing for commonly accessed pages. Web proxies can also increase network security by filtering out content that is considered insecure, such as executables, scripts, or viruses.

FTP Proxy FTP proxies handle the uploading and downloading of files from a server on behalf of a workstation. An FTP proxy operates in a fashion similar to a web proxy. As with web proxies, FTP proxies can filter out undesirable content (viruses and the like).

SMTP Proxy SMTP proxies handle Internet email. Here, the actual contents of the packet and mail can be automatically searched. Any packets or messages that contain material that is not considered secure can be blocked. Many SMTP proxies allow network virus protection software to scan inbound mail.

NOTE

Not every firewall falls into a simple category. Although firewalls are used to typically work in one arena, today's firewalls offer multiple solutions within one box or software program. Firewalls that perform more than one type of filtering service are sometimes referred to as *hybrid firewalls*.

Firewalls at the Application Layer vs. the Network Layer

By now, you know all about the OSI model and that the Application layer is at the top of the heap and the Network layer is third up from the bottom. And as a rule of thumb, the higher you get in the OSI model, the more complex the interactions become. This rule holds true for discussions of firewalls that work at the Application layer versus those that work at the Network layer.

The first firewalls that were developed functioned solely at the Network layer, and the earliest of these were known as *packet-filter firewalls*. I covered packet filtering a bit earlier in this chapter; as a refresher, all it means is that the firewall looks at an incoming packet and applies it against the set of rules in the ACL(s). If the packet passes, it gets sent on. If not, the packet is dropped.

This type of filtering is pretty basic because all the firewall considers is the individual packet. All that matters are the source and destination addresses, protocol, and port number. The firewall doesn't care whether that packet is stand-alone or part of another data stream. This process works fairly well for common protocols such as TCP and User Datagram Protocol (UDP), which communicate on predefined port numbers. People generally refer to two types of Network layer firewalls: stateful and stateless.

Stateful vs. Stateless Network Layer Firewalls

As I said in the last section, a basic packet filter doesn't care about whether the packet it is examining is stand-alone or part of a bigger message stream. That type of packet filter is said to be *stateless*, in that it does not monitor the status of the connections passing through it. Again, these work pretty well, but the firewall has no idea whether a packet is legitimate or possibly a rogue packet trying to sneak by. These types of firewalls tended to be susceptible to various DoS attacks and IP spoofing.

The one big advantage that a stateless firewall has over its stateful counterparts is that it uses less memory. Today, stateless firewalls are best used on an internal network where security threats are lower and there are few restrictions.

In contrast to a stateless firewall, a *stateful* firewall is one that keeps track of the various data streams passing through it. If a packet that is a part of an established connection hits the firewall, it's passed through. New packets are subjected to the rules as specified in the ACL. These types of firewalls are better at preventing network attacks that look to exploit existing connections, or DoS attacks.

A stateful firewall works by using the TCP three-way handshake. First, the client sends a packet with the SYN bit set to the firewall. The firewall interprets this as a new connection and passes the request to the appropriate service provider on the internal network. Next, the service provider responds with a packet that has both the SYN and ACK bits set. Finally, the client responds with a packet with only the ACK bit set. At that point, the connection is considered established and the firewall will only allow packets in that have the same connection identification. The established connection is logged in the *state table*.

If there is no data on the connection for a specified period of time, the connection will time out in the state table. Any new communication will need to be reestablished based on the ACL rules.

Stateful firewalls tend to be a bit slower at establishing connections than stateless ones because there is more to do. After the connection is established, though, stateful firewalls are usually faster because they just have to check the state table for the connection instead of comparing the packet against all the relevant ACLs. This is done via *stateful packet* inspection. Most stateful firewalls can also keep track of connections using connectionless protocols such as UDP.

NOTE

In a common DoS attack, the SYN flood, the attacker attempts to overload a firewall by spamming it with inordinate numbers of SYN requests. The firewall by default will keep sending SYN/ACKs back, thereby preventing it from responding to legitimate connection requests.

An additional problem for the firewall is that it maintains memory space for every SYN/ACK it sends out and the attacker never answers with a final ACK, so memory gets used up. Many of today's firewalls can circumvent this problem by not responding to multiple SYN requests from the same host.

Real World Scenario

Firewall Challenges

You were just given a firewall for your network and that firewall was appropriated from a different part of your company. You want to make sure hackers can't get in through that firewall on random ports. Fortunately for you, the firewall is default deny, so you don't have too many worries. You open up the ports for legitimate traffic, such as 80 for HTTP, 161 for Simple Network Management Protocol (SNMP), 21 for FTP, and so on. But users complain that they are unable to download files from the extranet using FTP. What happened?

FTP does work on port 21, but it also establishes connections on arbitrary high-number ports to complete its work. If those ports are not opened, FTP won't work. This is where a stateful firewall is handy. When FTP goes to open the new port, the firewall will see that the data intended for the new port is part of the existing FTP connection and let the data pass through. Yet another reason why stateful firewalls are so much better than stateless ones!

NGFW/Layer7 Firewall

Although stateful firewalls are more powerful and secure than stateless ones, Application layer firewalls (also called next generation firewalls [NGFWs] or Layer 7 firewalls) are even better. They work by inspecting more than just data in the IP header: They read data at the Application layer. In other words, they will know whether a packet is FTP, SNMP, HTTP, or whatever Application layer protocol it is. The one major drawback is speed. Because these devices have to read more information than their Network layer counterparts, they do tend to be a bit slower. It's generally not enough that you'll notice, though, unless you have the reaction time of Superman.

One nice feature of Application layer firewalls is that they let you set proxy rules for multiple applications on the same firewall. As a proxy, the firewall processes all data between the two endpoints and drops all packets that are suspicious. In theory, a rogue packet will never reach the system on your internal network. Application layer firewalls also handle complex protocols such as H.323, which is used for Voice over IP (VoIP), much better than their Network layer counterparts.

Scanning Services and Other Firewall Features

Most firewalls are capable of performing *scanning services*, which means that they scan different types of incoming traffic in an effort to detect problems. For example, firewalls can scan incoming HTTP traffic to look for viruses or spyware, or they can scan email looking for spam. You can often set scanning rules that will prevent users from downloading files over a certain size. On Cisco routers, scanning is administered by the Content Security and Control Security Services Module (CSC-SSM). Two categories of content are typically scanned: mail and web.

Table 15.1 shows some key default scanning settings within CSC-SSM.

TABLE 15.1 Default scanning settings

Category	Protocol	Function
Mail	SMTP and POP3	Scans all scannable files in an email
Mail	SMTP and POP3	Rejects all messages larger than 15 MB
Mail	SMTP	Rejects messages addressed to more than 100 recipients
Mail	SMTP	Cleans emails or attachments containing malware, and attaches a notification that the malware was deleted
Web	HTTP	Scans all file downloads
Web	HTTP	Scans web mail sites for AOL, MSN, Google, and Yahoo!
Web	FTP	Scans all file transfers
Web	HTTP and FTP	Skips scanning of files larger than 50 MB; can also enable deferred scanning
Web	HTTP and FTP	Cleans files in which malware is detected; deletes files that cannot be cleaned

The defaults give you a pretty good level of protection, but there may be instances where you want to change settings. For example, if you are concerned about bandwidth, then you can limit the size of files transferred via FTP or HTTP. If mail storage is an issue, then you can set the firewall to reject mail larger than 10 MB.

Keep in mind, though, that by changing some settings, you are increasing your security risk. If you offer deferred scanning for large files, it will allow you to begin viewing the data without a prolonged wait while the entire body of information is scanned. However, the unscanned portion of information can introduce a security risk.

NOTE If you are having problems with large file transfers timing out on your network, it's possible that it's partially caused by the firewall scanning the files immediately. Offering deferred scanning can help fix the problem, but you also need to weigh the additional security risk.

Content Filtering

Content filtering is very closely related to scanning services, and on Cisco routers it's also provided by the CSC-SSM. Specifically, *content filtering* means blocking data based on the content of the data rather than the source of the data. Most commonly, this is used to filter email and website access.

The reasons for using content filtering seem pretty obvious. Most companies have a zero-tolerance policy against hateful material or pornography. If a user on a company network uses that network to spread hate mail or porn, the company could be liable for damages in a lawsuit if they didn't take measures to prevent such actions. It's not only a moral issue, it's a legal issue too.

Content filtering is also important in places like schools. It's doubtful that parents want their kids to be able to stumble upon a porn site in the school library while researching a school project. Content filtering can block that site from being accessed so the problem never occurs. You can also find several parental-control software packages for home use that employ content filtering.

There are several ways to filter content; here are some of the more common categories used:

- Attachment (blocking attachments of a certain type, such as EXE files)
- Bayesian
- Content-encoding
- Email headers
- Language
- Phrases
- Proximity of words to each other
- URLs

Nearly all filtering methods use a combination of filters to protect users from improper content.

Signature Identification

Firewalls can also stop attacks and problems through a process called *signature identification*. Viruses that are known will have a signature, which is a particular pattern of data, within them. Firewalls (and antivirus programs) can use signatures to identify a virus and remove it. The same holds true for other software bugs, such as worms and spyware.

Numerous network attacks have signatures as well. For example, if your router starts getting hit by large numbers of SYN requests, you may be at the beginning of a SYN flood attack. The inundation of SYN traffic is a signature of a SYN flood.

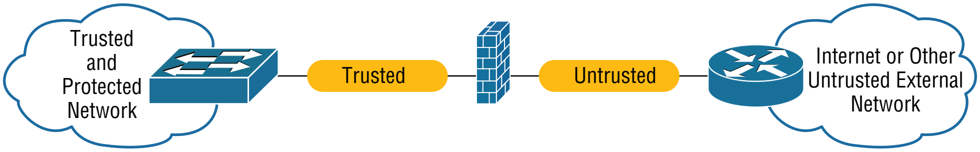
Context Awareness

A firewall that is "context aware" is one that can take into consideration the context in which traffic is arriving at the firewall. It can detect different applications, users, and devices—not just IP addresses. Because of this more sophisticated approach, it lets administrators track how applications are used across a range of devices. For example, it may track and/or prevent the posting or sharing of videos on Facebook using an iPhone, PC, or other device. It also enables companies to enforce policies, like not allowing a specific group of employees to access games on iPads.

Virtual Wire vs. Routed

Firewalls can control communications between segments by controlling traffic between Layer 3 segments (routed approach) or by a process called *virtual wire*. In this approach, the firewall is connected between a trusted and untrusted section of a network, as shown in Figure 15.7. To the devices connected to the firewall (in this figure a switch and router), it appears that only a single "wire" is connected between them.

FIGURE 15.7 Virtual wire


Trusted and Protected Network
Trusted
Untrusted
Internet or Other Untrusted External Network

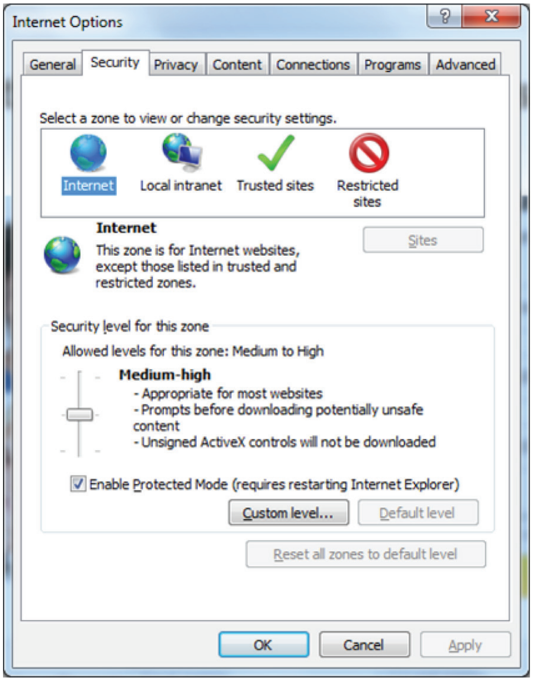
Virtual wire firewall interfaces do not need IP addresses. Security zones are defined on the physical interfaces of the virtual wire pair. Virtual wire does neither routing nor switching; it examines the traffic flow to perform deep packet inspection and enforces the firewall policy.

Zones

A *zone* is an individual area of the network that has been configured with a specific trust level. Firewalls are ideal devices to regulate the flow of traffic between zones. If you look back at Figure 15.3, this provides a good example of how zone levels could work. The Internet would be a zone with no trust or a low level of trust. The DMZ, located between the Internet and the internal network, could have a medium level of trust. The computers on the intranet would all be within a high trust zone. The higher the trust level, the less scrutiny you place on data coming from a computer in that zone.

Another way to look at zones is to understand how Internet Explorer deals with them. Figure 15.8 shows you what the Internet Options Security tab looks like. On this tab, you can see that there are four zones for which you can configure security levels: Internet, Local Intranet, Trusted Sites, and Restricted Sites. There are three default security levels for the Internet: High, Medium-High, and Low. Don't get this confused with the trust levels I talked about in the previous paragraph—they are basically opposites. If the security level is set to High, it means you have low trust.

FIGURE 15.8 Internet Options Security tab



Select a zone to view or change security settings.

Internet

This zone is for Internet websites, except those listed in trusted and restricted zones.

Security level for this zone

Allowed levels for this zone: Medium to High

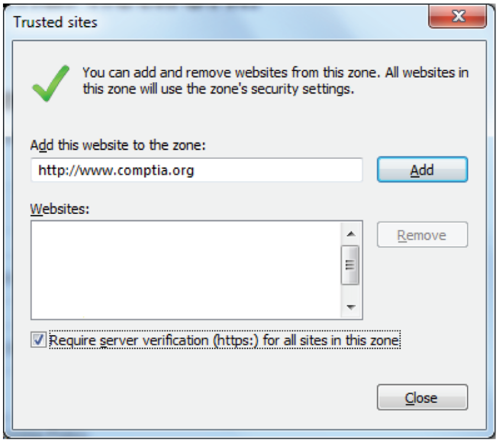
Medium-high

- Appropriate for most websites
- Prompts before downloading potentially unsafe content
- Unsigned ActiveX controls will not be downloaded

☑ Enable Protected Mode (requires restarting Internet Explorer)

A good way to ensure some security through your browser is to set the security level to Medium-High or High and leave it there. If there are sites that you download from frequently and that you trust, then you can put those sites into the Trusted Sites zone. Click Trusted Sites and then click the Sites button to get to the screen shown in Figure 15.9.

FIGURE 15.9 Adding a trusted site



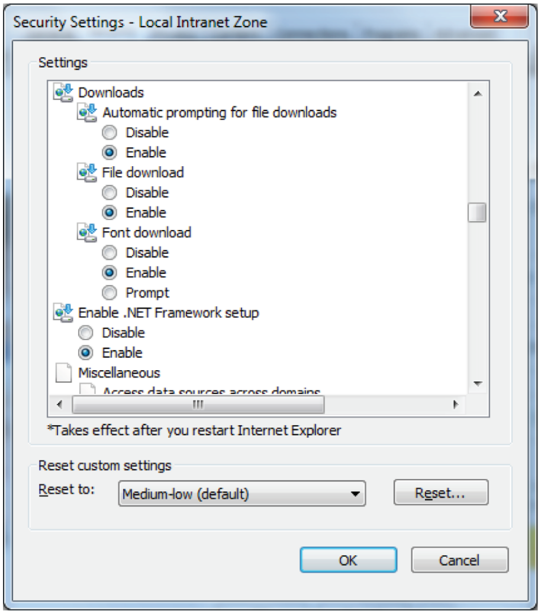
You can add and remove websites from this zone. All websites in this zone will use the zone's security settings.

Add this website to the zone: http://www.comptia.org

☑ Require server verification (https:) for all sites in this zone

Finally, you can customize the security level of any of the zones by clicking the Custom Level button near the bottom of the Internet Options window. This will take you to a screen similar to the one shown in Figure 15.10.

FIGURE 15.10 Custom security settings



- Downloads
  - Automatic prompting for file downloads
    - ○ Disable
    - ● Enable
  - File download
    - ○ Disable
    - ● Enable
  - Font download
    - ○ Disable
    - ● Enable
    - ○ Prompt
- Enable .NET Framework setup
  - ○ Disable
  - ● Enable
- Miscellaneous
  - Access data sources across domains

*Takes effect after you restart Internet Explorer

Reset to: Medium-low (default)

Within the custom settings, you can specify behavior for .NET framework components, ActiveX controls and plug-ins, downloads, scripting, user authentication, and several other options. Most of the options have choices to disable or enable or prompt you if you want to continue with the operation.

NOTE Although Internet Explorer security options can help protect your computer, do not think of them as a replacement for a firewall. The best security systems are multifaceted. You should have a firewall solution in place and then augment that with solid security measures on your local computer as well.

Intrusion Detection and Prevention Systems

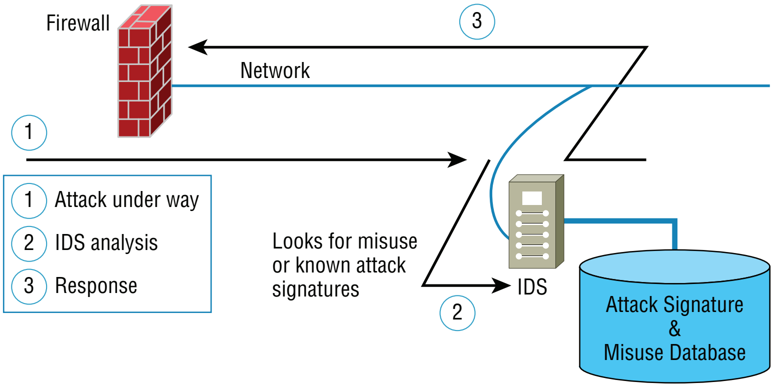
If someone has broken into your network, how would you know? I mean, it's not like you're going to find broken windows or the door left wide open, right? Although it's true that you won't be dusting for prints, bad guys who break into networks still leave clues behind that can help you sleuth out their identities as well as how they gained access. A great tool for doing network detective work is known as an *intrusion detection system (IDS)*.

Firewalls are designed to block nasty traffic from entering your network, but an IDS is more of an auditing tool: It keeps track of all activity on your network so you can see if someone has been trespassing. Because the technology behind IDSs is fairly new, people are busy developing ways to combine IDS technology with existing firewalls.

NOTE An intrusion detection system does *not* replace a firewall on your network!

There are two kinds of IDSs that can detect attacks or intrusions. The first, often referred to as a *misuse-detection IDS (MD-IDS)*, is based on the signature of an intrusion, and it works by looking for fingerprints. That's right—I said fingerprints, which in this case means strange or abusive use of the network. The IDS sends up an alarm only if it recognizes the fingerprints typical of attackers. The second approach looks for anomalies in network activity, or an *anomaly-detection IDS (AD-IDS)*. An AD-IDS basically watches for anything out of the ordinary; if it discovers fingerprints where there shouldn't be any, it will send out an alert. And a really cool feature is that it's known as a *smart system* because it learns on the go by keeping track of and building a history of network activity for norms to which you can compare unusual activity. Most IDSs today are a combination of two types of detection systems. Figure 15.11 shows an MD-IDS in action.

FIGURE 15.11 An MD-IDS system in action



NOTE

An intrusion detection system cannot detect attacks within encrypted traffic.

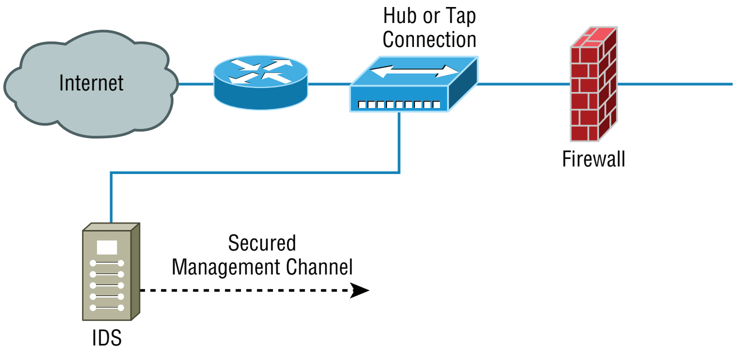
An IDS is a system made up of several components, including one or more sensors to detect events, a console to control and configure the sensors and monitor events, and a database that records the events. These three elements can all be on the same device, or they can be implemented on multiple devices.

The two most common types of IDS implementations are network based and host based.

Network-Based IDS

By far the most common implementation of a detection system is a *network-based IDS (NIDS)*, where the IDS is a separate device attached to the network via a machine like a switch or directly via a tap. Some IDSs are even capable of attaching to the network both outside and inside the firewall; this gives you the best security because you can see what is happening out in the wild and really nail exactly what's getting through your defenses. Figure 15.12 gives you an example of what a typical IDS setup can look like.

FIGURE 15.12 An IDS connected to the network



When your IDS detects an intrusion, it will respond to it either passively or actively. Passive responses are the easiest to configure and include the following:

Logging All activity to the intrusion is logged. The information gathered can be used to foil future attacks of the same type. Intrusions should always be logged.

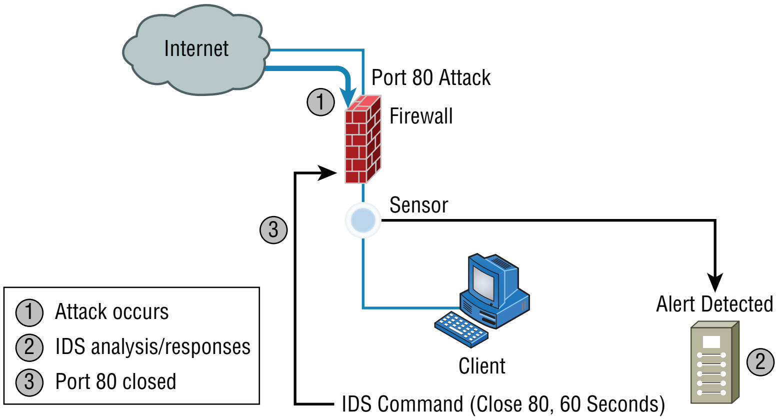
Notification When an attack occurs, an IDS can send an alert to one or more administrators.

Shunning I'm not kidding about this one—you can sometimes just ignore the attack because it's possible it won't affect your network. For instance, if someone launches an attack designed to cripple a Microsoft Exchange email server at a network that's running Lotus Notes, you're all good, so why waste time doing anything about it? I would recommend recording the event, though.

Active responses mean taking immediate action. When an IDS moves to prevent an attack, it's often called a reactive system or an *intrusion protection system (IPS)*. Here are three common active responses:

Changing Network Configuration Let's say an attack comes in on port 21. Your IDS can close the port either temporarily or permanently. The downside is that if the IDS closes ports, legitimate traffic can't get through either, but it will definitely stop the attack. Figure 15.13 shows an example of closing port 80 (HTTP) for 60 seconds.

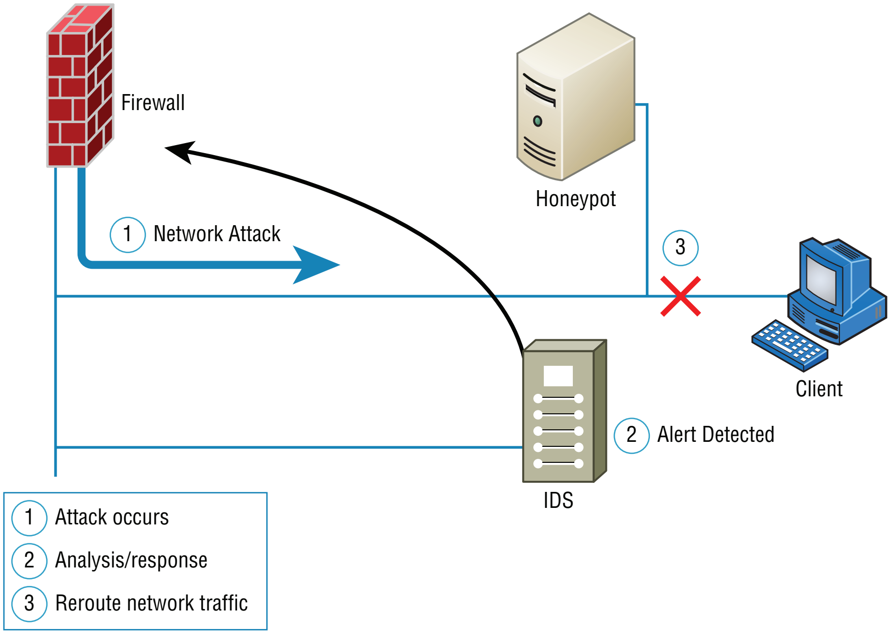
FIGURE 15.13 Shutting down port 80 for 60 seconds to stop an attack



Terminating Sessions When the IDS detects an attack, it can force all sessions to close and restart, which will affect and delay legitimate traffic, too, but not for long.

Deceiving the Attacker This one's the most fun because it tricks the bad guy into thinking their attack is really working when it's not. The system logs information, trying to pinpoint who's behind the attack and which methods they're using. This response requires something called a *honeypot*, typically a server or group of servers (called honeynets) or maybe even access points, to which the hacker is directed; it's intended to keep their interest long enough to gather enough information to identify them and their attack method so you can prevent another attack in the future. Figure 15.14 demonstrates this.

FIGURE 15.14 Deceiving an attacker with a honeypot



NOTE I am not endorsing using honeypots, just explaining the concept and how they work.

Host-Based IDS

In a *host-based IDS (HIDS)*, software runs on one computer to detect abnormalities on that system alone by monitoring applications, system logs, and event logs—not by directly monitoring network traffic.

Systems like these are typically implemented on servers because they're a bear to manage if spread across several client computers on a network. Plus, if the IDS database is on the local computer and its data becomes compromised by an attack, the IDS data could be corrupted too.

NOTE Other types of IDSs are protocol based (PIDS), which monitor traffic for one protocol on one server; application protocol based (APIDS), which monitor traffic for a group of servers running the same application (such as SQL); and hybrid IDS, which combine one or more IDS technologies.

Vulnerability Scanners

One of the most effective ways to determine if security holes exist in the network is to think like an attacker and attack your own network. In that case, why not use the same tools that the hacker might use to identify your weaknesses? For example, if I wanted to verify the proper application of some ACLs to a firewall, I could do so with scanning services supplied by a vulnerability scanner. In the following sections, I'll cover two of the most widely known and effective programs that can be used for this purpose.

Nessus

Nessus is a proprietary vulnerability scanning program that requires a license to use commercially yet is the single most popular scanning program in use. It normally is executed from the command line because it can thus be included in batch files that can automate its operation on a schedule. Its output can be reported in a variety of formats, including plain text, HTML, and XML.

It operates by performing a port scan and then follows up with more specific tests and scans based on the ports open. It can identify a wide array of weaknesses, including the following:

- Unsecured access to sensitive data on a system
- Misconfigurations like open mail relay and missing patches
- Password issues such as the use of default passwords, common passwords, and blank passwords on system accounts

It can also perform an active attack such as denial of service or a dictionary attack.

Nmap

Network Mapper (Nmap) was originally intended to simply identify devices on the network for the purpose of creating a network diagram. Its functionality has evolved, however, and now it can also do the following:

- Perform port scanning
- Identify versions of network services in operation on the network
- Identify operating systems

It can be used from the command line as with Nessus, but it also can be used with web-based interfaces to be controlled remotely.

Unified Threat Management (UTM)

Unified threat management (UTM) devices perform multiple security functions within the same appliance:

- Network firewalling
- Network intrusion prevention
- Gateway antivirus
- Gateway anti-spam

- VPN
- Content filtering
- Load balancing
- Data leak prevention
- On-appliance reporting

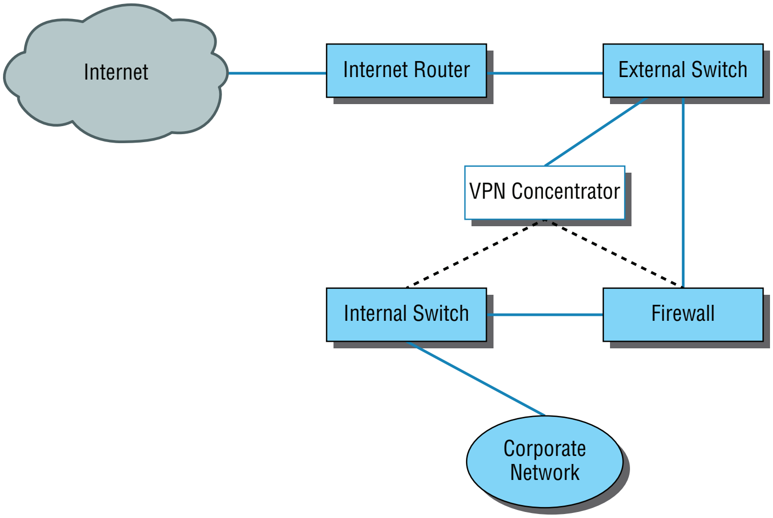
While the advantage of unified security lies in the fact that administering multiple systems is no longer necessary, some feel that a single point of failure is created and creating multiple layers of devices is a more secure approach.

VPN Concentrators

A *VPN concentrator* is a device that creates remote access for virtual private networks (VPNs) either for users logging in remotely or for a large site-to-site VPN. In contrast to standard remote-access connections, remote-access VPNs often allow higher data throughput and provide encryption. Cisco produces VPN concentrators that support anywhere from 100 users up to 10,000 simultaneous remote-access connections.

Encryption for a remote-access VPN through a concentrator is usually handled by Internet Protocol Security (IPSec) or by Secure Sockets Layer (SSL), and user authentication can be achieved via Microsoft's Active Directory; Kerberos; Remote Authentication Dial In User Service (RADIUS); Rivest, Shamir, and Adleman (RSA); and digital certificates. Many VPN concentrators also have a built-in authentication server and allow ACLs to be implemented through them. In Figure 15.15, you can see where VPN concentrators are usually placed within a network setup.

FIGURE 15.15 VPN concentrator in a network



The dotted lines indicate that you can opt to run your remote-access clients through the firewall before they're granted internal access, or you can just let the concentrator handle the security.

Understanding Problems Affecting Device Security

Throughout this whole chapter, I've been going on and on about the myriad devices we use to secure traffic coming into our networks and devices and the things we depend on to detect and prevent attacks on them. It's an important subject and one that you must solidly understand in order to be effective in networking. Knowing how to implement a tight security program requires working knowledge of these devices, but it doesn't end there because there's always more you can know.

There happen to be a few more really significant and valuable concepts you should have a good grasp of when setting up and managing the security on your network. So that's the direction in which we're going to head for the remainder of this chapter—we'll cover key issues you need to be aware of, including physical security and corresponding logical security structures, and restricting access.

Physical Security

Over the years, I've visited lots of different companies, large and small, public and private, and analyzed, advised, troubleshot, designed, and implemented their networks. Without fail, the system administrators I've met along the way have been really eager to tell me all about the security systems they have in place. "Look at this awesome firewall setup!" "Check out the cool Group Policy structure we have!" "Watch how quickly our fault tolerance springs into action!" They're very proud, and rightly so, of what they've worked so hard to set up, because doing that isn't easy.

But interestingly, one of the things few people brag about is physical security—like it's some kind of afterthought. Maybe the server room has a locked door, maybe it doesn't. Maybe the badges that open that door are owned by the right people, or maybe they aren't. I guess that on a subconscious level, we tend to inherently trust the people working within the walls and focus our fears, suspicions, and ammo on mysterious outside forces that we're sure are incessantly trying to break in, steal data, or totally murder our networks. Some of the sharpest, most talented, and savvy system administrators I've ever met still have a tendency to neglect inside security and fail to reasonably monitor things going on within the building.

And there are some seriously vital things to nail down on the inside. For instance, does it really matter if your network has a secured subnet for the servers, with its own dedicated internal firewall? Definitely—I've actually found servers in racks like sitting ducks in a hallway right across from the lunch room. When I pointed out the fact that this was not so good, I was assured that it was only temporary until the server room construction was complete. I don't know about you, but for some reason, that didn't cut it and didn't make me feel anywhere near okay with the situation. At another company, I found the door to the server room propped open because otherwise "it got too hot in there." Because that toasty server room didn't exactly have a guard posted, anyone could just walk in and do whatever; the backup tapes were clearly marked and sitting there on a shelf—yikes! And don't even get me started about the heat. The bottom line is that if your system is not physically secured, you're basically sending out an open invitation to a Pandora's box of problems without even realizing it.

Real World Scenario

Beware the Big Gulp

Several years ago when I was teaching a networking class, one of my best students issued me a challenge. He was proud of the security configuration on his server computer in the classroom and went so far as to tell me there was no way I could get to or damage any files on his system. He was really sure about that. Well, it just so happens I like a good challenge.

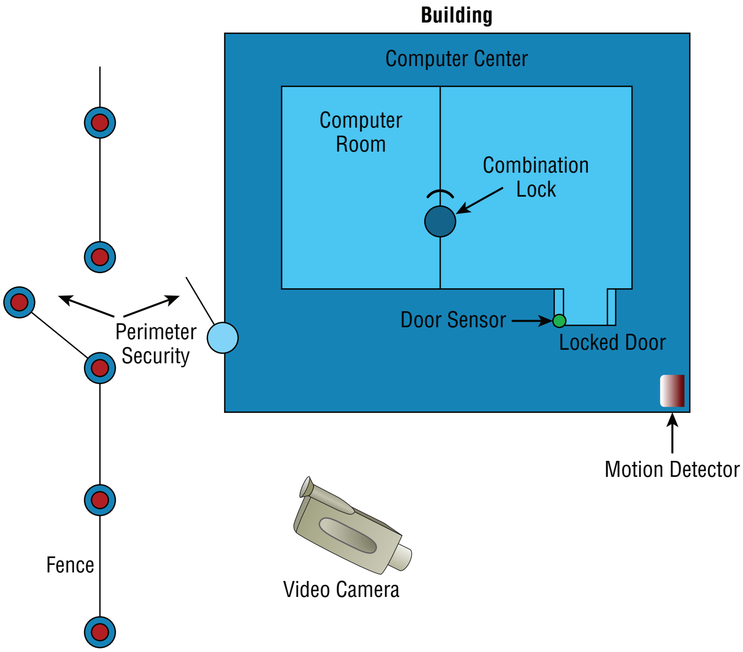
The students went off to lunch, and I stayed behind to work on a few things. While they were gone, I got out my handy Partition Magic diskette (I said this was a while ago) and popped it into his system. One reset button push later, I was in business. I wiped out the partitions on his hard drive and shut down the system.

When he came back from lunch, he looked a bit confused. He clearly remembered leaving his computer on, and upon booting up and playing around for a minute, he realized that his hard drive was gone. At first, he was more than a little angry at me for doing that, but then I asked him to give me a chance to prove a point—an important one. That is, when someone has access to your computer, they can do whatever they want. Yes, they might not be able to read your files (although I could have done that too), but they can still do a lot of damage. My tool of destruction was a partitioning program, but going back to that "servers out in the open across from the lunch room" situation, all it would take is a spilled soft drink to cause mass destruction. In any case, the data clearly was not safe, so physical security needs to be a top priority.

Physical Barriers

Your first objective is to keep people from physically getting to your equipment. Clearly, end users need to be able to get to their workstations, but only authorized personnel should be anywhere near your servers. The best way to do this is to have a dedicated, two-stage, air-conditioned server room with really secure doors and locks. Even better, your data center should have more than one form of physical security—preferably three. We call that a *multiple barrier system*. For instance, you could have a perimeter security system controlling access to the building as your first line of defense. The second would be a secured door to the computer room, and the third would be another security door to the server room itself. This is illustrated in Figure 15.16.

FIGURE 15.16 A three-layer security model



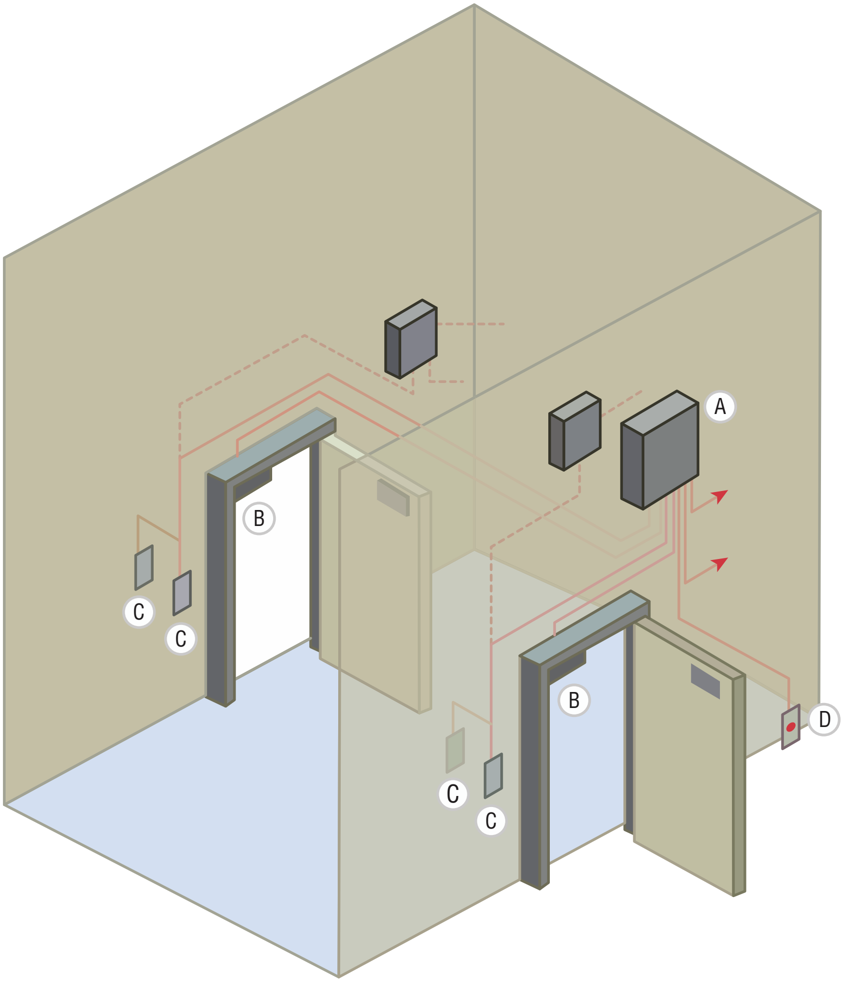
Security Zones

Your network probably has different security zones. Let's say your servers are in one zone and the clients are in another. Maybe your engineering department has its own zone. So why not have the same zones for physical access to the computers? Many companies today use RFID badges to control where employees are allowed to go inside the building. You may need a safety clearance and/or certification before you can go in the room where the pilot production machine lives. People should be cleared and certified before they're allowed in the server room as well.

Mantraps

A mantrap is a series of two doors with a small room between them. The user is authenticated at the first door and then allowed into the room. At that point, additional verification will occur (such as a guard visually identifying the person) and then they are allowed through the second door. These doors are typically used only in very high-security situations. They can help prevent tailgating. A mantrap design is shown in Figure 15.17.

FIGURE 15.17 Mantrap



Network Closets

While much of the network equipment should be locked securely in the server room, there are frequently cases where it is also stored in a smaller location or closets. If that is the case, these locations should be locked as securely as the server room, and access to them should be controlled through mechanisms such as cipher doors or proximity locks.

Video Monitoring

In many high-security scenarios it may be advisable to visually monitor the area 24 hours a day. When this is the case, it will make sense to deploy video monitoring. We'll look at two options, IP cameras and CCTV systems.

IP Cameras IP video systems are a good example of the benefits of networking applications. These systems can be used both for surveillance of the facility and for facilitating collaboration.

CCTVs While an IP camera is a type of digital video camera commonly employed for surveillance, analog closed circuit television (CCTV) cameras are unable to send their images across IP networks. CCTV cameras record directly to a medium such as video tape or hard drive. It is possible to convert the signal to digital in cases where you need to send it across an IP network.

Door Access Controls

While mantraps may justify their cost in some high-security scenarios, not all situations require them. Door controls should be used to prevent physical access to important infrastructure devices such as routers, switches, firewalls, and servers. Door control systems are covered in the following sections.

Proximity Readers/Key Fob

Proximity readers are door controls that read a card from a short distance and are used to control access to sensitive rooms. These devices can also provide a log of all entries and exits. Usually, a card contains the user information required to authenticate and authorize the user to enter the room.

A key fob, on the other hand, is a type of security token: a small hardware device with built-in authentication mechanisms. The mechanisms in the key fob control access to network services and information. An advantage of a key fob is that it can support multifactor authentication.

For example, a user may have a personal identification number (PIN), which authenticates them as a device's owner; after the user correctly enters their PIN, the device displays a number that allows them to log on to the network

Biometrics

Biometric systems are designed to operate using characteristic and behavioral factors. While knowledge factors (password, PIN, or something you know) are the most common authentication factors used, characteristic factors represent something that you are (fingerprint, iris scan), while behavioral factors represent something that you do (signature analysis).

Multifactor authentication is achieved by combining authentication factors. When two factors are combined, such as a retina scan (characteristic factor) and a password (knowledge factor), dual-factor authentication is required. When three factors are combined, such as a retina scan (characteristic factor), a password (knowledge factor), and signature analysis (behavioral factor), then multifactor authentication is in effect.

One of the issues with biometrics is the occurrence of false positives and false negatives. A false positive is when a user that should *not* be allowed access is indeed allowed access. A false negative, on the other hand, is when an authorized individual is denied passage by mistake.

Keypad/Cipher Locks

Cipher locks that use a keypad require a user to know the key code. These devices can also come with additional security features. The lock can be combined with a set time for opening the door as well as a battery standby system. Three types of alarm systems are available. A burglar alarm interface is available to indicate when the door is breached. An error alarm can reveal someone who tries to guess the code. Finally, a hostage alarm can be triggered to indicate that entry was made under duress.

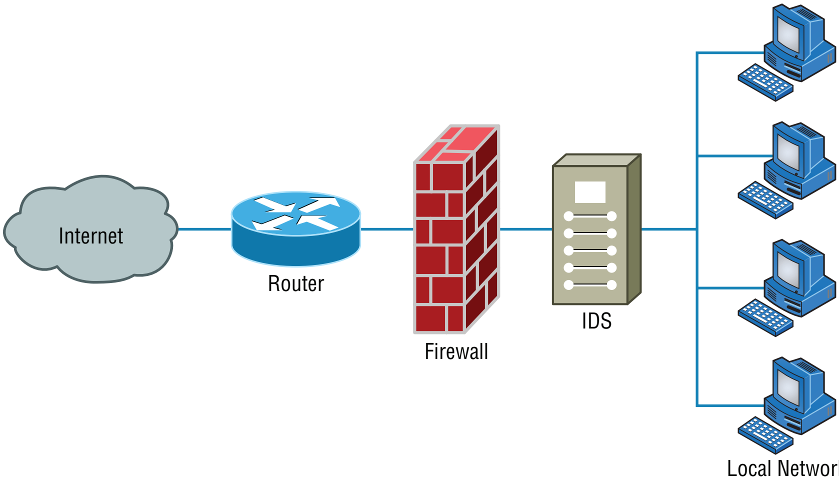
Security Guard

In cases where judgment may be required to control entry, a security guard may be advisable. While the cost is generally higher than with an automated system, there are advantages to this. This offers the most flexibility in reacting to whatever occurs. One of the keys to success when using guards is to ensure that they are trained with a response to every conceivable eventuality. Finally, the biggest advantage is that guards can use discriminating judgment in a situation, which an automated system cannot.

Logical Security Configurations

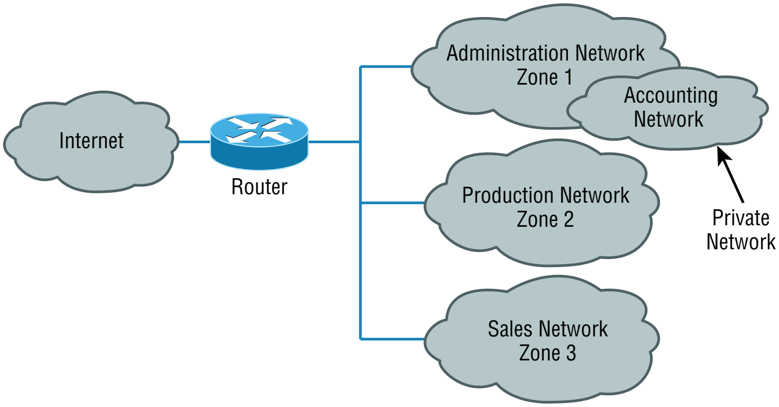
Now that you have your physical network locked down tight, it's time to review the security configuration of your network. The same concepts that apply to physical security apply here, too. First, you want to ensure that your network has an outside barrier and/or a perimeter defense. This is usually achieved by having a solid firewall, and it's best to have an IDS or IPS of some sort as well. Figure 15.18 shows what this might look like.

FIGURE 15.18 Network perimeter defense



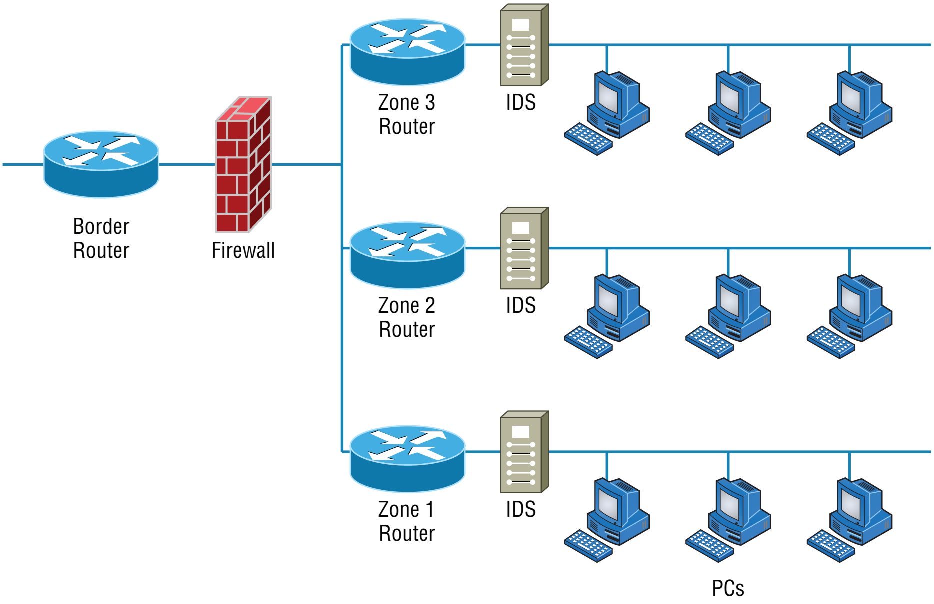
That may be enough for your network, but maybe not. Let's say that your network serves several distinct departments at your company. The admin, production, and sales groups all have their own unique needs. What you can now do is divide up your internal network into smaller administrative zones by creating VLANs and using a DMZ. Maybe your network would logically look like the one shown in Figure 15.19.

FIGURE 15.19 Network divided into security zones



Finally, your network might be similar to the one shown in Figure 15.19 but just larger. Maybe traffic is heavy and you need to break up physical segments. Perhaps different groups are in different buildings or on different floors of a building and you want to effectively segment them. There could be any number of reasons for you to "physically" separate your network into different groups, effectively partitioning your network by using multiple routers, as shown in Figure 15.20.

FIGURE 15.20 Using routers to divide a network into security zones



Risk-Related Concepts

All organizations should identify and analyze the risks they face. This is called risk management. In the following sections, you'll find a survey of topics that all relate in some way to identifying risks and mitigating them.

Power Management

Power is the lifeblood of the enterprise and continued access to it is essential. In this section well look at a few mitigations or countermeasures.

Redundant circuits

Data centers usually deploy redundant power sources to maintain constant power. Redundancy can be provided in several ways.

- Parallel redundancy or the N+1 option describes an architecture where there is always a single extra UPS available (that's the +1) and the N simply indicates the total number of UPSs required for the data center. As the system runs in two feeds and there is only one redundant UPSs, this system can still suffer failures.
- 2N redundancy means the data center provides double the power required by the data center. This ensures that the system is fully redundant.

Dual power supplies

Redundancy also refers to using redundant power supplies on the devices. Many servers come with two supplies and you can also buy additional power supplies as well. Always ensure that the power supply you buy can supply all the needs of the server.

Disaster Recovery

A disaster is an emergency that goes beyond the normal response of resources. The causes of disasters are categorized into three main areas according to origin:

- Technological disasters (device failures)
- Manmade disasters (arson, terrorism, sabotage)
- Natural disasters (hurricanes, floods, earthquakes)

The severity of financial and reputational damage to an organization is largely determined by the amount of time it takes the organization to recover from the disaster. A properly designed disaster recovery plan (DRP) minimizes the effect of a disaster. The DRP is implemented when the emergency occurs and includes the steps to restore functions and systems so the organization can resume normal operations. The goal of a DRP is to minimize or prevent property damage and prevent loss of life.

Business Continuity

One of the parts of a DRP is a plan to keep the business operational while the organization recovers from the disaster, known as a business continuity plan (BCP). Continuity planning deals with identifying the impact of any disaster and ensuring that a viable recovery plan for each function and system is implemented. By prioritizing each process and its supporting technologies, the company can ensure that mission-critical systems are recovered first and systems that are considered luxuries can be recovered as time allows.

One document that should be created to drive this prioritization is the business impact analysis. In this document, the impact each system has on the ability of the organization to stay operational is determined. The results list the critical and necessary business functions, their resource dependencies, and their level of criticality to the overall organization.

Recovery Sites

Although a secondary site that is identical in every way to the main site with data kept synchronized up to the minute would be ideal, the cost cannot be justified for most organizations. Cost-benefit analysis must be applied to every business issue, even disaster recovery. Thankfully, not all secondary sites are created equally. They can vary in functionality and cost. We're going to explore three types of sites.

Cold Sites

A cold site is a leased facility that contains only electrical and communications wiring, air conditioning, plumbing, and raised flooring. No communications equipment, networking hardware, or computers are installed at a cold site until it is necessary to bring the site to full operation. For this reason, a cold site takes much longer to restore than a hot or warm site.

A cold site provides the slowest recovery, but it is the least expensive to maintain. It is also the most difficult to test.

Warm Sites

A warm site is somewhere between the restoration time and cost of a hot site and a cold site. It is the most widely implemented alternate leased location. Although it is easier to test a warm site than a cold site, a warm site requires much more effort for testing than a hot site.

A warm site is a leased facility that contains electrical and communications wiring, full utilities, and networking equipment. In most cases, the only thing that needs to be restored is the software and the data. A warm site takes longer to restore than a hot site but less than a cold site.

Hot Sites

A hot site is a leased facility that contains all the resources needed for full operation. This environment includes computers, raised flooring, full utilities, electrical and communications wiring, networking equipment, and uninterruptible power supplies (UPSs). The only resource that must be restored at a hot site is the organization's data, usually only partially. It should only take a few minutes to bring a hot site to full operation.

Although a hot site provides the quickest recovery, it is the most expensive to maintain. In addition, it can be administratively hard to manage if the organization requires proprietary hardware or software. A hot site requires the same security controls as the primary facility and full redundancy, including hardware, software, and communication wiring.

Snapshots

Using special backup utilities, you can also perform what are called *snapshot backups*. These are lists of pointers or references to the data and are somewhat like a detailed table of contents about the data at a specific point in time. They can speed the data recovery process when it is needed. There are two types of snapshots: copy-on-write and split mirror.

Keep in mind that snapshots are *not* a replacement for regular backups. In many cases the snapshot is stored on the same volume as the data so if the drive goes bad you will also lose the snapshot.

Copy-on-Write

This type of snapshot is taken every time a user enters data or changes data, and it only incudes the changed data. It allows for rapid recovery from a loss of data, but it requires you to have access to all previous snapshots during recovery. As changes are made, multiple copies of snapshots will be created. Some will contain changes not present in others. There will also some data that remains unchanged in all of them.

Split Mirror

This type of snapshot also is created every time a change is made, but it is a snapshot of everything rather than just the changes. However, as you can imagine it takes significant storage space and the restore process will be slower.

SLA requirements

SLAs are agreements about the ability of the support system to respond to problems within a certain time frame while providing an agreed level of service. These agreements can be internal between departments or external, with a service provider. Agreeing on the quickness with which various problems are addressed introduces some predictability to the response to problems; this ultimately supports the maintenance of access to resources.

MTTR

One of the metrics that used in planning both SLAs and IT operations in general is Mean time to repair (MTTR). This value describes the average length of time it takes a vendor to repair a device or component. By building these into SLAs IT can assure that the time taken to repair a component or device will not be a factor that causes them to violate the SLAs requirements. Sometimes MTTR is considered to be from the point at which the failure is first discovered until the point at which the equipment returns to operation. In other cases it is a measure of the elapsed time between the point where repairs actually begin until the point at which the equipment returns to operation. It is important that there is a clear understanding by all parties with regard to when the clock starts and ends when calculating MTTR.

MTBF

Another valuable metric typically provided is the mean time to repair (MTTR), which describes the average amount of time it will take to get the device fixed and back online.

Battery Backups/UPS

One risk that all organizations should prepare for is the loss of power. All infrastructure systems should be connected to uninterruptible power supplies (UPSs). These devices can immediately supply power from a battery backup when a loss of power is detected. You should keep in mind, however, that these devices are not designed as a long-term solution. They are designed to provide power long enough for you to either shut the system down gracefully or turn on a power generator. In scenarios where long-term backup power is called for, a gas-powered generator should be installed.

First Responders

A first responder is the first person to discover a data breach or other security incident. First responders are covered in the section "Basic Forensic Concepts" in Chapter 14.

Data Breach

A data breach is a risk that the organization should always be prepared to address. Procedures for responding to data breaches and other security incidents are covered in the section "Basic Forensic Concepts" in Chapter 14.

End User Awareness and Training

One of the issues related to the risk involved in security incidents and disasters over which the company has some control is the amount of preparation spent on training users. Regardless of whether the incident is as small as the mistaken deletion of a key document or as large as a fire destroying the entire building, users should be trained in how to respond to every eventuality.

Moreover, it would be even better if recovery teams were created to address the stages of disaster recovery. The following teams should be assembled and trained before a disaster occurs:

- Damage assessment team
- Legal team
- Media relations team
- Recovery team
- Relocation team
- Restoration team
- Salvage team
- Security team

Each team should rehearse its response to various scenarios. One exercise that seems to work well is called a tabletop exercise. A tabletop exercise is an informal brainstorming session that encourages participation from business leaders and other key employees. In a tabletop exercise, the participants agree to a particular disaster scenario upon which they will focus.

Single Point of Failure

One concept that makes any IT technician nervous is the existence of a single point of failure anywhere in the network. During the process of creating the BCP, all single points of failure should be identified. The process begins as described in the following sections, with the identification of critical assets and nodes, which is followed by providing redundancy where indicated.

Critical Nodes

Critical nodes are individual systems or groups of systems without which the organization cannot operate. The process of identifying these systems should begin with prioritization of the business processes that each supports. Once this has been done, it is simple to identify the servers and other systems that are required to allow that process to continue to function. If this investigation reveals a system that is critical and a single point of failure, action should be taken to provide some form of redundancy to the node.

Critical Asset

While critical nodes need to be identified and provided with additional support to prepare for disasters and smaller issues, some critical business processes depend on access to assets such as data that may reside in a database or in connections to vendors and partners. These assets also need to be identified and an action plan developed that recognizes their importance. In almost all cases, the solution is some form of redundancy, as covered in the next section.

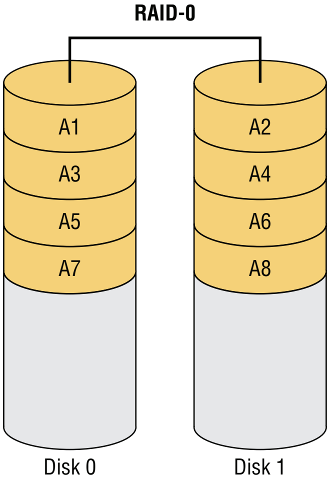
Redundancy

Redundancy occurs when an organization has a secondary component, system, or device that takes over when the primary unit fails. Redundancy can be implemented in many forms. The organization should assess any systems that have been identified as critical to determine if it is cost effective to implement redundant systems. Redundant systems include redundant servers, redundant routers, redundant internal hardware, and even redundant backbones.

One form of fault tolerance that can be provided to a system is Redundant Array of Independent Disks (RAID). This technology allows for automatic recovery from a hard drive failure (within certain limits based on the exact form of RAID) in a system. The major forms of RAID are as follows:

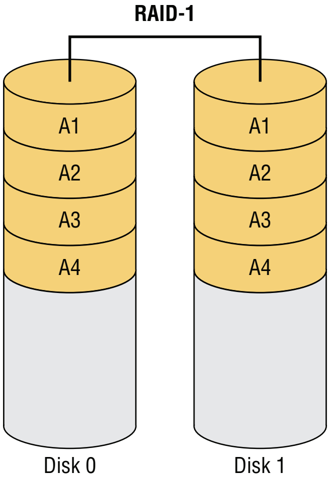
RAID-0 Also called disk striping, this method writes the data across multiple drives. While it improves performance, it does not provide fault tolerance. RAID-0 is depicted in Figure 15.21.

FIGURE 15.21 RAID-0



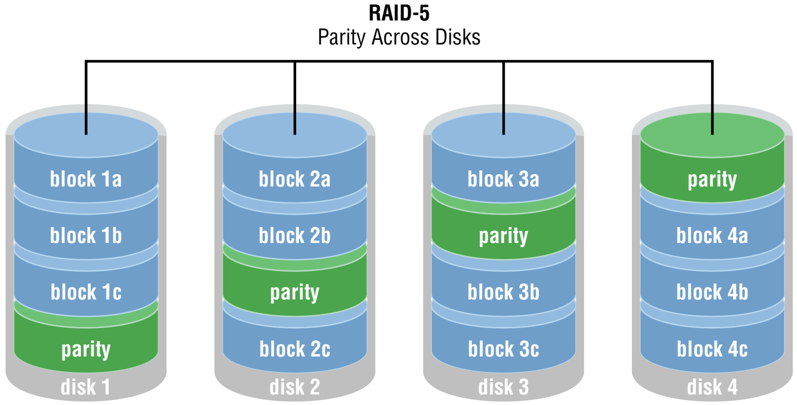
RAID-1 Also called disk mirroring, RAID-1 uses two disks and writes a copy of the data to both disks, providing fault tolerance in the case of a single drive failure. RAID-1 is depicted in Figure 15.22.

FIGURE 15.22 RAID-1



RAID-5 Requiring at least three drives, this method writes the data across all drives like striping, and then parity information is also written across all drives. With hardware RAID-5, the spare drives that replace the failed drives are usually hot swappable, meaning they can be replaced on the server while it is running. RAID-5 is depicted in Figure 15.23.

FIGURE 15.23 RAID-5



Adherence to Standards and Policies

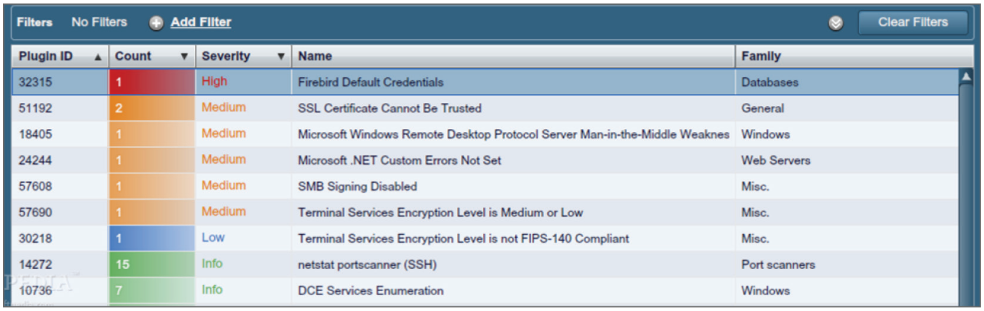
Policies and standards are created to communicate to employees the behavior expected from them in various situations. This includes policies related to business continuity and disaster recovery. Security policies and procedures are covered in detail in Chapter 14.

Vulnerability Scanning

Part of the security policy of an organization should address the type and frequency of vulnerability scans. These scans are designed to identify any security vulnerabilities that exist.

A vulnerability scanner can probe for a variety of security weaknesses, including misconfigurations, out-of-date software, missing patches, and open ports. One of the most widely used is Nessus, a proprietary vulnerability scanner developed by Tenable Network Security. A partial screen shot is shown in Figure 15.24. In the output, the issues found on a host are rated, and issues with the highest severity are at the top by default.

FIGURE 15.24 Nessus



Plugin ID ▲	Count ▼	Severity ▼	Name	Family
32315	1	High	Firebird Default Credentials	Databases
51192	2	Medium	SSL Certificate Cannot Be Trusted	General
18405	1	Medium	Microsoft Windows Remote Desktop Protocol Server Man-in-the-Middle Weaknes	Windows
24244	1	Medium	Microsoft .NET Custom Errors Not Set	Web Servers
57608	1	Medium	SMB Signing Disabled	Misc.
57690	1	Medium	Terminal Services Encryption Level is Medium or Low	Misc.
30218	1	Low	Terminal Services Encryption Level is not FIPS-140 Compliant	Misc.
14272	15	Info	netstat portscanner (SSH)	Port scanners
10736	7	Info	DCE Services Enumeration	Windows

Penetration Testing

A penetration test is designed to simulate an attack on a system, network, or application. Its value lies in its potential to discover security holes that may have gone unnoticed. It differs from vulnerability testing in that it attempts to exploit vulnerabilities rather than simply identify them.

Strategies for penetration testing are based on the testing objectives as defined by the organization:

Blind Test The testing team is provided with limited knowledge of the network systems and devices, using publicly available information. The organization's security team knows that an attack is coming. This test requires more effort by the testing team.

Double-Blind Test This test is like a blind test except the organization's security team does *not* know that an attack is coming. This test usually requires equal effort for both the testing team and the organization's security team.

Target Test Both the testing team and the organization's security team are given maximum information about the network and the type of test that will occur. This is the easiest test to complete, but it will not provide a full picture of the organization's security.

Summary

In this chapter, you learned a lot about physical and hardware security. We dove into this increasingly important subject by looking at one of the most useful network protection devices around: firewalls. You found out the differences between network-based and host-based firewalls and then learned the specific ways that firewalls work to protect our data and networks by using access control lists (ACLs). You also learned about other key firewall topics, like demilitarized zones (DMZs), protocol switching, packet filtering, and proxy services. I talked about how firewalls can operate at the Network layer or the Application layer of the OSI model. For those operating at the Network level, there are stateful firewalls that keep track of the established connections passing through them and stateless firewalls that don't. Firewalls also provide services like scanning, signature identification, content filtering, and breaking your network up into security zones.

We then moved on and discussed two other vital hardware devices: intrusion detection and prevention systems and VPN concentrators. You learned that IDS and IPS devices can be network or host based, just like firewalls, but unlike firewalls, which block traffic based on specific rules, IDS and IPS devices allow traffic in and then initiate a reaction if any problems are detected. (An IPS is an IDS that can generate an active response when an intrusion is detected.) We then covered VPN concentrators, which are specifically designed to allow several hundred—even several thousand—users to remotely access your network either through a secure connection or by setting up a virtual secure network between two locations.

Finally, you discovered some often-overlooked aspects of physical security that can seriously affect your network. You now know that beyond a doubt, if people can get to your hardware, they can do damage to your infrastructure, intentionally or not.

Exam Essentials

Understand and utilize network segmentation. This includes segmentation at Layers 2 and 3 and the proper location of devices such as IPS, IDS, honeypots, and honeynets.

Understand the difference between a network-based firewall and a host-based firewall. A network-based firewall is a hardware device on the network or on a router that protects a group of computers. A host-based firewall is software installed on one individual machine, and it protects only that machine.

Compare and contrast risk-related concepts. Understand how to identify and prioritize key systems and business functions. Create standards and policies to ensure the continued operation of these functions to support business continuity and disaster recovery.

Understand how a firewall determines which traffic can pass through it. Firewalls use access control lists (ACLs), which are sets of rules, to determine which traffic is allowed to pass through.

Describe and apply proper physical security controls. This includes door access controls, biometric systems, and the use of cameras and security guards.

Remember where a DMZ can be placed. A demilitarized zone (DMZ) can be located outside a firewall, connected directly to the Internet. However, it can also be placed after the firewall inside your network. You need to remember that it can be placed in either location.

Understand what a proxy server is and what types of proxying are common. A proxy server is a computer that makes and fulfills requests on behalf of another computer. Many firewalls can act as proxies. Common proxy services include IP proxy, web proxy, FTP proxy, and mail (SMTP) proxy.

Know on which levels of the OSI model various security devices operate. Firewalls work at the Application layer or the Network layer. Port security on switches operates at the Data Link layer.

Understand the difference between stateful and stateless firewalls. A stateful firewall keeps track of the established connections passing through it. When another packet is received that's part of an existing connection (part of a current state), the packet is passed without checking the ACLs. A stateless firewall examines each packet individually and does not track existing states. This makes it a bit slower and more susceptible to network attacks.

Know what types of services firewalls can provide. Most firewalls provide scanning services, content filtering, signature identification, and the ability to segregate network segments into separate security zones.

Know the difference between an IDS and an IPS. An intrusion detection system (IDS) monitors network traffic, looking for signs of an intrusion. Intrusions are detected by matching activity versus known signatures within the IDS's database. If an intrusion is detected, a passive response such as logging or notifying a network administrator is executed. An intrusion prevention system (IPS) is like an IDS, but with two key differences. First, it learns what is "normal" on the network and can react to abnormalities even if they're not part of the signature database. Second, it can issue an active response such as shutting down a port, resetting connections, or attempting to lull the attacker into a trap.

Written Lab

In this section, write the answers to the following security questions. You can find the answers in Appendix A.

1. Which type of firewall interface does not use IP addresses?
2. Which type of firewall keeps track of existing connections passing through it?
3. If you wanted to ensure that your firewall could block inflammatory email, which type of service would you look for?
4. The main security issue with UTM devices is that they constitute a __________ .
5. If you wanted to allow remote access to 500 users, which type of device is recommended?
6. If data from one of your subnets should be restricted from entering another subnet, the subnets should be configured as different __________ .
7. A series of two doors with a small room between them is called a __________ .
8. How does an ACL treat any traffic type by default?
9. What is a group of servers used to lure attackers called?
10. Logging, notification, and shunning are what types of reactions from what type of security device?

Review Questions

You can find the answers to the review questions in Appendix B.

1. In general, firewalls work by ___________ .
   - A. Rejecting all packets regardless of security restrictions
   - B. Forwarding all packets regardless of security restrictions
   - C. Allowing only packets that pass security restrictions to be forwarded
   - D. None of the above
2. Which of the following devices can read an entry card from a distance?
   - A. Biometric reader
   - B. Proximity reader
   - C. Mantrap
   - D. Key fob
3. What is the main difference between a network-based firewall and a host-based firewall?
   - A. A network-based firewall protects the Internet from attacks.
   - B. A network-based firewall protects a network, not just a single host.
   - C. A network-based firewall protects the network wires.
   - D. A network-based firewall protects a CD from data loss.
4. Which of the following minimizes the effect of a disaster and includes the steps necessary to resume normal operation?
   - A. SLA
   - B. BIA
   - C. DRP
   - D. ARP
5. Which of the following items cannot be identified by the Nessus program?
   - A. Default password use
   - B. Incorrect IP addresses
   - C. Unsecured data
   - D. Missing security patches
6. What is the benefit of using a firewall?
   - A. Protects external users
   - B. Protects external hardware
   - C. Protects LAN resources
   - D. Protects hardware from failure

7. IDSs can identify attackers by their ___________ .
   - A. Port number
   - B. Signature
   - C. Timing
   - D. IV

8. Which of the following is also called disk striping?
   - A. RAID-0
   - B. RAID-1
   - C. RAID-3
   - D. RAID-5

9. Which is not a type of access control list (ACL)?
   - A. Standard
   - B. Extended
   - C. Referred
   - D. Outbound

10. What is it called when the firewall ignores an attack?
    - A. Logging
    - B. Shunning
    - C. Notification
    - D. False negative

11. What is the function of a DMZ?
    - A. To separate a security zone for an IPS and IDS server
    - B. To create a security zone for VPN terminations
    - C. To create a security zone that allows public traffic but is isolated from the private inside network
    - D. To create a security zone that allows private traffic but is isolated from the public network

12. Which of the following are types of services that firewalls can provide?
    - A. Content filtering
    - B. Segregation of network segments
    - C. Signature identification
    - D. Scanning services
    - E. All of the above

13. In which type of test is the testing team provided with limited knowledge of the network systems and devices, using publicly available information, while the security team knows the test is coming?
    - **A.** Blind test
    - **B.** Double-blind test
    - **C.** Target test
    - **D.** Open test

14. Which of the following is a vulnerability scanner?
    - **A.** Network Monitor
    - **B.** Nessus
    - **C.** Traceroute
    - **D.** Tripwire

15. Which of the following is *not* a function of Nmap?
    - **A.** Perform port scanning
    - **B.** Identify operating systems
    - **C.** Collect passwords
    - **D.** Identify versions of network services in operation on the network

16. Changing network configurations, terminating sessions, and deceiving the attacker are actions that can be taken from what type of security device?
    - **A.** Access control list (ACL)
    - **B.** Content filter
    - **C.** Security zones
    - **D.** Intrusion prevention system (IPS)

17. ___________ act on behalf of the whole network to completely separate packets from internal hosts and external hosts.
    - **A.** Honeypots
    - **B.** IDSs
    - **C.** IPSs
    - **D.** Proxies

18. Which of the following cannot be identified by Nessus?
    - **A.** Unsecured access to sensitive data on a system
    - **B.** IP address conflicts
    - **C.** Misconfigurations like open mail relay
    - **D.** Password issues

19. A ___________ firewall keeps track of the established connections passing through it.

A. Hardware

B. Software

C. Stateful

D. Network

20. A(n) ___________ learns what is "normal" on the network and can react to abnormalities even if they're not part of the signature database.

A. IDS

B. Firewall

C. IPS

D. VPN concentrator

Chapter 16

Wide Area Networks

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching.**

- Explain the concepts and characteristics of routing and switching.

✓ **1.5 Compare and contrast the characteristics of network topologies, types and technologies**

- Types
  - LAN
  - MAN
  - WAN

✓ **2.5 Compare and contrast WAN technologies**

- Service type
  - ISDN
  - T1/T3
  - E1/E3
  - OC-3 – OC-192
  - DSL
  - Metropolitan Ethernet
  - Cable broadband
  - Dial-up
  - PRI
- Transmission mediums
  - Satellite
  - Copper
  - Fiber
  - Wireless

- Characteristics of service
  - MPLS
  - ATM
  - Frame relay
  - PPP
  - DMVPN
  - SIP trunk
- Termination
  - Demarcation point
  - CSU/DSU
  - Smart jack

✓ **3.3 Explain common scanning, monitoring, and patching processes and summarize their expected outputs**

- Metrics
- Error rate
- Utilization
- Packet drops
- Bandwidth/throughput

We have wide area networks (WANs) and local area networks (LANs), but what's really the key difference between the two? Clearly there's the distance factor, but these days, wireless LANs can cover respectable turf. Is it a bandwidth thing? Not so much—some seriously big pipes can be had for a price in many places, so what is it that actually sets the two apart?

One of the main ways a WAN differs from a LAN is that you usually own your LAN infrastructure, whereas WAN infrastructure is typically leased from a service provider instead. To be honest, modern technologies actually blur this definition a bit, but it still fits neatly into the context of CompTIA's Network+ exam objectives. Anyway, I've already talked about the data link that you usually own (Ethernet), so it's time to explore the kind you usually don't own—the type most often leased from a service provider.

You've probably heard of T-series connections, which are leased line connections that reserve or dedicate lines to provide paths between network segments. In addition to these, we'll survey broadband services, including the array of Digital Subscriber Line (DSL) and cable modem connectivity that most of us use to connect to the Internet from home. We'll even check out a more modern home-based option known as a passive optical network, which essentially means running fiber to a specific site.

Cellular technologies have evolved over the years, and more and more people are opting to use them for connecting to the Internet. For this reason, we'll talk about HSPA+, WiMAX, and LTE and discuss the evolution of 1G, 2G, 3G, and 4G.

We'll also spend some time looking into the different kinds of WAN connectivity achieved through other kinds of links and over different transmission media. WAN technologies run the gamut from short-range *Bluetooth* to the serious, long-distance coverage available via satellite transmissions. I'll also focus on key WAN protocols, which are basically sets of rules that establish exactly how long-distance communication and connectivity should occur. We'll even review some not-so-modern technologies like *Integrated Services Digital Network (ISDN)*, *Frame Relay*, and *Asynchronous Transfer Mode (ATM)* and talk about the legacy phone-company network and some of its terminology too. I'll guide you through everything you'll need to know about different speed links—including T1s and E1s, SONET fiber links, and the plain old telephone service (POTS) lines that connect us to the Public Switched Telephone Network (PSTN). With all of these subjects nailed down, you'll be well equipped with the knowledge you'll need to confidently meet the CompTIA Network+ objectives!

NOTE

To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

What's a WAN?

As local area networks grew and developed, it became increasingly necessary to be able to connect their resources together over long distances. We initially met these challenges via the phone company network—the Public Switched Telephone Network (PSTN)—and the first successful network able to establish voice communications over disparate locations was born.

Few of us remember back to a world without phone service, which made PSTN an obvious solution. It was already a fully operational, circuit-switching network, enabling every phone call to establish a unique circuit from one endpoint (phone) to another through a path of switches. So, instead of reinventing the wheel to design LANs, early network planners used packet switching as their communications-delivery method. As you can imagine, wiring these packet-switched networks to enable communication over vast locales wasn't exactly something we could get done quickly, so even wide area networks (WANs) used the existing phone company network back in the day! But all solutions aren't created equally, and this one just wasn't so great due to its hefty price tag and because it imposed some ugly data transfer limitations on the very networks it served.

So that's the history for you, but know that it's not a thing of the past—yet. Today's WANs are communication networks that cover broad geographic areas, and they still frequently use phone companies (service providers) in concert with their circuit-switched networks to connect LANs together. Competition can be a great motivator, and with the Internet entering the scene, giving us an alternative way to connect LANs, we benefit tremendously from the resulting reduction in the cost of our connectivity. These new connection options, along with their related protocols and technologies, can greatly reduce the cost of a WAN's infrastructure, and lowered transport costs are a huge relief for network administrators and designers alike!

An important fact to lock into memory is that WAN protocols and technologies all occupy at least two of the OSI model's lower three layers—the Physical layer, the Data Link layer, and sometimes the Network layer as well. Coming up, we'll examine the various types of connections, technologies, topologies, and devices used with WANs as well as how to create WAN connections using different transmission media such as air (wireless), space (satellite), and both copper and glass fiber for wired connections. But before we go there, you'll need to know some basic WAN terms.

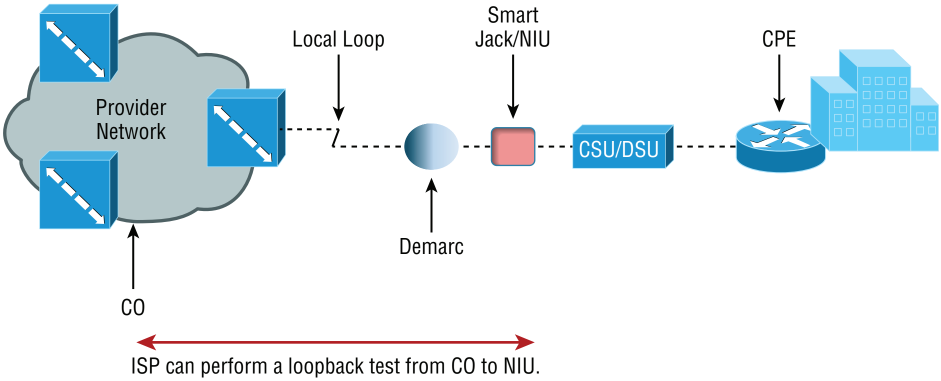
Defining WAN Terms

Before you run out and order a WAN service type from a provider, you really need to understand the following terms that service providers typically use:

Customer Premises Equipment (CPE) *Customer premises equipment (CPE)* is equipment that's owned by the service provider but located on the subscriber's (your) property.

CSU/DSU *Channel service unit/data service unit (CSU/DSU)* is a Layer 1 device that connects the serial ports on your router to the provider's network and connects directly to the *demarcation point* (demarc) or location. These devices can be external, as shown in Figure 16.1, or they can be internal cards on the router. The CSU/DSU provides clocking of the line to the CPE—in this case, your router—and provides other important options, like voltage regulation.

FIGURE 16.1 A typical wide area network



Smart Jack/NIU As you can see, there's a smart jack, or network interface unit (NIU), installed between the demarcation location and the CSU/DSU at the customer premises equipment (CPE) location. But why is it there and what does it do? For starters, a smart jack can provide signal conversion by converting codes and protocols (e.g., framing types) into something the customer equipment requires. Plus, the NIU can buffer and/or regenerate the signal to compensate for signal degradation from line transmission. This is very similar to what a repeater does.

But there's more. Smart jacks also typically provide diagnostic capabilities to the ISP, something a demarcation location just can't. A very common and vital capability gained via a smart jack is the ability to perform a loopback test, where the signal from the provider is transmitted back to the provider's location. Doing this allows the ISP to test the line from the central office, without the need to have test equipment or a technician at the customer site. Of course, this loopback test will bring down the line, but then again, they wouldn't need to perform the test if you didn't call in a problem in the first place!

Demarcation Point Just so you're clear, a demarc is the precise spot where the service provider's or local exchange carrier's responsibility ends and the CPE begins. It's generally a device in a telecommunications closet owned and installed by the telecommunications company (telco). It's your responsibility to cable—a task called *extended demarc*—from this box to the CPE, which is usually a connection to a CSU/DSU or ISDN interface.

Copper Line Drivers/Repeaters A copper line driver or repeater allows for a demarc extension length of up to 5,000 feet from the telephone company's demarc. These can be used to connect equipment across a campus, between floors of a high-rise office building, even between office buildings with underground cable connections.

Local Loop A cable consisting of a pair of copper wires called the *local loop* connects the demarc to the closest switching office, known as a *central office (CO)*.

Central Office (CO) A phone company building that connects the customer's network to the provider's switching network. It's also good to know that a CO is sometimes referred to as a *point of presence (POP)*.

Toll Network The *toll network* is a trunk line inside a WAN provider's network. This network is a collection of switches and facilities owned by the ISP.

With all this said, let's take another look at Figure 16.1, which uses all these items to describe a typical WAN connection.

You would find the typical WAN (as shown in Figure 16.1) when you order a T1 or Frame Relay circuit. Definitely familiarize yourself with these terms because they're crucial to understanding WAN technologies.

The Public Switched Telephone Network

As I mentioned a bit earlier, the portion of the PSTN that runs from your house to the rest of the world is known as *plain old telephone service (POTS)*, and it's a popular method for connecting remote users to a local network due to simplicity, low cost, and easy installation. Connecting to PSTN via ISDN, DSL, a cable modem, or even your cellular service is becoming increasingly popular.

Two key concepts to keep in mind about PSTN are public and switched. *Public* basically means that, for a fee, anyone can lease the use of the network without being required to run any cabling. *Switched* explains how the phone system works. Even though one or more wires are actually connected to your home and/or office, all of them aren't always online or being used. Any dormant wires are still available to you in their offline state so you can get online and join the network whenever you want. Think of it as like a standing reservation and your phone number is used as an ID to access it. Because you initiate the connection by dialing a certain phone number, it's easy to imagine how technically impractical, if not impossible, it would be for this method to work if every phone number stayed connected all the time. If connections stayed active 24/7, the resulting backbone cabling requirements and problems would be insurmountable.

Take, for instance, the U.S. and worldwide telephone systems. The actual numbering sequence varies in other countries, but the concept is identical. The phone company runs the local loop from the demarc to the CO. All the pairs from all the local loop cables within a small regional area come together at a central point a lot like a patch panel in a LAN based on unshielded twisted-pair (UTP) cable.

This centralized point has a piece of equipment attached called a *switch*, which opens a communications session when it's initiated by a user who's dialed the phone number of the receiver and keeps it open until the "conversation" ends and the session is closed. On one side of the switch is the neighborhood wiring, and on the other side are lines that connect to either another switch or a local set of wiring.

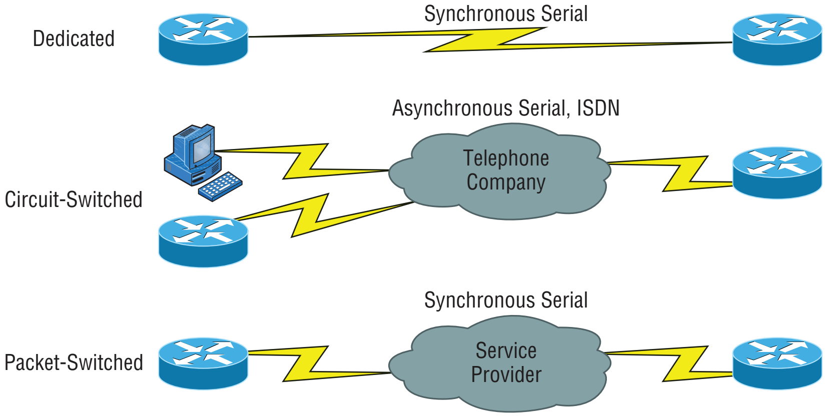
To make this concept really clear, picture the following scenario: When you want to make a call, you pick up the phone, which completes a circuit, and in most cases that gives you a dial tone. The tone is the switch's way of saying, "I'm ready." When you don't get that dial tone, it means that either there's a break in the equipment chain or the switch is too busy processing other requests. In many areas of the world, you hear a fast on-and-off tone (somewhat like a fast busy signal) after giving a command string (phone number) to the local switch. This means that the other switches that the local switch is attempting to communicate with are too busy at that time.

Recently, this tone thing has been replaced with a voice recording saying something like, "We're sorry. All circuits are busy. Please try your call later." Sometimes you even get offered the shady-sounding "For only 99 cents, you can interrupt this call" added to the message. This happens frequently on holidays or during natural disasters because the local area's phone company uses only the minimum number of wires, called *trunk lines*, required to handle the norms of usage capacity plus a few auxiliary lines for peak usage. They keep equipment to a minimum because wiring and switches are really expensive; it's essentially a trade-off between providing 100 percent uptime and keeping the costs of leasing the connection from the phone company reasonably affordable.

WAN Connection Types

With all that in mind, it's time to go over the various types of WAN connections you'll find on the market today. Figure 16.2 shows the different WAN connection types that can be used to connect your LANs together.

FIGURE 16.2 WAN connection types



Let's talk about the different WAN connection types you see pictured here:

Dedicated (Leased) Lines These are usually referred to as *point-to-point* or dedicated connections. A dedicated *leased line* is a preestablished WAN communications path that goes from the CPE through the DCE switch and then over to the CPE of the remote site. The CPE enables DTE networks to communicate at any time with no cumbersome setup procedures to muddle through before transmitting data. When you've got plenty of cash, this is the way to go because it uses synchronous serial lines up to 45 Mbps. High-Level Data Link Control (HDLC) and Point-to-Point Protocol (PPP) encapsulations are frequently used on leased lines.

Circuit Switching When you hear the term *circuit switching*, think phone call. The big advantage is cost—you only pay for the time you actually use. No data can transfer before an end-to-end connection is established. Circuit switching uses dial-up modems or ISDN and is used for low-bandwidth data transfers. I know what you're thinking: "Modems? Did he say modems? Aren't those only in museums now?" After all, with all the wireless technologies available, who uses modems these days? Believe it or not, some people still use ISDN. It's still viable, and there are many places on Earth where you definitely need a modem to get connected. Also, circuit switching can actually be used in some of the newer WAN technologies as well.

Packet Switching This WAN switching method allows you to share bandwidth with other companies to save money. *Packet switching* can be thought of as using a network that's designed to look like a leased line yet charges you more like circuit switching does. But less isn't always more—there's definitely a downside, and if you need to transfer data constantly, just forget about this option. Instead, get yourself a leased line. Packet switching will only work for you if your data transfers are the bursty type, not continuous. Frame Relay and the super-old X.25 are packet-switching technologies with speeds that can range from 56 Kbps up to T3 (45 Mbps).

LANs use packet-switching technology. The source and destination addresses in the packet header guide the network as it moves the packet closer and closer to the destination in the same way the post office takes an addressed letter and keeps it moving incrementally closer to its destination. This approach avoids the necessity of establishing an actual contiguous electrical circuit from one end to the other—the method phone companies use to facilitate a phone call in their circuit-switched networks.

Most WAN connections work on the phone company's circuit-switched network where the point-to-point nature of most connections eliminates the need for addressing because there's only one possible destination between endpoints. But you still need a proper addressing scheme within your LAN to ensure that data packets reach their correct destinations.

Bandwidth or Speed

Satisfying the need for speed involves moving large volumes of data, voice, and video loaded packets across vast distances to communicate. Companies' volume requirements have grown right along with their appetites for ever bigger, faster connections. Speed, typically made possible with more bandwidth, is measured in bits per second or multiples of bits per second, such as kilobits (thousands of bits) per second.

And no surprise here—the winner of the "Slowest WAN Connection" prize is the much-maligned dial-on-demand dial-up connection. Modern dial-up modems typically have a maximum theoretical transfer speed of 56 Kbps, although in most cases 40 Kbps to 50 Kbps is the norm. Factors such as phone-line noise as well as the quality of the modem itself play a large part in determining connection speeds. Modems are required to *modulate/demodulate* the signal, which means translating the analog signal our ears hear into a digital stream for transfer across a digital network. Some connections may be as slow as 20 Kbps in extremely "noisy" environments like hotel rooms where phone lines are shared with an abundant number of extensions.

Megabyte (MB) and *gigabyte (GB)* usually refer to the amount of storage capacity available, whereas *bandwidth* and *speed* refer to units that measure how much data (bits) can be sent per second. In the networking world, speed is essentially the measurement of how fast the data flows (Hz) and also refers to how fast data flows within memory systems. Sometimes the terms *bandwidth* and *speed* are used interchangeably.

T-Series Connections

The basic, entry level in bandwidth or speed for leased lines that provide synchronous connections between sites is known as the T1. It serves up 24 Digital Signal 0 (DS0) 64 Kbps channels in the United States, Japan, and South Korea. There's a slightly bigger/faster version with 32 DS0 channels that's available in Europe and called the E1 or E carrier line.

T1s use Digital Signal 1 (DS1) bit patterns to transmit packets; DS1 has to do with the service to be sent over a T1—originally, 24 digitized voice channels. The terms *T1* and *DS1* have become synonymous and include a bunch of different services from voice to data to clear-channel pipes. The line speed is always consistent at 1.544 Mbps (millions of bits per second), but the payload can vary greatly. For trivia lovers, T1 came from the carrier letter or part number assigned by AT&T to the technology.

But That Doesn't Add Up!

Twenty-four of these channels are a composite of 1.536 Mbps, not 1.544 Mbps! Why is there a difference? The reason is that after a byte (8 bits) of data is sent from each channel (24 × 8 = 192 bits), there is an extra bit used for synchronizing called a frame bit. Hence, 193 bits are sent, and this increase of 1 bit per 192 causes the speed to increase to 1.544 Mbps.

T-series connections are digital connections that you can lease from the telephone company. They can use copper pairs like regular phone lines, or they can be brought in as part of a backbone, which is also called a trunk line. At this point, T-series connections use time-division multiplexing, or TDM, to divide the bandwidth into channels of equal bit rate.

T-series connection types are denoted by the letter *T* followed by a number. Each connection type differs in its speed and in the signal used to multiplex the channels. Table 16.1 lists some of the T-series connections and their maximum data rates. The most commonly used T-series lines are T1 and T3.

TABLE 16.1 T-series connections

Connection	Maximum speed
T1	1.544 Mbps
T1C	3.152 Mbps
T2	6.312 Mbps
T3	44.736 Mbps
T4	274.176 Mbps

The T1 Connection

So a T1 is a 1.544 Mbps digital connection that's typically carried over two pairs of copper wires. This 1.544 Mbps connection uses DS1 and aggregates 24 discrete, 64 Kbps channels that use DS0, which refers to the time slots within a channel. Each channel can carry either voice or data. In the POTS world, T1 lines are used to convert and bundle analog phone conversations over great distances due to the better quality of a digital signal and the use of a great deal less wiring than would be needed if each pair carried only one call. This splitting into independent channels also allows a company to combine voice and data over one T1 connection or to use the T1 as if it were an unchannelized 1.544 Mbps pipe. You can also order a fractional T1 (FT1) circuit that's delivered on a T1 but doesn't allow the use of all 24 channels.

The European version of the T1 is the E1, which operates at 2.048 Mbps and uses 32 64 Kbps channels (32 DS0s). It was designed later, based on T1s, and is a little bigger. You'll also find the J1, which is the Japanese version of the T1 and operates at 1.544 Mbps, just like the T1.

Real World Scenario

What's a Good Speed for a Business?

Many of you who happen to be in charge of setting up your company's Internet connection may think that a T1 is definitely what you should go with. Unfortunately, T1 connections to the Internet can be really pricey. If you're in the business of selling Internet connections as an ISP is, you can justify spending the big bucks on large bandwidth pipes. Another example of when it would make sense for you to opt for a T1 is if you have loads of users on your network—at least 50 or more.

But even if you've got bunches of users on your network, it could be worth it to check out alternative solutions that offer similar speeds at lower costs, like DSL or a cable modem. You can always use a virtual private network (VPN) if you need the security. And there are inexpensive wireless connection options out there as well that provide good bandwidth. Do your research before you buy!

The T3 Connection

A T3 line works similarly to a T1 connection but carries a whopping 44.736 Mbps. This is equivalent to 28 T1 circuits and a whopping 672 DS0 channels! It uses a signal known as Digital Signal 3 (DS3) that's definitely not the same as DS1, which is generally delivered over fiber-optic cable. Many local ISPs have T3 connections to their next-tier ISPs. Other entities that often opt for T3 are large multinational companies because they need the capacity to send voice and data between their major regional offices. And don't forget that the reason the math doesn't quite work out is because of those frame bits!

As it goes with the T1, the T3's European counterpart is the E3, which operates at 34.368 Mbps. The Japanese Digital Hierarchy specifies the J3 circuit, which operates at 32.064 Mbps.

This Doesn't Add Up Again!

Why does an E1 have more capacity than a T1 but a T3 has more capacity than an E3? E and T lines are incremented differently. A T3 is 28 T1s, while an E3 is only 16 E1s.

Transmission Media

Another aspect of WAN technologies that can have a big effect on the speed, bandwidth, and volume of data that can be transferred is the type of transmission media. Wireless transmissions use air as transmission media. This not only creates a bit of a challenge concerning security, it also presents us with signal degradation—the further the signal has to travel from the original source, the weaker it gets. A solution to this last snag comes to us via microwave repeaters, which retransmit signals through the air and bolster them. This approach is a lot more efficient because it can preserve signal strength over much greater distances.

The most far-reaching technology uses the air and even empty space to send electromagnetic signals to satellites from which they are then re-sent to distant geographic locations.

Wired Connections

Back on Earth, wired connections use either copper wire or glass fiber to carry bits as voltages or light pulses, respectively. That attenuation issue I just talked about under wireless technology, where the signal gradually weakens over distances, also relates to copper wire transmissions and limits the length of wire you can use. Fiber offers a lot more bandwidth and it's a lot less susceptible to noise, but it also costs a lot more to buy and install! In the United States, the standard for synchronous data transmission on optical fiber is called *Synchronous Optical Network (SONET)*. The international equivalent of SONET is Synchronous Digital Hierarchy (SDH). SONET defines a base data rate, or *throughput*, of 51.84 Mbps, and multiples of this rate are known as optical carrier (OC) levels, like OC-3, OC-12, and so on. Table 16.2 depicts common OC levels and their associated data rates.

TABLE 16.2 Common optical carrier levels (OC-*x*)

Level	Data rate
OC-1	51.84 Mbps
OC-3	155.52 Mbps
OC-12	622.08 Mbps
OC-48	2.488 Gbps
OC-192	9.953 Gbps
OC-768	39.813 Gbps

Regardless of the media used to carry WAN traffic, the growing volume of voice and video traversing data networks has led to new traffic problems. Regular data traffic can arrive out of order and be reassembled back into its original order on the receiving end, but voice and video data require real-time delivery to be intelligible. Clearly, this makes regular data a lot less vulnerable to congestion or busy traffic conditions that can delay voice and video communications and totally mess them up. The explosion in the popularity and amount of multimedia being sent over data networks is a big reason the never-ending quest for greater bandwidth and speed to avoid traffic jams on WAN links is so vital today.

Wavelength Division Multiplexing

Wavelength Division Multiplexing (WDM) is a technology that multiplexes several optical carriers on a single optical fiber by using different wavelengths. Remember, fiber-optic signals are light, so using different wavelengths of the light spectrum is somewhat like using different frequencies in a radio wave.

Dense Wavelength Division Multiplexing (DWDM) multiplexes within a specific band (1550 nm), allowing for the use of erbium-doped fiber amplifiers (EDFAs) that boost the signal. This allows for upgrading the bit rate of a single strand line by simply replacing equipment at either end of the line. The system consists of the following:

- DWDM terminal multiplexer
- Intermediate line repeater (every 80–100 km)
- Intermediate terminal multiplexer (remote amplification site)
- DWDM terminal de-multiplexer

Coarse Wavelength Division Multiplexing (CWDM) uses larger chunks of the light spectrum and is defined by wavelengths, whereas DWDM is defined by frequencies and fits 40-plus channels into the same frequency range used by just 2 CWDM channels. So why use CWDM at all then? Because CWDM can match the basic capabilities of DWDM at a lower capacity at a significant discount! This allows ISPs to help customers in a metropolitan area network (MAN) physical location where fiber is still too pricey to implement.

Passive Optical Network

Passive Optical Network (PON), also called *fiber to the premises*, is a new option for connecting homes and business to the Internet. It is point-to-multipoint technology with a single fiber strand used for multiple premises (typically 16–28). Unpowered optical splitters are used in the process and are the reason for using the term *passive*.

The system consists of an optical line termination (OLT) at the telco's office and a number of optical network units (ONUs) near end users. These systems typically have downlink speeds of 155 Mbps to 655 Mbps and uplink bursts to 155Mbps.

Wireless Technologies

Now let's get back to that distance issue. You know that different technologies offer different distance ranges and that optical fiber carries signals much farther than copper cabling can. You also know that fiber comes with a much higher price tag to match its higher capacity and that it's much harder to install.

By now, most of us know what Bluetooth is—a type of wireless technology that's only used for short-distance wireless transmissions. Bluetooth is actually a wireless protocol that creates *personal area networks (PANs)*. It utilizes short-range communications technology enabling data transmission between fixed and/or mobile devices. Most of us have mobile phones and those who have smartphones can even get their email, news, and directions to where they're headed, not to mention the best Italian restaurant. They can tell friends where to meet them and post it all on social media in real time. But it's already illegal to talk on your cell phone while driving in some U.S. states and, as time goes on, likely more, if not all. Even using a wireless headset while driving can get you in trouble in some places. Those headsets, along with wireless keyboards and mice, all use Bluetooth technology.

Bluetooth uses a radio technology called Frequency Hopping Spread Spectrum that chops up the data being sent and transmits chunks of it through the air on up to 75 different frequencies in the 2.4 GHz range. The transmitter and receiver change frequencies or channels in a prearranged pattern. Getting all of our wireless toys to play nicely with each other and synch up can be a hassle initially, but meeting that need is exactly what the people who created Bluetooth intended to do—develop a single digital wireless protocol, capable of connecting multiple devices and overcoming problems arising from trying to synchronize them. Bluetooth achieves this goal and even allows us to synch our cars with our phones to chat away legally while driving again!

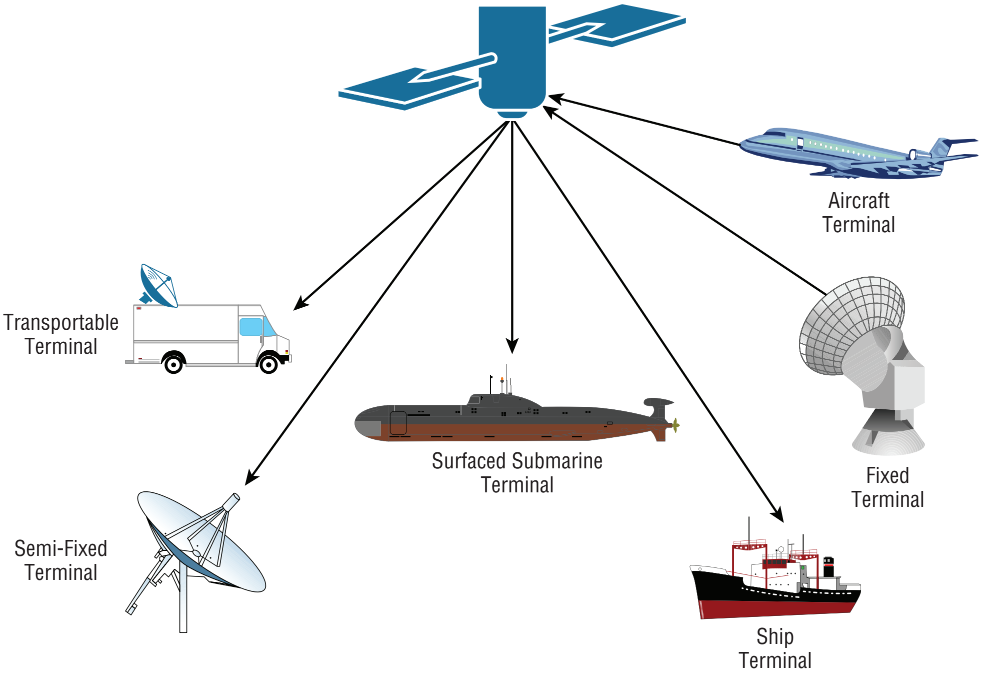
Microwave radio relay is a technology for transmitting digital and sometimes even analog signals between two locations on a line-of-sight radio path through the atmosphere. During microwave radio relay, radio waves are transmitted between the two locations with directional antennas that form a fixed radio connection between them. A really long connected series of links can form line-of-sight transcontinental communication systems. Now, if this sounds familiar, it should—if you didn't skip Chapter 12, "Wireless Networking," that is! Anyway, although having a dedicated microwave connection is still common because it allows you to purchase your own frequency range from the FCC to ensure that you don't get any interference, a much less costly installation is the wireless 802.11 specification, which provides us with long-distance solutions and a healthy amount of bandwidth to boot.

A *communications satellite (comsat)* is an artificial satellite stationed in space for telecommunications purposes. Modern communications satellites use a variety of orbits. Here's a list of them:

- Geostationary orbits
- Molniya orbits (*molniya* means lightning in Russian), named after a series of communications satellites from Russia
- Low-polar and non-polar Earth orbits from which the satellite can first boost communications signals and then send them back to Earth

There are other elliptical orbits too, but I'm not going to go into them in this book because you're not reading this to help you get your FCC license. Instead, you want to pass the CompTIA Network+ exam, and to do that, you do need to understand point-to-multipoint services and how communications satellites provide microwave radio relay technology, as shown in Figure 16.3.

FIGURE 16.3 An example of a satellite point-to-multipoint



This technology is also used for mobile applications like GPS communications to ships, vehicles, planes, and handheld terminals as well as for fun stuff like watching football on satellite HDTV and radio broadcasting. These all require capabilities that are impractical or impossible to use with other technologies like cable.

So yeah, this satellite thing is pretty awesome, but of course it comes with a few problems too. First of all, it's expensive, and although it isn't necessarily slow, there's a lot of latency because of the time it takes to get from your terminal to the satellite to the provider and back. This is totally understandable since you're transmitting about 20,000 miles or more, and once you get a good TCP stream—something like an FTP download—speeds can really get moving. Still, for bursty traffic, like email messages, you'll probably encounter enough latency to drive you batty enough to head straight back to a modem!

Broadband Services

Before I get into telling you all about the WAN protocols required to meet the CompTIA objectives, I've got to talk about cable modems and DSL as solutions for connecting to WANs. I think briefing you on them will really help you understand the practical differences between DSL and cable-modem networking, and they just happen to be CompTIA objectives as well!

Dedicated broadband services include transmissions over media in a broad range of frequencies. The various forms of *Digital Subscriber Line (DSL)* services are broadband in the sense that digital information is sent over a high-bandwidth channel above the baseband voice channel on a single pair of wires. Ethernet digital signals sent over a *cable modem* from your local cable television service provider compete with DSL service.

Although it's true that DSL and cable Internet services do indeed have a lot in common, they still have some basic, essential differences that are really important for you to understand:

Speed Most people would tell you that cable is faster than DSL Internet, but they wouldn't be right because cable doesn't always win the race in the real world.

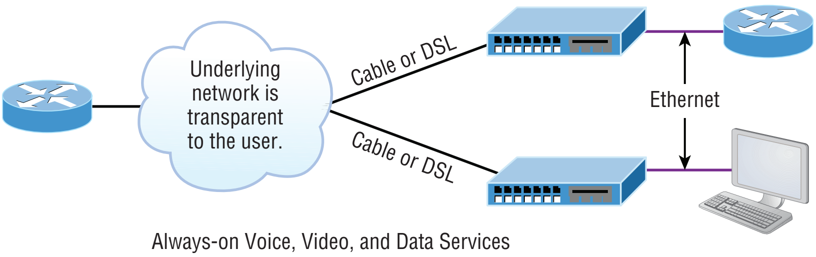
Security DSL and cable are based upon different network-security models, and until recently, cable has been the reputed loser in this contest. But now it's pretty much a toss-up, with both offering adequate security to meet the needs of most users. And when I say adequate, I don't mean anywhere near great—there are still some very real security issues relating to both alternatives, no matter what your ISP says!

Popularity Cable Internet is definitely "best in show" in the United States, but DSL is beginning to catch up.

Customer Satisfaction Here, the reverse is true—in the United States, DSL is top dog. Still, do you really know anyone who's satisfied with their ISP?

Figure 16.4 shows how a connection can terminate from modems to either a PC directly or to a router. The two devices that lie between the router and the cloud and between the computer and the cloud represent the cable or DSL modem. Typically, your router would run Dynamic Host Configuration Protocol (DHCP) on that interface as well as Point-to-Point Protocol over Ethernet (PPPoE), which we discussed back in Chapter 13, "Authentication and Access Control."

FIGURE 16.4 Broadband access using cable or DSL


Underlying network is transparent to the user.
Cable or DSL
Cable or DSL
Ethernet
Always-on Voice, Video, and Data Services

Both DSL and cable high-speed Internet services are available to millions of residential and business consumers worldwide, but in some areas, only one and sometimes neither service is available. Surprisingly, some of the differences between DSL and cable modem have nothing to do with the actual technologies—it comes down to the individual ISP. All other things being equal, issues like cost, reliability, and quality of customer support for both installation and maintenance really do vary significantly from one provider to the next.

DSL Technology and *x*DSL

DSL is not a complete end-to-end solution. It is really a physical layer transmission technology like dial-up, cable, or wireless. DSL connections are deployed in the *last mile* of a local telephone network or local loop. The term *last mile* has been used quite a bit in the last few years with broadband-type connections. It basically means the same thing as *local loop* and defines the physical connection from the customer to the first aggregation device of the provider network.

A DSL connection is set up between a pair of modems on either end of a copper wire that is between the CPE and the digital subscriber line access multiplexer (DSLAM). A DSLAM is the device located at the provider's CO that concentrates connections from multiple DSL subscribers.

xDSL is really a family of technologies that have become popular for data transmission over phone lines because *x*DSL uses regular PSTN phone wires to transmit digital signals and is extremely inexpensive compared with other digital communications methods. The *x* in *x*DSL represents the various letters that refer to different DSL flavors. *x*DSLs use high-frequency signals, whereas regular phone calls use low-frequency signals over the same lines.

Communicating via *x*DSL requires an interface to a PC. All *x*DSL configurations require a DSL modem called an *endpoint* and a network interface card (NIC) in your computer. The NIC can be connected directly to the DSL modem using a straight-through Ethernet UTP patch cord with standard RJ-45 connectors on each end. But if there are other connecting devices between the computer and the cable modem, you'll need either a special switchable port or an Ethernet crossover cable for things to work out well.

So Are These Really Modems?

Actually, neither ISDN nor cable modems are actually modems in the sense that no analog-to-digital signal modulation is occurring. But the industry calls them modems anyway!

A nice feature of *x*DSL implementations is that they cost tens of dollars instead of the hundreds, sometimes up to the thousands, you would have to pony up for a dedicated, digital point-to-point link like a T1. These cost-effective implementations include the following:

High Bit-Rate Digital Subscriber Line (HDSL) HDSL was the first DSL technology to use a higher-frequency spectrum of copper twisted-pair cables. HDSL was developed in the United States as a better technology for high-speed, synchronous circuits. It was typically used to interconnect local-exchange carrier systems and to carry high-speed corporate data links and voice channels using T1 lines.

Symmetric Digital Subscriber Line (SDSL) Symmetric (meaning same rate in both directions) Digital Subscriber Line (SDSL) provides T1/E1 type speeds symmetrically for both uploading and downloading data, but doesn't allow low-frequency phone calls on the same line as Asymmetric Digital Subscriber Line (ADSL) does. How much it will set you back ranges between the cost of ADSL and T1s. This option is typically used by small to medium-sized businesses that don't require the higher performance of a leased line for connecting to a server.

Very High Bit-Rate Digital Subscriber Line (VDSL) VDSL, or Very High Bit-Rate DSL (VHDSL), provides faster data transmission over single, flat, untwisted or twisted pairs of copper wires. This capacity for blazingly fast speeds mean that VDSL is capable of supporting high-bandwidth applications like HDTV and telephone services like the ever popular Voice over IP (VoIP) as well as general Internet access over a single connection. VDSL is deployed over existing wiring used for POTS and lower-speed DSL connections. Second-generation VDSL2 systems utilize bandwidths of up to 30 MHz to provide data rates exceeding 100 Mbps simultaneously in both the upstream and downstream directions. The maximum available bit rate is achieved at a range of about 300 meters with the signal performance degrading as the loop attenuation increases.

Asymmetric Digital Subscriber Line (ADSL) Asymmetric (meaning different upload and download speed) DSL has become the most popular *x*DSL because it focuses on providing reasonably fast upstream transmission speeds (768 Kbps) and very fast downstream transmission speeds of up to 9 Mbps (ADSL2+ can get up to 20 Mbps). This makes downloading graphics, audio, video, and data files from any remote computer a snap! The majority of web traffic is downstream. The best part is that ADSL works on a single phone line without losing voice call capability. This is accomplished with something called a *splitter* that enables the use of multiple frequencies on your POTS line.

Cable Modem

Cable is a great cost-effective connection for a small office or home office (SOHO)—yes, there is an acronym for everything. Even in larger organizations, cable, or even DSL, can be great to have around as a backup link.

Here are a few cable network terms:

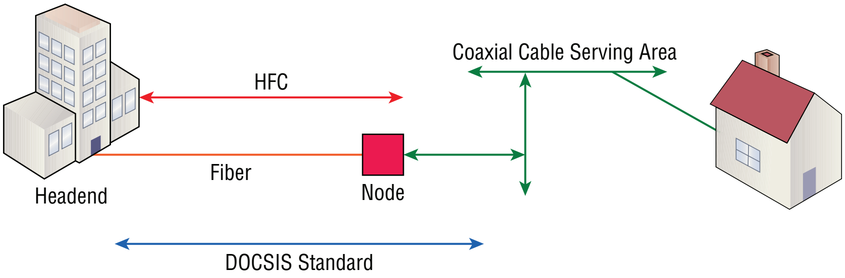
Headend This is where all cable signals are received, processed, and formatted. The signals are then transmitted over the distribution network from the headend.

Distribution Network These are relatively small service areas that usually range in size from 100 to 2,000 customers. They're typically composed of a mixed, fiber-coaxial, or hybrid fiber-coaxial (HFC) architecture, with optical fiber substituting for the distribution network's trunk portion. The fiber forms both the connection from the headend and an optical node that changes light to radio frequency (RF) signals that are then distributed through a coaxial cable throughout the specific service area—that is, your home or office.

Data over Cable Service Interface Specifications (DOCSIS) This specification provides the interface requirements for a data-over-cable system, including that of high-speed data transfer to an existing cable TV system. All cable modems and similar devices have to measure up to this standard.

Figure 16.5 shows where you would be likely to find the various types of networks and how the terms I just listed would be used in a network diagram. The area on the right where coaxial cable is in use is the distribution network, and the box labeled Node is the optical node where light is converted to RF signals for use on the coaxial cable.

FIGURE 16.5 Cable network



The problem with this is that ISPs often use a fiber-optic network that extends from the cable operator's master headend—sometimes even to regional headends—out to a neighborhood's hubsite and finally arrives at a fiber-optic node that services anywhere from 25 to 2,000 or more homes. I'm really not picking on cable, but here's another issue: If you have cable, open your PC's command prompt, type `ipconfig`, and check out your subnet mask. It's probably a /20 or /21 Class B address—yikes! You already know that translates to either 4,094 or 2,046 hosts per cable network connection—definitely not good.

NOTE

When I say *cable*, I really mean using coax (coaxial) cable for transmission. Community antenna television (CATV) is now used as a means to offer cost-effective broadcasting to subscribers. Cable is able to provide voice and data, plus analog and digital video, without requiring your whole paycheck!

Your average cable connection gives you a maximum download speed of 20 Mbps (theoretically, some providers sell this up to 50 Mbps). And remember—you have to share that bandwidth with all the other subscribers. As if that weren't enough, there are other things like overloaded web servers and plain old network congestion that factor into the mix as well. But your email-checking neighbors really aren't making that much of a difference. So who or what is? Well, if you're an online gamer, you will likely notice a bit more lag during peak periods, which could be a matter of virtual life and death. And if somebody in your neighborhood is uploading a large amount of data, like, say, an entire collection of pirated *Star Wars* movies, it could definitely max out the entire connection and bring everyone's browser to crawl speed or worse.

Cable-modem access may or may not be faster or easier to install than DSL, and your mileage will vary, depending on where you live plus a variety of other factors. But it's usually more available and a tad less pricey, making it a winner by a nose. But no worries, if cable access isn't available in your neighborhood, DSL is okay—anything is better than dial-up!

Metro Ethernet

Metropolitan-area Ethernet is a metropolitan area network (MAN) that's based on Ethernet standards and can connect a customer to a larger network and the Internet.

If available, businesses can use Metro Ethernet to connect their offices together, which presents another very cost-effective connection option. MPLS-based Metro Ethernet networks use MPLS in the ISP by providing an Ethernet or fiber cable to the customer as a connection. From the customer, it leaves the Ethernet cable, jumps onto MPLS, and then Ethernet again on the remote side. This is a smart and thrifty solution that's very popular if you can get it in your area.

Wireless WAN Technologies

At one time, it was taken as gospel that wireless technologies, especially WAN technologies, could never be completely acceptable, especially when compared to terrestrial technologies. Today, that given is being challenged with a number of new technologies that can provide acceptable Internet and even multimedia performance without a landline. In the following sections, we'll look at some of the cellular WAN technologies and see how far we've really come in this regard.

Cellular WAN

Cellular technologies have evolved since their introduction in the late 1970s. Terms like *1G* (first generation) *2G*, *3G*, and *4G* are often used to describe significant advances in the technology. First I'll give you a quick overview of the major developments, and then we'll look more closely at a couple of the newer technologies, specifically what these technologies bring to the table and what they may promise for the future.

First-generation cellular (1G) was a voice-only analog network. The second generation (2G) marked the switch to digital, which allowed voice and, for the first time, simple data, such as a text message. Fourth generation (4G) is still the most widely used globally at this writing, but things change quickly. 4G allows high-speed voice and data, even Internet. This is the type of network supporting most of your smartphones.

GSM, or Global System for Mobile Communications, is a standard developed by the European Telecommunications Standards Institute (ETSI). It delineates protocols for 2G digital cellular networks, which are used by mobile phones, and it's the default global standard for mobile communications and enjoys over 90 percent market share. 2G is available in over 219 countries and territories worldwide.

The GSM standard was created to replace first-generation (1G) analog cellular networks and originally described a digital, circuit-switched network optimized for full-duplex voice telephony. It evolved to include data communications, at first via circuit-switched transport, then through packet data transport via General Packet Radio Services (GPRS) and EDGE, alternately via Enhanced Data Rates for GSM Evolution (EGPRS).

Code division multiple access (CDMA) is a channel access method that's used by various radio communication technologies. CDMA offers multiple access, where several transmitters can send information simultaneously over a single communication channel, allowing several users to share a band of frequencies. To make this work without a bunch of interference between users, CDMA relies upon spread-spectrum technology and a special coding scheme in which each transmitter is assigned a unique code.

Fourth generation (4G) is actually still an emerging technology that has two variants, LTE and WiMAX. An organization called the Third Generation Partnership Project 2 (3GPP2) has set specific requirements that must be met for a system to call itself 4G. Its 4G project, UMB, was abandoned. At this point in time, LTE and WiMAX meet these requirements.

The goal of 4G is to provide data rates way beyond what's typically available today. Even so, uplinks from the mobile device to the tower will always be much slower, and actual performance in the real world still isn't always so hot. I'll provide a few figures to clarify all this, but just know that 4G systems really should still be backward compatible with 3G systems most of the time to fully achieve the performance goals that 4G was created to meet. Oh, and obviously, the device itself has got to be 4G capable to start with!

HSPA+

Evolved High Speed Packet Access (HSPA+) is really considered a 3.5 generation technology. It does include an optional all-IP architecture, which is one of 4G's requirements, and it actually has greatly improved data rates over its HSPA forerunner. Because HSPA+ can use an all-IP architecture, it has the potential to evolve into a true 4G technology someday. Because of all the variables involved, it is difficult to give a set download and upload speed.

WiMAX

World Wide Interoperability for Microwave Access (WiMAX) is considered a true 4G technology, and it's based on the IEEE 802.16 standard. It supports both fixed, tower-to-tower applications and mobile applications. It was originally designed as a last-mile technology to deliver Internet to areas where implementing landlines wasn't possible as an alternative to DSL and cable.

But it has its challenges too—WiMAX just isn't compatible with 2G and 3G technologies, and it's pricey and requires lots of power. Worse, it also lags behind LTE in speed, with downlink speeds of 5 Mbps to 6 Mbps and uplink speeds of 2 Mbps to 3 Mbps.

LTE

This brings us to *Long Term Evolution (LTE)*, which is definitely the most promising of all emerging 4G technologies. It uses an all-IP-based core, it offers the highest data rates, and it's compatible with 3G and WiMAX! And it happens to have the best indoor coverage while maintaining high data rates all the way to the edge of a coverage cell. If that isn't enough for you, it also accommodates more devices in a given area and still performs really well by maintaining data rates of 7 Mbps to 12 Mbps on the downlink and 3 Mbps to 5 Mbps on the uplink.

WAN Protocols

We'll be focusing on these five technologies in the following sections:

- ISDN
- Frame Relay
- PPP
- ATM
- MPLS

Integrated Services Digital Network

ISDN is a digital, point-to-point WAN technology capable of maximum transmission speeds of about 1.5 Mbps (Primary Rate Interface [PRI]), although speeds of 128 Kbps (Basic Rate Interface [BRI]) are more the reality within a SOHO environment.

ISDN uses the same UTP wiring as POTS, yet it can transmit data at higher speeds. But that's where the similarity ends. The main thing that makes ISDN different from a regular POTS line is how it utilizes the copper wiring. Instead of carrying an analog voice signal, it carries digital signals, which also happens to be the key behind several more vital differences.

First, a computer connects to the 128 Kbps ISDN line via an ISDN *terminal adapter (TA)* that's often incorrectly referred to as an ISDN modem. An ISDN TA is not a modem because it doesn't convert a digital signal from the computer to an analog signal on the subscriber line—ISDN signals are digital on the subscriber line. A TA is technically an ISDN-compatible device that has one or more non-ISDN ports for devices like computer serial interfaces and RJ-11 analog phones, which work to give these non-ISDN devices access to the ISDN network.

Second, an ISDN line has two types of channels. The data is carried on special *Bearer channels*, or *B channels*, each of which can carry 64 Kbps of data. A BRI ISDN line has 2 B channels, and a PRI has 23 64 Kbps channels. One channel can be used for a voice call while the other can be used for data transmissions, and it's all made possible by time-division multiplexing (TDM) on one pair of copper wires.

The other type of channel in ISDN is also multiplexed onto only one copper pair. It's used for call setup and link management and is known as the *signaling channel*, *D channel*, or *Delta channel*. This channel has only 16 Kbps of bandwidth in BRI and 64 Kbps in PRI.

To maximize throughput, the two B channels are often combined into one data connection for a total bandwidth of 128 Kbps. This is known as *Bandwidth on Demand Interoperability Group (BONDING)* or *inverse multiplexing*.

But this still leaves the D channel free for signaling purposes. In rare cases, you may see user data, such as credit-card verification, on the D channel. This was introduced as an additional feature of ISDN, but it hasn't really caught on.

Some of the main advantages of ISDN are as follows:

- It offers higher bandwidth than POTS. BONDING yields 128 Kbps bandwidth.
- There is no conversion from digital to analog.

ISDN has the following disadvantages:

- Low latency.
- It's more expensive than POTS.
- Specialized equipment is required both at the phone company and at the remote computer.
- ISDN equipment isn't compatible to connect to every other type of equipment out there.
- Why use ISDN if you can get DSL or cable?
- It's just a plain outdated technology.

Remember that ISDN is a type of dial-up connection that must be initiated.

So, you now know that ISDN is another form of high-speed Internet access that delivers digital services (on 64 Kbps channels) over conditioned telephone copper pairs. As I mentioned earlier, the device you must hook up to your computer to access ISDN services is properly known as an ISDN terminal adapter, which doesn't change from digital to analog like a modem does. It's only capable of changing between digital transmission formats.

The box itself is about the size of a modem and happens to look pretty similar to one. And also like DSL modems, it has a phone jack and an Ethernet jack. You connect a phone cord from the phone jack to the wall jack where your ISDN services are being delivered, and then you connect an Ethernet cable from your PC to the ISDN TA's Ethernet jack. Older, less-capable TAs used an Electronic Industries Association/Telecommunications Industry Alliance (EIA/TIA) 232 serial port for PC connectivity. It's exactly these similarities that cause people to confuse ISDN TAs with standard modems.

Frame Relay Technology

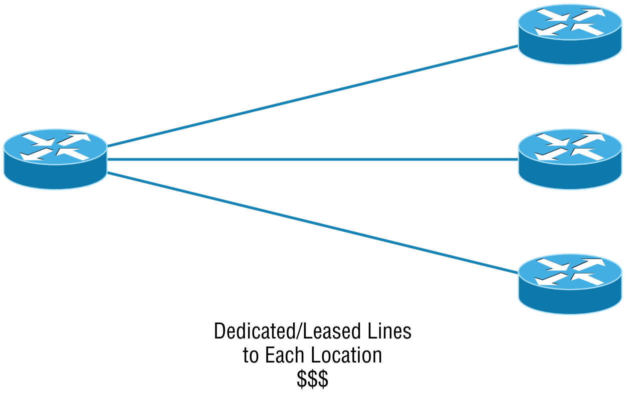
Frame Relay is a WAN technology in which variable-length packets are transmitted by switching. *Packet switching* involves breaking messages into chunks at the sending device. Each packet can be sent over any number of routes on its way to its destination. The packets are then reassembled in the correct order at the receiving device. Because they are packet-switched and the exact path is unknown, we use a cloud when creating diagrams to illustrate how data travels throughout this type of service.

From everything you've learned so far, just telling you that Frame Relay is a packet-switched technology should make you immediately realize a couple of things about it:

- Frame Relay doesn't work like a point-to-point leased line (although it can be made to look and act like one).
- Frame Relay is usually less expensive than leased lines are, but there are some sacrifices to make to get that savings.

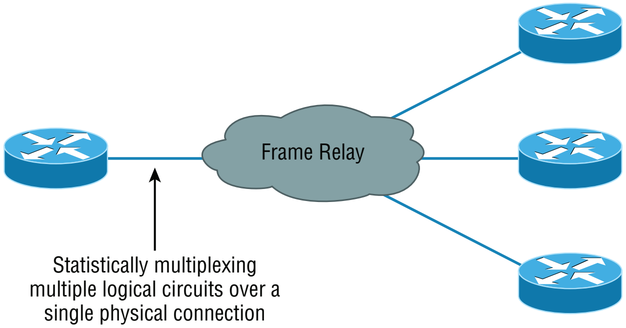
So, why would you even consider using Frame Relay? Take a look at Figure 16.6 to get an idea of what a network looked like before Frame Relay.

FIGURE 16.6 Before Frame Relay



Now check out Figure 16.7. You can see that there's now only one connection between the corporate router and the Frame Relay switch. That saves some major cash.

FIGURE 16.7 After Frame Relay


Frame Relay
Statistically multiplexing multiple logical circuits over a single physical connection

Let's say you need to add seven remote sites to the corporate office and you have only one free serial port on your router. Frame Relay to the rescue! Of course, I should probably mention that you now also have one single point of failure, which is not so good. But Frame Relay is used to save money, not to make a network more resilient.

Coming up, I'm going to cover the Frame Relay technology information you need to know about when studying for the CompTIA Network+ exam.

Committed Information Rate

Frame Relay allows for a packet-switched network to be provided to many different customers at the same time. This is really good because it spreads out the cost of the switches among lots of customers. But remember, Frame Relay is based on the assumption that all customers won't need to transmit data constantly—or even all at the same time.

Frame Relay works by providing a portion of dedicated bandwidth to each user, and it also allows the user to exceed their guaranteed bandwidth if resources on the telco network happen to be available. So basically, Frame Relay providers allow customers to buy a lower amount of bandwidth than they really use. There are two separate bandwidth specifications with Frame Relay:

Access Rate The maximum speed at which the Frame Relay interface can transmit.

Committed Information Rate (CIR) The maximum bandwidth of data guaranteed to be delivered. In reality, it's the average amount that the service provider will allow you to transmit, based upon what you purchased.

If these two values are the same, the Frame Relay connection is pretty much just like a leased line. But they can actually be set to different values. Here's an example: Let's say that you buy an access rate of T1 (1.544 Mbps) and a CIR of 256 Kbps. By doing this, you're guaranteed that the first 256 Kbps of traffic you send will be delivered. Anything beyond that is called a *burst*—a transmission that exceeds your guaranteed 256 Kbps rate and can total any amount up to the T1 access rate, if that amount is permitted in your contract. If your combined committed burst, which is the basis for your CIR, and excess burst sizes, known as the maximum burst rate (MBR), exceed the access rate, you can pretty much say good-bye to your additional traffic because it will most likely be dropped! Whether this happens or not basically comes down to the subscription level offered by a particular service provider.

In a perfect world, this always works beautifully—but remember that little word *guarantee*—as in guaranteed rate, of 256 Kbps to be exact? This means any burst of data you send that exceeds your guaranteed 256 Kbps rate will be delivered on something called a "best effort" delivery basis. Or maybe not—if your telco's equipment doesn't have the capacity to deliver it at the time you transmitted, then your frames will be discarded and the DTE will be notified. Timing is everything—you can scream data out at six times your guaranteed rate of 256 Kbps (T1) *only if* your telco has the capacity available on its equipment at that moment!

Virtual Circuits

Frame Relay operates using *virtual circuits* as opposed to the actual circuits that leased lines use. These virtual circuits are what link together the thousands of devices connected to the provider's "cloud." Frame Relay provides a virtual circuit between your two DTE devices, making them appear to be connected via a circuit when in reality they're dumping their frames into a large, shared infrastructure. You never see the complexity of what's actually happening inside the cloud because you only have a virtual circuit.

And on top of all that, there are two types of virtual circuits—permanent and switched. Permanent virtual circuits (PVCs) are by far the most common type in use today. What *permanent* means here is that the telco creates the mappings inside its gear and as long as you pay the bill, they'll remain "permanently" in place.

Switched virtual circuits (SVCs) are more like phone calls. The virtual circuit is established when data needs to be transmitted, and it's taken down when the data transfer is complete.

NOTE I have never seen a Frame Relay service using SVCs offered by a telco in North America. It's used mainly in private Frame Relay networks.

Data Link Connection Identifiers

Frame Relay PVCs are identified to DTE end devices by *Data Link Connection Identifiers (DLCIs)*. A Frame Relay service provider typically assigns DLCI values, which are used on Frame Relay interfaces to distinguish between different virtual circuits. Because many virtual circuits can be terminated on one multipoint Frame Relay interface, many DLCIs are often affiliated with it.

Let me explain. Suppose you have a central HQ with three branch offices. If you were to connect each branch office to HQ using a T1, you would need three serial interfaces on your router at HQ, one for each T1. Simple, right? Well, suppose you use Frame Relay PVCs instead. You could have a T1 at each branch connected to a service provider and only a *single* T1 at HQ. There would be three PVCs on the single T1 at HQ, one going to each branch. And even though you'd have only a single interface and a single CSU/DSU, the three PVCs would function as three separate circuits. Remember what I said about saving money? How much for two additional T1 interfaces and a pair of CSU/DSUs? Answer: A lot! So, why not go ahead and ask for a percentage of the savings in your bonus?

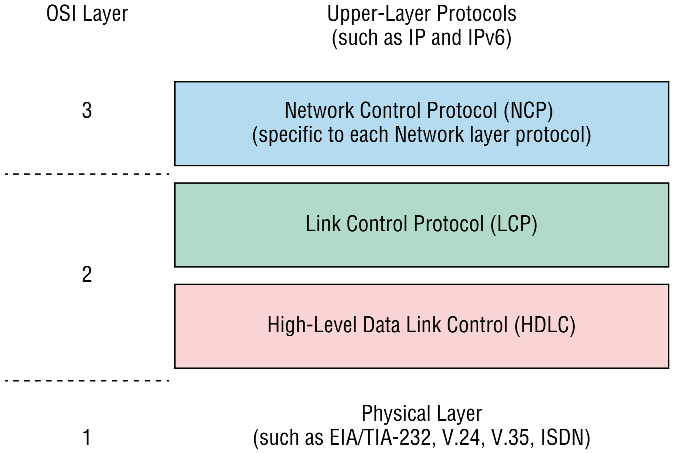
Point-to-Point Protocol

Point-to-Point Protocol (PPP) is a Data Link layer protocol that can be used over either asynchronous serial (dial-up) or synchronous serial (ISDN) media. It relies on Link Control Protocol (LCP) to build and maintain data-link connections. Network Control Protocol (NCP) enables multiple Network layer protocols (routed protocols) to be used on a point-to-point connection.

Because High-level Data Link Control (HDLC) is the default serial encapsulation on Cisco serial links and it works great, why in the world would you choose to use PPP? Well, the basic purpose of PPP is to transport Layer 3 packets across a Data Link layer point-to-point link, and it's nonproprietary. So unless you have all Cisco routers, you need PPP on your serial interfaces because the HDLC encapsulation is Cisco proprietary, remember? Plus, since PPP can encapsulate several Layer 3 routed protocols and provide authentication, dynamic addressing, and callback, PPP could actually be the best encapsulation solution for you over HDLC anyway.

Figure 16.8 shows the PPP stack compared to the OSI reference model.

FIGURE 16.8 Point-to-Point Protocol stack


OSI Layer
Upper-Layer Protocols (such as IP and IPv6)
3
Network Control Protocol (NCP) (specific to each Network layer protocol)
Link Control Protocol (LCP)
2
High-Level Data Link Control (HDLC)
Physical Layer (such as EIA/TIA-232, V.24, V.35, ISDN)
1

PPP contains four main components:

EIA/TIA-232-C, V.24, V.35, and ISDN A Physical layer international standard for serial communication.

HDLC A method for encapsulating datagrams over serial links.

LCP A method of establishing, configuring, maintaining, and terminating the point-to-point connection. It also provides features such as authentication. I'll give you a complete list of these features coming up soon in the next section.

NCP A method of establishing and configuring different Network layer protocols for transport across the PPP link. NCP is designed to allow the simultaneous use of multiple Network layer protocols. Two examples of protocols here are Internet Protocol Control Protocol (IPCP) and Cisco Discovery Protocol Control Protocol (CDPCP).

Burn it into your mind that the PPP protocol stack is specified at the Physical and Data Link layers only. NCP is used to allow communication of multiple Network layer protocols by identifying and encapsulating the protocols across a PPP data link.

Next, we'll cover the options for LCP and PPP session establishment.

Link Control Protocol (LCP) Configuration Options

Link Control Protocol (LCP) offers different PPP encapsulation options, including the following:

Authentication This option tells the calling side of the link to send information that can identify the user. The two methods for this task are PAP, EAP, and CHAP.

Compression This is used to increase the throughput of PPP connections by compressing the data or payload prior to transmission. PPP decompresses the data frame on the receiving end.

Error Detection PPP uses Quality and Magic Number options to ensure a reliable, loop-free data link.

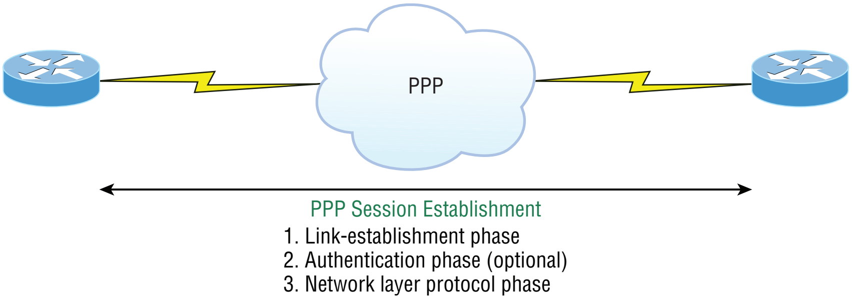
Multilink The multilink option makes several separate physical paths appear to be one logical path at Layer 3. This means that the two T1s running multilink PPP would show up as a single 3 Mbps path to a Layer 3 routing protocol.

PPP Callback On a dial-up connection, PPP can be configured to call back after successful authentication. *PPP callback* can be a very good thing because it allows us to keep track of usage based upon access charges for accounting records and a bunch of other reasons. With callback enabled, a calling router (client) will contact a remote router (server) and authenticate. Predictably, both routers have to be configured for the callback feature for this to work. Once authentication is completed, the remote router will terminate the connection and then reinitiate a connection to the calling router.

PPP Session Establishment

When PPP connections are started, the links go through three phases of session establishment, as shown in Figure 16.9:

FIGURE 16.9 PPP session establishment


PPP
PPP Session Establishment
1. Link-establishment phase
2. Authentication phase (optional)
3. Network layer protocol phase

Link-Establishment Phase LCP packets are sent by each PPP device to configure and test the link. These packets contain a field called Configuration Option that allows each device to see the size of the data, the compression, and authentication. If no Configuration Option field is present, then the default configurations will be used.

Authentication Phase If required, CHAP, EAP, or PAP can be used to authenticate a link. Authentication takes place before Network layer protocol information is read, and it's also possible that link-quality determination will occur simultaneously.

Network Layer Protocol Phase PPP uses the *Network Control Protocol (NCP)* to allow multiple Network layer protocols to be encapsulated and sent over a PPP data link. Each Network layer protocol (e.g., IP, IPv6, which are routed protocols) establishes a service with NCP.

PPP Authentication Methods

There are three methods of authentication that can be used with PPP links:

Password Authentication Protocol (PAP) *Password Authentication Protocol (PAP)* is the least secure of the three methods. Passwords are sent in clear text and PAP is performed only upon the initial link establishment. When the PPP link is first established, the remote node sends the username and password back to the originating target router until authentication is acknowledged. Not exactly Fort Knox!

Challenge Handshake Authentication Protocol (CHAP) The *Challenge Handshake Authentication Protocol (CHAP)* is used at the initial startup of a link and at periodic checkups on the link to ensure that the router is still communicating with the same host. After PPP finishes its initial link-establishment phase, the local router sends a challenge request to the remote device. The remote device sends a value calculated using a one-way hash function called MD5. The local router checks this hash value to make sure it matches. If the values don't match, the link is immediately terminated.

Extensible Authentication Protocol (EAP) EAP is a framework that supports multiple authentication methods using a variety of credential types, based on the specific implementation.

NOTE

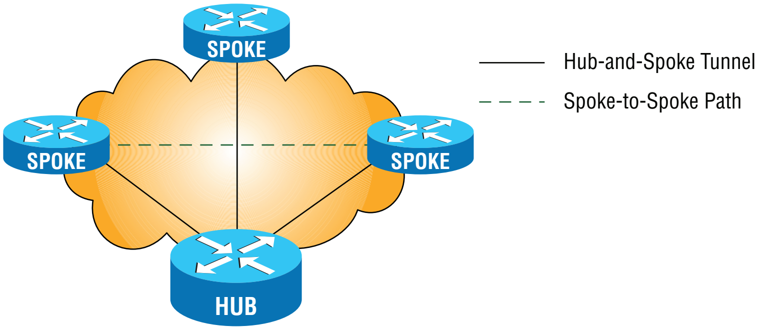
CHAP authenticates at the beginning of the session and periodically throughout the session.

DMVPN

Dynamic Multipoint VPN provides the capability to build a dynamic mesh VPN network by defining only the hub on a hub-and-spoke configuration. It is supported on Cisco and Huawei routers and on USG firewalls and some Unix-like operating systems. The benefit is the ability to deploy additional spokes without any reconfiguration of the hub.

Once the DMVPN is deployed, another interesting feature is the ability of the spokes to communicate with one another without passing the traffic though the hub. The spokes do this by dynamically setting up connections to one another by contacting the hub, obtaining the necessary information about the other end, and creating a dynamic IPSec VPN tunnel directly between them, as shown in Figure 16.10.

FIGURE 16.10 DMVPN



The benefits to DMVPNs are as follows:

- Traffic between remote sites does not need to traverse the hub.
- They eliminate additional bandwidth requirements at the hub.
- They eliminate additional network delays.
- They conserves WAN bandwidth.
- Costs for VPN circuits are lower.
- They provide increased resiliency and redundancy.

SIP Trunks

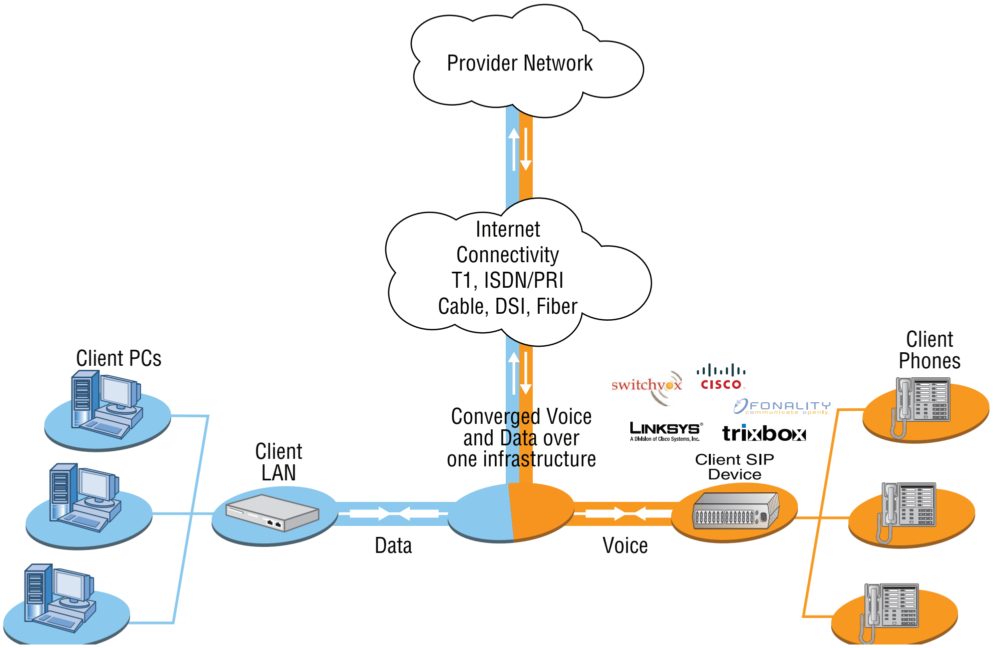
A Session Initiation Protocol (SIP) trunk is a link providing streaming media and unified communications to an organization by an Internet telephony service provider. It connects to organizations equipped with SIP-based Private Branch Exchange (PBX) systems and Unified Communications (UC) facilities.

The SIP trunk provides a connection between two different domains of responsibility:

- Private Domain (responsibility of the organization), the network connected to the organization's PBX or unified communications server
- Public Domain (responsibility of the provider), the part of the network that allows access into the PSTN (Public Switched Telephone Network) or PLMN (Public Land Mobile Network)

The SIP architecture is shown in Figure 16.11.

FIGURE 16.11 SIP trunk



Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM), not to be confused with automated teller machines, first emerged in the early 1990s. ATM was designed to be a high-speed communications protocol that doesn't depend on any specific LAN topology. It uses a high-speed cell-switching technology that can handle data as well as real-time voice and video. The ATM protocol breaks up transmitted data into 53-byte cells. A *cell* is analogous to a packet or frame, except that an ATM cell is always fixed in length and is relatively small and fast, whereas a frame's length can vary.

ATM is designed to switch these small cells through an ATM network very quickly. It does this by setting up a virtual connection between the source and destination nodes; the cells may go through multiple switching points before ultimately arriving at their final destination. The cells may also arrive out of order, so the receiving system may have to reassemble and correctly order the arriving cells. ATM, like Frame Relay, is a connection-oriented service, in contrast to most Data Link protocols, which are best-effort delivery services and do not require virtual circuits to be established before transmitting user data.

Data rates are scalable and start as low as 1.5 Mbps, with speeds of 25 Mbps, 51 Mbps, 100 Mbps, 155 Mbps, and higher. The common speeds of ATM networks today are 51.84 Mbps and 155.52 Mbps; both of them can be used over either copper or fiber-optic cabling. You can also get ATM with a speed of 622.08 Mbps, but that is currently used exclusively over fiber-optic cable. ATM supports very high speeds because it's designed to be routed by hardware rather than software, which makes faster processing speeds possible.

Fiber-based service-provider ATM networks are running today at data rates of 10 Gbps, and they're becoming more and more common. These fast speeds make real-time payloads like voice and video travel with data on an ATM network and arrive without too much delay, or *latency*. The small size of the payload, compared to the size of each cell's header, makes ATM less efficient than other WAN technologies. In other words, ATM networks are fast, but they get bad gas mileage. ATM never made much market impact.

MPLS

MultiProtocol Label Switching (MPLS) is a data-carrying mechanism that emulates some properties of a circuit-switched network over a packet-switched network. So MPLS is actually a switching mechanism that imposes labels (numbers) to packets and then uses them to forward packets. The labels are assigned on the edge of the MPLS network, and forwarding inside the MPLS network is carried out solely based on the labels. The labels usually correspond to a path to Layer 3 destination addresses, which is on par with IP destination-based routing. MPLS was designed to support the forwarding of protocols other than TCP/IP. Because of this, label switching within the network is achieved the same way, irrespective of the Layer 3 protocol. In larger networks, the result of MPLS labeling is that only the edge routers perform a routing lookup. All the core routers forward packets based on the labels, which makes forwarding the packets through the service provider network faster. This is a big reason most companies have replaced their Frame Relay networks with MPLS service today. Last, you can use Ethernet with MPLS to connect a WAN, and this is called Ethernet over MPLS, or EoMPLS.

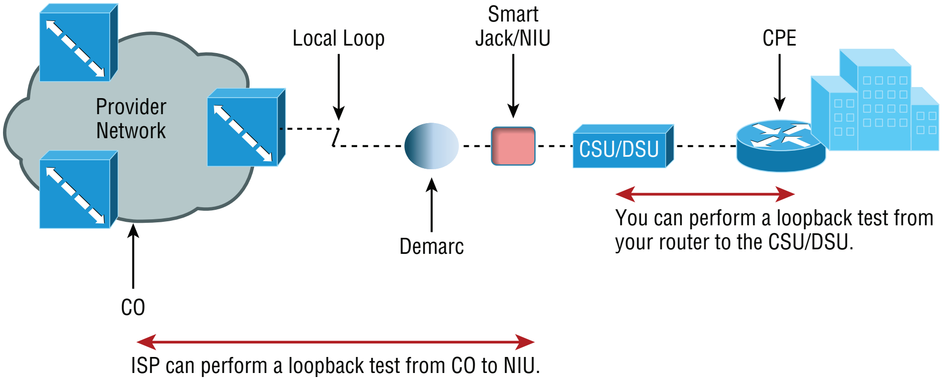
WAN Troubleshooting

Troubleshooting WANs can be tough at times because you don't control and own the physical lines. You definitely do receive the trouble tickets and stressful emails, but you're relying on someone else to do their job, and you have limited visibility in a lot of areas. However, that doesn't mean you're powerless, but it does mean that you've got to narrow the problem down to make sure you're working on the correct issue.

Loss of Internet Connectivity

The most common trouble ticket you'll receive is someone complaining about not being able to connect to the Internet. This issue can be caused by the WAN link dropping the CSU/DSU or internal wiring, but most of the time, it's due to an ISP issue. This doesn't mean you don't need to check your local physical WAN connections, though. A better approach is to double-check all your power to all devices, including the smart jack, and run a loopback test from the router to the CSU/DSU to verify that specific links come up locally. Figure 16.12 shows the different spots you would typically need to check out.

FIGURE 16.12 WAN troubleshooting spots


Provider Network
Local Loop
Smart Jack/NIU
CPE
CSU/DSU
Demarc
CO
You can perform a loopback test from your router to the CSU/DSU.
ISP can perform a loopback test from CO to NIU.

One more thing—if you have either a copper line driver or repeaters in your WAN link, you've got to be sure to check those connections too!

Interface Errors/Monitoring

There are a couple of key interfaces you need to check when verifying your WAN. If you have cable or DSL, you'll need to check into interface errors on the LAN port connecting to your router first. Let's take a look at an example to clarify how to use this information for interface monitoring to scrutinize errors, utilization, discards, packet drops, interface resets, and duplex issues:

```
Router#sh int fa0/0
FastEthernet0/0 is up, line protocol is up
[output cut]
  Full-duplex, 100Mb/s, 100BaseTX/FX
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input 00:00:05, output 00:00:01, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     1325 packets input, 157823 bytes
     Received 1157 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 watchdog
     0 input packets with dribble condition detected
     2294 packets output, 244630 bytes, 0 underruns
     0 output errors, 0 collisions, 3 interface resets
     347 unknown protocol drops
     0 babbles, 0 late collision, 0 deferred
     4 lost carrier, 0 no carrier
     0 output buffer failures, 0 output buffers swapped out
```

Link Status The first thing we'll check when there is a trouble ticket or our network management tools alert us of a link error is the link status. This is the first line in the output as shown. This would be the same on serial links as it is on Ethernet links.

```
Router#sh int fa0/0
FastEthernet0/0 is up, line protocol is up
```

The first up listed is carrier detect. If this shows down, then you have a physical layer problem locally and you need to get to that port stat and check the cable and port. The second statistic, which is `protocol is up` in this example, is keepalives from the remote end. If you see `up/down`, then you know your local end is good but you're not getting a digital signal from the remote end.

You've got to be able to analyze interface statistics to find problems there if they exist, so let's pick out the important factors relevant to meeting that challenge effectively now:

Speed and Duplex Settings Make a mental note that the most common cause of interface errors is a mismatched duplex mode between two ends of an Ethernet link. This is why it's so vital to verify that the switch and its hosts—PCs, router interfaces, cable modems, and so on—all have the same speed setting. If they don't, they just won't connect. And if they have mismatched duplex settings, you'll receive a legion of errors, which cause nasty performance issues, intermittent connectivity, and sometimes even a total loss of communication!

A common strategy is to use autonegotiation for speed and duplex, and it's enabled by default. But if this fails for some reason, you'll have to set the configuration manually like this:

```
Router(config)#int gi0/1
Router(config-if)#speed ?
  10    Force 10 Mbps operation
  100   Force 100 Mbps operation
  1000  Force 1000 Mbps operation
  auto  Enable AUTO speed configuration
Router(config-if)#speed 1000
Router(config-if)#duplex  ?
  auto  Enable AUTO duplex configuration
  full  Force full duplex operation
  half  Force half-duplex operation
Router(config-if)#duplex  full
```

If you have a duplex mismatch, a telling sign is that the late collision counter will increment.

Input Queue Drops If the input queue drops counter increments, this tells you that more traffic is being delivered to the router than it can process. If this value is consistently high, try to determine exactly when these counters are increasing and how the events relate to CPU usage. Know that you'll see the ignored and throttle counters increment as well.

Output Queue Drops This counter indicates that packets were dropped due to interface congestion, leading to lost data and queuing delays. When this occurs, applications like VoIP will experience performance issues. If you observe this constantly incrementing, consider QoS as the culprit.

Input Errors Input errors often indicate high-level errors such as CRCs. This can point to cabling problems, hardware issues, or duplex mismatches.

Output Errors This issue equals the total number of frames that the port tried to transmit when an issue such as a collision occurred.

These errors can also be caused by interference of the line itself, which means you'll have to call the ISP to sort them out.

On serial interface, start by checking out the physical connection to your router. Are you receiving clocking? This comes from the CSU/DSU. Check out the output to see how to do that:

```
Router>sh controllers s0/0
Interface Serial0/0
Hardware is PowerQUICC MPC860
DTE V.35 TX and RX clocks detected.
```

Okay, we've verified we're receiving clocking, so let's move on to look at the what the interface is telling us:

```
Router#sh int s0/0
Serial0/0 is up, line protocol is down
  Hardware is PowerQUICC Serial
  Description: Connection to CR1
  Internet address is 192.168.11.1/24
  MTU 1500 bytes, BW 1000 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation PPP, LCP Closed, loopback not set
  Keepalive set (10 sec)
  CRC checking enabled
  Last input never, output never, output hang never
  Last clearing of "show interface" counters 00:02:58
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
    1565789 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     0 packets output, 0 bytes, 0 underruns
     0 output errors, 0 collisions, 2 interface resets
     0 output buffer failures, 0 output buffers swapped out
     0 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up

BR1#
```

See that? We can see a problem with this interface right there in the first line output. The Serial0/0 is up, but the line protocol is down, which tells us that our local router interface connecting to the CSU/DSU is working, but we're still not seeing the remote router. Once in a while this indicates a remote router problem, but it's usually an ISP issue. So again, it means you've got to call into the ISP if you're getting this error. And look at all those input errors! This is screaming that you've got a troubled line—probably some type of interference, which needs to be reported.

Split Horizon

Split horizon issues usually happen when using Frame Relay in an environment where you have multiple PVCs coming into a single serial WAN interface. This configuration makes the routing protocol think that it's receiving routes on the same interface that they were being sent out of, which in this case would result in the routes being dropped. A great way to solve this problem is to create subinterfaces (logical interfaces) on the serial interface to make the routing protocol believe there are multiple interfaces—one for each subnet—so the routing advertisement will be received. The configuration would go from looking like this:

```
interface Serial0/0
 ip address 10.1.12.1 255.255.255.0
 no ip directed-broadcast
 encapsulation frame-relay
```

to looking like this:

```
interface Serial0/0
 no ip address (notice there is no IP address on the physical interface!)
 no ip directed-broadcast
 encapsulation frame-relay
!
interface Serial0/0.102 point-to-point
 ip address 10.1.12.1 255.255.255.0
 no ip directed-broadcast
frame-relay interface-dlci 102
!
interface Serial0/0.103 point-to-point
 ip address 10.1.13.1 255.255.255.0
 no ip directed-broadcast
frame-relay interface-dlci 103
!
```

DNS Issues

Another issue that could make it appear as if the Internet connectivity has gone down completely involves DNS. If users cannot resolve names, it seems like everything is broken to them. The first step to solving a DNS issue is to understand exactly how your DNS is set up on your specific network. Do you have a local DNS server or are you using the ISP's DNS server? If you can ping a site, such as 74.125.228.50, but can't ping `www.google.com` from an internal host, you know you're dealing with a DNS resolution issue. Start by verifying the local DNS server, if you use one, and if that checks out, call the ISP.

Router Configurations

Router configurations can also be the culprit when WAN services just aren't working right. All you need is an admin that enters some routing protocol information incorrectly and your access to the Internet goes poof! So your first step is always to verify your default route to the ISP when troubleshooting the routers that connect you to the Internet.

By using the command `show ip route` on a router, we can see the routing table—a map of the internetwork that the router uses to make its forwarding decisions:

```
Router#sh ip route
Codes: L - local, C - connected, S - static,
[output cut]
        10.0.0.0/8 is variably subnetted, 6 subnets, 4 masks
C       10.0.0.0/8 is directly connected, FastEthernet0/3
L       10.0.0.1/32 is directly connected, FastEthernet0/3
C       10.10.0.0/16 is directly connected, FastEthernet0/2
L       10.10.0.1/32 is directly connected, FastEthernet0/2
C       10.10.10.0/24 is directly connected, FastEthernet0/1
L       10.10.10.1/32 is directly connected, FastEthernet0/1
S*      0.0.0.0/0 is directly connected, FastEthernet0/0
```

Verify the default route, which is the one that starts with an `S*`. If this route points to the wrong next hop or wrong exit interface, you're going to have some serious problems!

Company Security Policy

Another common culprit that can often cause WAN-related problems is the company security policy. For example, if there's a firewall blocking ports, say, on applications that need to get to the Internet, it mimics a WAN issue when the root of the problem is actually bad configuration on your firewall(s)!

Another common source of trouble tickets has to do with slow response time, which again can make it look as though it's the WAN link that's having issues. But again, it's possible that it's the security policy that's throttling bandwidth on certain applications. I can't tell you how typical this is these days! Many company policies block certain sites, demanding that you provide URL filtering to them, especially social media or streaming news feeds. People often refer to these security-oriented limitations as fair access policies or utilization limits, which are forced upon certain activities for several reasons but most often to preserve bandwidth.

Summary

In this chapter, you learned about the important issues involved in providing WAN connectivity between geographically separated network locations as well as about the different kinds of WAN connections, including point-to-point connections, circuit-switched service provider networks, and packet-switched service provider networks.

You also became aware of the impacts different transmission media and different distance parameters have on WAN connections. In addition, you learned about the choices for leased-line connections along with broadband technologies like *x*DSL and cable modems.

You studied the different WAN protocols and technologies used in connecting today's high-speed WANs, including ISDN, Frame Relay, ATM, and MPLS, and were equipped with helpful strategies to troubleshoot and solve common WAN connection issues.

Exam Essentials

Be able to differentiate the kinds of WAN technologies. You must be able to identify the speeds and capacities of the different remote-access and WAN technologies as well as the media over which they are implemented.

Identify the basic characteristics of various Internet access technologies. These include DSL, broadband cable, POTS, and fiber to the premises (PON). It is important to know the differentiating features of these access technologies. Know their advantages and disadvantages so you can identify the best use of each.

Be knowledgeable about the differences between circuit-switched and packet-switched technologies, and know which protocols use each. Frame Relay is a packet-switched technology, and ISDN is a circuit-switched digital solution. ATM is considered to be a cell-switched technology because it incorporates a 53-byte cell. Both MPLS and ATM are considered connection-oriented technologies because the connection is set up first.

Be clear about the differences involving speed and distance between different media and between different WAN protocols. The use of both wireless and fiber is growing, and their standards are facilitating faster speeds and coverage of greater distances.

Be able to differentiate cellular WAN technologies like HSPA+, WiMAX, and LTE. HSPA+ is considered 3.5G, while LTE and WiMAX are considered true 4G.

Be able to differentiate between the different WAN protocols and technologies, their relative costs and speeds, and the types of implementations for which each would serve as a best solution. ISDN is rarely used nowadays in its BRI configuration except for small home or office solutions. Frame Relay is relatively inexpensive, but service providers have overbooked their Frame Relay clouds, resulting in poor performance. ATM is fast but inefficient, and MPLS is fast and more efficient but complicated to administer.

Identify the two different domains of responsibility on a SIP trunk. The SIP trunk provides a connection between two different domains of responsibility, the Private Domain (responsibility of the organization), which is the network connected to the organization's PBX or unified communications server, and the Public Domain (responsibility of the provider), which is the part of the network that allows access into the PSTN (Public Switched Telephone Network) or PLMN (Public Land Mobile Network).

Describe the benefits of using DMVPN. These benefits include elimination of traffic between remote sites traversing the hub, elimination of additional bandwidth requirements at the hub, elimination of additional network delays, conservation of WAN bandwidth, lower costs for VPN circuits, and increased resiliency and redundancy.

Written Lab

You can find the answers to the written labs in Appendix A.

1. What is the greatest advantage of PSTN (POTS)?
2. Which technology uses the term *HFC*?
3. You have one serial port on your router but need to connect many remote sites. What WAN protocol could you consider as an option?
4. What is the maximum speed for T1?
5. What does the acronym DSL stand for?
6. Which WAN technologies are considered packet-switching networks?
7. Which cellular technologies are considered 4G?
8. Which WAN technology is considered a cell-switching network?
9. What are the different flavors of *x*DSL?
10. What is another name for PON?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following is not a WAN protocol or technology?
   - **A.** ATM
   - **B.** ISDN
   - **C.** MPLS
   - **D.** RIP

2. What OSI model layers do WAN protocols operate in?
   - **A.** Layer 6, Layer 4, Layer 2
   - **B.** Transport, Data Link, Network
   - **C.** Physical, Data Link, Network
   - **D.** Application, Data Link, Network

3. If you have a device in a telecommunications closet owned and installed by the telecommunications company (telco) and it's your responsibility to cable from this box to the CPE, which term should you use to refer to the device?
   - **A.** Customer premises equipment
   - **B.** Demarcation point
   - **C.** Toll network
   - **D.** Central office

4. You have an E1. How many DS0s are used in this point-to-point connection?
   - **A.** 24
   - **B.** 25
   - **C.** 30
   - **D.** 32

5. Where does the local exchange carrier responsibility end and your responsibility begin on a WAN link?
   - **A.** POP
   - **B.** Central office
   - **C.** Demarc
   - **D.** Smart jack

6. You have a small office, home office environment. What WAN technology would most likely be used?
   - **A.** T1
   - **B.** T3
   - **C.** Frame Relay
   - **D.** Cable modem

7. Which type of communication has a line speed of 1.544 Mbps (millions of bits per second)?
   - **A.** T3
   - **B.** T1C
   - **C.** T1
   - **D.** T4

8. Which cellular WAN technology has the best data rate?
   - **A.** HSPA
   - **B.** HSPA+
   - **C.** LTE
   - **D.** WiMAX

9. Which is not a common optical carrier level (OC-*x*)?
   - **A.** OC-1
   - **B.** OC-4
   - **C.** OC-12
   - **D.** OC-192

10. Which wireless protocol utilizes a short-range communications technology facilitating data transmission from fixed and/or mobile devices, creating wireless personal area networks (PANs)?
    - **A.** Bluetooth
    - **B.** Microwave radio relay
    - **C.** Comsat
    - **D.** Point-to-multipoint

11. What does the *x* in *x*DSL represent?
    - **A.** Wire type
    - **B.** Transmission speed
    - **C.** DSL type
    - **D.** Download speed

12. Which is not a type of *x*DSL?
    - **A.** ADSL
    - **B.** HDSL
    - **C.** SONET
    - **D.** SDSL

13. What does the acronym DOCSIS stand for?
    - **A.** Data over cable service interface spectrum
    - **B.** Data over cable systems Internet specification
    - **C.** Data over cable service Internet specification
    - **D.** Data over cable service interface specifications

14. What is the bandwidth for OC-12?

A. 1.544 Mbps

B. 45 Mbps

C. 622 Mbps

D. 1000 Mbps

15. Which WAN protocol utilizes cell-switching technology?

A. Frame Relay

B. ISDN

C. ATM

D. RIP

16. Which WAN protocol utilizes packet-switched technology?

A. Frame Relay

B. ISDN

C. ATM

D. RIP

17. What is the CIR in Frame Relay?

A. Virtual circuit that is established when data needs to be transmitted

B. Maximum speed at which the Frame Relay interface can transmit

C. Rate at which the Frame Relay switch guarantees to transfer data

D. Rate at which the Frame Relay switch agrees to receive data

18. You are having DSL Internet connection issues and time-outs. You check the interface on your router and notice a lot of input errors. What could the problem be?

A. CSU/DSU

B. Demarc

C. Duplex configuration

D. Clocking is down

19. Which part of a SIP trunk is the responsibility of the provider?

A. Private domain

B. Community domain

C. Public domain

D. External domain

20. Which technology can eliminate VPN traffic between remote sites traversing the hub?

A. DMVPN

B. SIP trunk

C. DMDW

D. DNSSEC

Chapter 17

Troubleshooting Tools

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **5.2 Given a scenario, use the appropriate tool**

- Software tools
  - Command line
    - ping
    - tracert, traceroute
    - nslookup
    - ipconfig
    - ifconfig
    - iptables
    - netstat
    - tcpdump
    - pathping
    - nmap
    - route
    - arp
    - dig

Most of us are running Transmission Control Protocol/Internet Protocol (TCP/IP) version 4 on our networks these days, so we absolutely need a way to test IP connectivity. But we also need to be able to test and verify IPv6 networks. The reason for this is that even though Microsoft makes the majority of client platforms, a lot of the commands used to test IP connectivity are really platform independent, and most of the platforms can now use both IPv4 and IPv6. Even so, keep in mind that the Network+ exam focuses on the basic concepts of the function and use of the TCP/IP utilities that come with Windows.

You can use several utilities, both command line and GUI, to verify TCP/IP function on Windows workstations, and most of them are listed in the chapter objectives. Here's a list of all the utilities I'm going to discuss:

- `Traceroute` (`tracert` in Microsoft)
- `ipconfig/winipcfg` (`ifconfig` in Unix)
- `ping`
- `arp`
- `nslookup` (`dig` in Unix)
- `Mtr` (pathping)
- `route`
- `nbtstat`
- `netstat`
- `ftp`
- `telnet`

And by the way, it's very important that you don't just blow through the output that I've supplied for each command. Instead, pay serious attention to it because to meet the Network+ objectives, you'll be required to correctly identify each command's output.

So, let's cut right to the chase and take a look at some of these commands and their output. Oh, and do try and have fun with it!

NOTE

To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Protocol Analyzers

Protocol analyzers, also called sniffers or network monitors, are used to capture packets in their raw format as they cross the network. Windows desktop operating systems before Windows Vista came with a built-in protocol analyzer called Network Monitor, but that is no longer the case, although you can download one for free that will work with the newer operating systems.

The Network Monitor tool that comes with these operating systems will capture only packets that are sourced from or destined to the computer on which the tool is running. Commercial sniffers like Wireshark and Omnipeek can capture any packets because they set the NIC to operate in promiscuous mode, which means the NIC processes all packets that it sees.

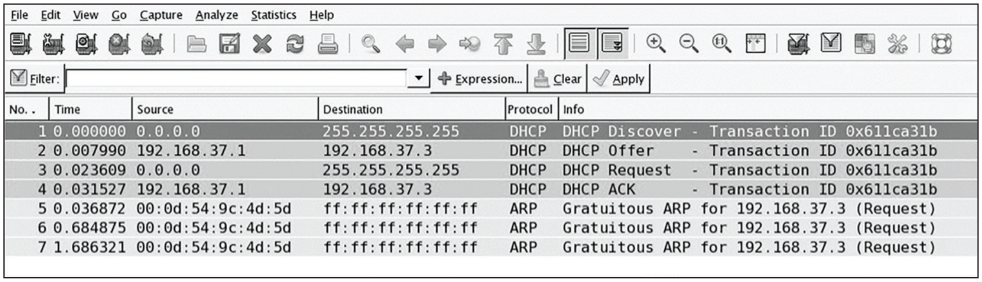
Protocol analyzers can be used to determine the type of traffic that you have in your network, and depending on the product and the bells and whistles contained therein, you may be able to sort the results based on port numbers, protocols, and so on. Another use of a sniffer is to examine the traffic that should be occurring on the network when something is not working to aid in troubleshooting. These devices can capture and display all packets involved in the connection setup, including, for example, request and response headers to a web server.

For example, earlier in the book we discussed the operation of DHCP, and you learned that there are a series of four packet types that must occur for a DHCP client to receive an IP configuration from the server. As a review, those packets are as follows:

- DHCP Discover
- DHCP Offer
- DHCP Request
- DHCP ACK

If you turned on the analyzer and then executed the `ipconfig/release` and `ipconfig/renew` commands on the client (more on those commands later in this chapter), you should see these four packets in the analyzer's capture file. The packets would be interspersed with the hundreds and perhaps thousands of other packet types that would be captured, but by using the display filtering options in the software, you can easily segregate out the DHCP traffic. An example of the DHCP process, as seen in a capture, is shown in Figure 17.1.

FIGURE 17.1 DHCP capture



No. .	Time	Source	Destination	Protocol	Info
1	0.000000	0.0.0.0	255.255.255.255	DHCP	DHCP Discover - Transaction ID 0x611ca31b
2	0.007990	192.168.37.1	192.168.37.3	DHCP	DHCP Offer - Transaction ID 0x611ca31b
3	0.023609	0.0.0.0	255.255.255.255	DHCP	DHCP Request - Transaction ID 0x611ca31b
4	0.031527	192.168.37.1	192.168.37.3	DHCP	DHCP ACK - Transaction ID 0x611ca31b
5	0.036872	00:0d:54:9c:4d:5d	ff:ff:ff:ff:ff:ff	ARP	Gratuitous ARP for 192.168.37.3 (Request)
6	0.684875	00:0d:54:9c:4d:5d	ff:ff:ff:ff:ff:ff	ARP	Gratuitous ARP for 192.168.37.3 (Request)
7	1.686321	00:0d:54:9c:4d:5d	ff:ff:ff:ff:ff:ff	ARP	Gratuitous ARP for 192.168.37.3 (Request)

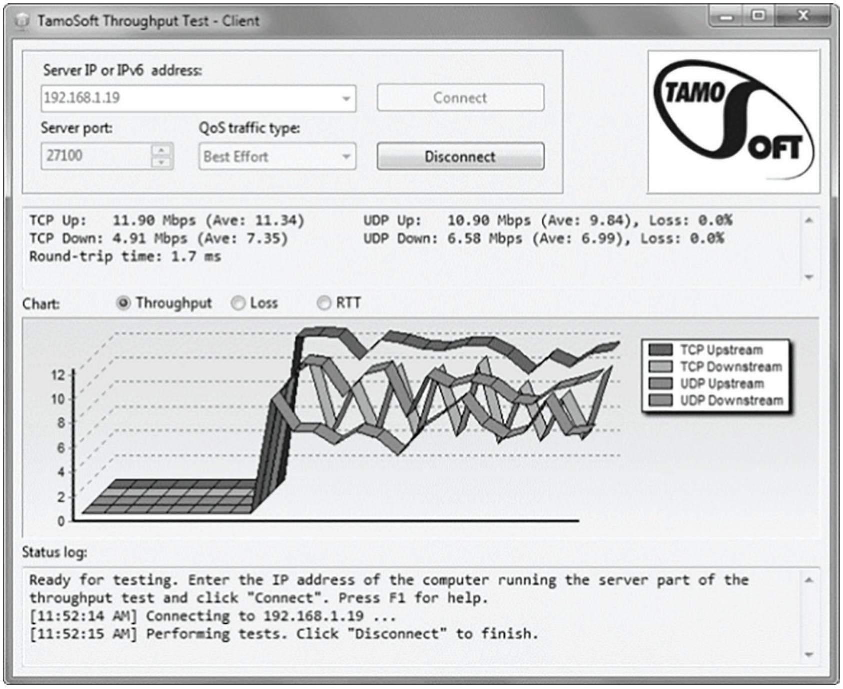
If all you saw in the capture were the DHCP Discover packets with no DHCP Offer packets, you could reasonably assert that the DHCP server is not receiving the DHCP Discover packets (perhaps it is located in another broadcast domain or perhaps it is not on). Additionally, you could examine fields in the DHCP Offer packets that may tell you that the DHCP server is out of addresses. The point is that the tool can be used to troubleshoot the issue.

Throughput Testers

Users of a network often complain about the speed of the network. Network "speed" is in some ways a personal perception because some people have more patience than others. To determine when a network slowdown is real as opposed to perceived, you need to actually measure the throughput. That's what throughput testers are used for.

These devices, typically software based, work much like a protocol analyzer in that they measure the traffic seen on the network and can also classify the types of traffic that are eating up your bandwidth (which is probably what you really need to know). Figure 17.2 shows one version of this software by TamoSoft.

FIGURE 17.2 Throughput



Server IP or IPv6 address: 192.168.1.19

Server port: 27100

QoS traffic type: Best Effort

```
TCP Up:   11.90 Mbps (Ave: 11.34)        UDP Up:   10.90 Mbps (Ave: 9.84), Loss: 0.0%
TCP Down: 4.91 Mbps (Ave: 7.35)          UDP Down: 6.58 Mbps (Ave: 6.99), Loss: 0.0%
Round-trip time: 1.7 ms
```

Chart: ● Throughput ○ Loss ○ RTT

Status log:

```
Ready for testing. Enter the IP address of the computer running the server part of the
throughput test and click "Connect". Press F1 for help.
[11:52:14 AM] Connecting to 192.168.1.19 ...
[11:52:15 AM] Performing tests. Click "Disconnect" to finish.
```

This software is installed on a server and also on a client. In the figure, the software is measuring traffic between the client and a server. It shows the throughput for traffic in real time and in this shot is breaking that traffic up by unicast (TCP) and broadcast (UDP) types and by direction.

Earlier in this book, I discussed the importance of baselines, and this is another area where they are important. Network throughput figures mean little without a baseline with which comparisons can be made. How do you know what is abnormal when you don't know what normal is? Baselines should be taken when the network is operating well, but they should also be taken when the traffic load is normal.

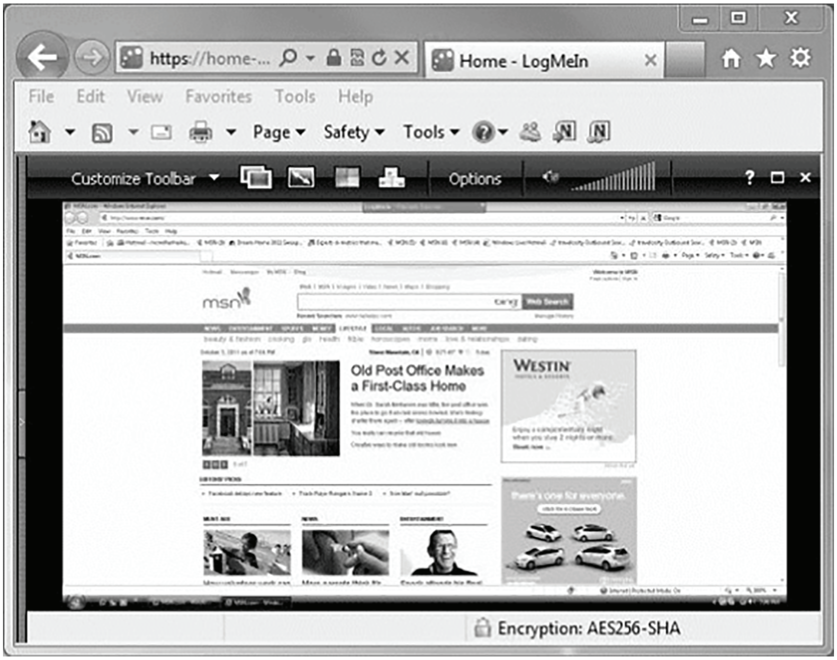
Connectivity Software

There are times when you need to make a remote connection to a machine to perform troubleshooting but you are miles away. Connectivity software is designed to allow you to make a connection to the machine, see the desktop, and perform any action you could perform if you were sitting in front of it.

Microsoft has made what it calls Remote Desktop software available for free with Windows products since Windows NT. When this software is installed (installed by default in later versions) on both source and destination computers, a remote desktop connection can be made.

Commercial tools are also available that (of course) claim to have more functionality, and they probably do have a few extra bells and whistles. These include LogMeIn.com, GoToMyPC, and others. Figure 17.3 shows the session window for a LogMeIn.com session.

FIGURE 17.3 LogMeIn



Encryption: AES256-SHA

The advantages of these connectivity tools are obvious. With these tools, you can do anything you need to on the machine as long as you can connect. They also allow you to see what a user is actually doing when they encounter a problem rather than having to rely on what they tell you they are doing. You can even show a user what they are doing wrong. Most of these tools allow for chat sessions and for either end of the connection to take control of the machine. You can also transfer files to them if required (maybe a DLL got deleted, for example).

Using *traceroute*

For starters, let's pose these questions: Where do all those packets really go when we send them over the Internet? And, how do all the packets actually get to their destinations? Well, we can use the TCP/IP `traceroute` (`tracert` with Windows) command-line utility to help us answer both questions because its output will show us every router interface a TCP/IP packet passes through on the way to its destination.

`Traceroute` (`trace` for short) displays the path a packet takes to get to a remote device in all its glory by using something we call IP packet Time to Live (TTL) time-outs and Internet Control Message Protocol (ICMP) error messages. And it's also a handy tool for troubleshooting an internetwork because we can use it to figure out which router along a path through that internetwork happens to be causing a network failure when a certain destination machine or network is, or suddenly becomes, unreachable.

To use `tracert`, at a Windows command prompt, type **`tracert`**, a space, and the Domain Name Service (DNS) name or IP address of the host machine to which you want to find the route. The `tracert` utility will respond with a list of all the DNS names and IP addresses of the routers that the packet is passing through on its way. Plus, `tracert` uses TTL to indicate the time it takes for each attempt.

Following is the `tracert` output from my workstation in Boulder, Colorado, to my `Lammle.com` server in Dallas, Texas:

```
C:\Users\tlammle>tracert www.lammle.com

Tracing route to lammle.com [206.123.114.186]
over a maximum of 30 hops:

  1     1 ms    <1 ms    <1 ms  dslmodem.domain.actdsltmp [192.168.0.1]
  2    53 ms    52 ms    52 ms  hlrn-dsl-gw36-228.hlrn.qwest.net [207.225.112.228]
  3    52 ms    53 ms    52 ms  hlrn-agw1.inet.qwest.net [71.217.189.25]
  4    75 ms    75 ms    74 ms  dal-core-01.inet.qwest.net [67.14.2.53]
  5    76 ms    76 ms    76 ms  dap-brdr-01.inet.qwest.net [205.171.225.49]
  6    76 ms    76 ms    76 ms  205.171.1.110
  7    75 ms    76 ms   106 ms  xe-0-0-0.er2.dfw2.us.above.net [64.125.26.206]
  8    76 ms    76 ms    76 ms  209.249.122.74.available.above.net [209.249.122.74]
  9    76 ms    76 ms    76 ms  65.99.248.250
 10    76 ms    76 ms    76 ms  pageuppro.pageuppro.com [206.123.114.186]
Trace complete.
```

Were you able to see that the packet bounces through several routers before arriving at its destination? Good! This utility is useful if you are having problems reaching a web server on the Internet and you want to know if a wide area network (WAN) link is down or if the server just isn't responding. What this means to you is that, basically, wherever the trace stops is a great place to start troubleshooting. No worries here, though—the previous output shows that every router is up and responding. Last, notice in the output the `ms`. This is the latency of each hop, meaning the delay. `Tracert` (or `traceroute`) is a great troubleshooting tool you can use to find out where your network bottlenecks are.

If you use `traceroute` or `tracert` and receive an asterisk, this indicates that the attempt to reach that router took longer than the default time-out value. This is very good to know because it can mean that either the router is extremely busy or a particular link is slow. Another reason for getting an asterisk could be that the administrator has disabled ICMP on the router that the packet is trying to hop through.

Why would someone want to do that? For security reasons, that's why. It happens to be a typical strategic move done on the routers that interface to the ISP to conceal their actual location so bad guys can't hack into them and therefore into your internetwork. It's a good idea, and I highly recommend doing it.

NOTE If you are running `traceroute` and see repeating addresses and TTL time-outs, you probably have a routing loop.

In addition to `traceroute` and `tracert`, you can use `pathping`, which is a lot like `traceroute`:

```
C:\Users\Todd Lammle>pathping lammle.com
Tracing route to lammle.com [184.172.53.52]
over a maximum of 30 hops:
  0  WIN-Q14VTD8DH0G.localdomain [192.168.133.147]
  1  192.168.133.2
  2     *        *        *
Computing statistics for 25 seconds...
            Source to Here   This Node/Link
Hop  RTT    Lost/Sent = Pct  Lost/Sent = Pct  Address
  0                   WIN-Q14VTD8DH0G.localdomain [192.168.133.147]
                                0/ 100 =  0%   |
  1    0ms     0/ 100 =  0%     0/ 100 =  0%  192.168.133.2

Trace complete.

C:\Users\Todd Lammle>
```

This provides a nice feedback at the end of the output.

NOTE In addition to `traceroute` and `tracert`, which show the path of an IPv4 packet, you can use `tracert -6` for a Windows trace, `traceroute6` for MAC and Unix, and `traceroute -6` for Cisco routers to trace an IPv6 packet through an internetwork.

Using *ipconfig* and *ifconfig*

The utilities known as `ipconfig` (in Windows) and `ifconfig` (in Unix/Linux/Mac) will display the current configuration of TCP/IP on a given workstation—including the current IP address, DNS configuration, Windows Internet Naming Service (WINS) configuration, and default gateway. In the following sections, I will show you how to use both.

Using the *ipconfig* Utility

With the new Mac, Windows 10, and Windows Server 2016 operating systems, you can now see the IPv6 configuration because IPv6 is enabled by default. The output of the `ipconfig` command provides the basic routed protocol information on your machine. From a DOS prompt, type **`ipconfig`**, and you'll see something like this:

```
C:\Users\tlammle>ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  . : domain.actdsltmp
   Link-local IPv6 Address . . . . . : fe80::2836:c43e:274b:f08c%11
   IPv4 Address. . . . . . . . . . . : 192.168.0.6
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.0.1

Wireless LAN adapter Wireless Network Connection:
   Connection-specific DNS Suffix  . : qwest.net
   Link-local IPv6 Address . . . . . : fe80::20e7:7fb8:8a00:832b%10
   IPv4 Address. . . . . . . . . . . : 10.0.1.198
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : fe80::21b:63ff:fef3:3694%10
                                       10.0.1.1

Tunnel adapter Local Area Connection* 6:
   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
```

```
Tunnel adapter Local Area Connection* 7:
   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
 [output cut for brevity]
```

Wow, there sure are a lot of options in this output compared to the output for earlier versions of Windows! First, what's up with all these interfaces showing? I only have two—one Ethernet and one wireless. You can see that my Ethernet adapter shows up first, and it has an IP address, a mask, and a default gateway plus an IPv6 address and a DNS suffix. The next configured interface is the wireless local area network (LAN) adapter, which has an IP address, a mask, a default gateway, an IPv6 address, and the IPv6 default gateway as well. This IPv6 default gateway address is simply my router advertising that it runs IPv6 and saying, "I am the way out of the local LAN!"

The next adapters are disconnected because they are logical interfaces and I'm not using them—my machine actually shows eight, but I cut the output because it provides no new information. They're automatically inserted because IPv6 is installed and running on my machine, and these adapters allow me to run IPv6 over an IPv4-only network.

But just in case the `ipconfig` command doesn't provide enough information for you, try the `ipconfig /all` command—talk about details. Here's the beginning of that output:

```
C:\Users\tlammle>ipconfig /all
Windows IP Configuration
   Host Name . . . . . . . . . . . . : globalnet-todd
   Primary Dns Suffix  . . . . . . . : globalnet.local
   Node Type . . . . . . . . . . . . : Hybrid
   IP Routing Enabled. . . . . . . . : No
   WINS Proxy Enabled. . . . . . . . : No
   DNS Suffix Search List. . . . . . : globalnet.local
                                       domain.actdsltmp
                                       qwest.net

Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  . : domain.actdsltmp
   Description . . . . . . . . . . . : Intel(R) 82566MM Gigabit
Network Connection
   Physical Address. . . . . . . . . : 00-1E-37-D0-E9-35
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::2836:c43e:274b:f08c%11(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.0.6(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Monday, October 20, 2008 9:08:36 AM
   Lease Expires . . . . . . . . . . : Tuesday, October 21, 2008 9:08:39 AM
   Default Gateway . . . . . . . . . : 192.168.0.1
   DHCP Server . . . . . . . . . . . : 192.168.0.1
   DNS Servers . . . . . . . . . . . : 192.168.0.1
                                       205.171.3.65
   NetBIOS over Tcpip. . . . . . . . : Enabled

Wireless LAN adapter Wireless Network Connection:
   Connection-specific DNS Suffix  . : qwest.net
   Description . . . . . . . . . . . : Intel(R) Wireless WiFi Link 4965AGN
   Physical Address. . . . . . . . . : 00-1F-3B-3F-4A-D9
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::20e7:7fb8:8a00:832b%10(Preferred)
   IPv4 Address. . . . . . . . . . . : 10.0.1.198(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Monday, October 20, 2008 10:43:53 AM
   Lease Expires . . . . . . . . . . : Monday, October 20, 2008 2:43:53 PM
   Default Gateway . . . . . . . . . : fe80::21b:63ff:fef3:3694%10
                                       10.0.1.1
   DHCP Server . . . . . . . . . . . : 10.0.1.1
   DNS Servers . . . . . . . . . . . : 10.0.1.1
   NetBIOS over Tcpip. . . . . . . . : Enabled

Tunnel adapter Local Area Connection* 6:
   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : isatap.globalnet.local
   Physical Address. . . . . . . . . : 00-00-00-00-00-00-00-E0
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes

Tunnel adapter Local Area Connection* 7:
   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : isatap.{9572A79F-3A58-4E9B- 9BD0-8F6FF2F058FC}
   Physical Address. . . . . . . . . : 00-00-00-00-00-00-00-E0
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
[output cut]
```

As you can see, it's more of the same—a whole lot more. The most important thing I want you to notice is that I've received the hardware information about each interface, including the Media Access Control (MAC) address. Also significant is that I can see the Dynamic Host Configuration Protocol (DHCP) lease times and DNS addresses now.

But why stop here? There are two more valuable options you need to use with the `ipconfig` command. They are `/release` and `/renew`.

When you change networks, you need to get the IP address of that subnet and/or virtual LAN (VLAN). Windows 10 works most of the time without doing anything, but sometimes I do have to renew the IP configuration when changing networks. But that's easy—just type **`ipconfig /renew`** from a command prompt, and if you're connected to a DHCP server that's available, you'll then magically receive an IP address.

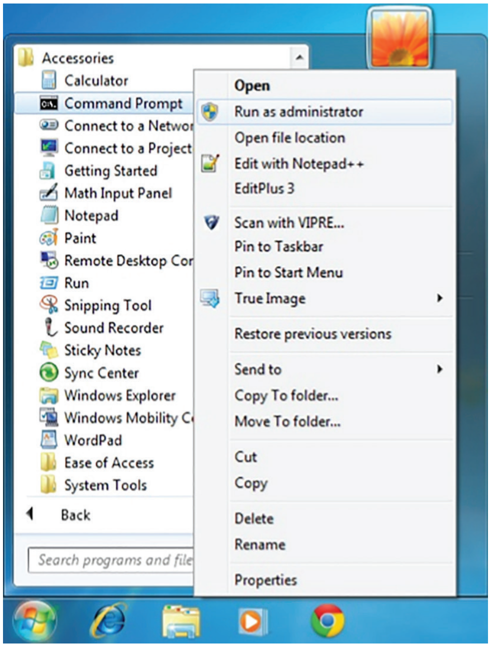
Now, if it still doesn't work, you'll need to release and renew your TCP/IP settings. To release your current DHCP TCP/IP information, you must elevate your command prompt or you'll get this warning:

```
C:\Users\tlammle>ipconfig /release
The requested operation requires elevation.
C:\Users\tlammle>
```

Should this happen to you, choose Start ➢ All Programs ➢ Accessories ➢ Command Prompt, right-click, and choose Run As Administrator. (Of course, you'll have to enter your name and password to do this if you are using Windows 7 or 10. But we love Windows 7 and 10, right? Okay, maybe not always.) Figure 17.4 shows how I did this.

Once your command prompt has been duly elevated, you can use the `ipconfig /release` command and then the `ipconfig /renew` command to get new TCP/IP information for your host.

FIGURE 17.4 Elevating your command prompt



Using the *ifconfig* Utility

There is a utility in Linux/Unix/Mac that will give you information similar to what `ipconfig` shows. It's called `ifconfig` (short for *interface configuration*). Although `ipconfig` and `ifconfig` show similar information, there are major differences between these two utilities. The `ipconfig` utility is mainly used to view the TCP/IP configuration for a computer. You can use `ifconfig` to do the same thing, but `ifconfig` can also be used to configure a protocol or a particular network interface.

The general syntax of the `ifconfig` command is as follows:

```
ifconfig interface [address [parameters]]
```

The `interface` parameter equals the Unix name of the interface, such as `eth0`. If the optional `address` parameter is specified, the `ifconfig` command sets the IP address for the interface to the address you've specified. When the `ifconfig` command is used by itself with no parameters, all configured interfaces will be reported on. But if only the interface name is specified, you'll get output that looks like this:

```
# ifconfig eth0
eth0  Link encap 10Mbps Ethernet  HWaddr 00:00:C0:90:B3:42
inetaddr 172.16.0.2 Bcast 172.16.0.255 Mask 255.255.255.0 UP
BROADCAST RUNNING  MTU 1500  Metric 0
   RX packets 3136 errors 217 dropped 7 overrun 26
   TX packets 1752 errors 25 dropped 0 overrun 0
```

Looking at this, we can see that the `eth0` interface is a 10 Mbps Ethernet interface. The interface's MAC and IP address information is displayed in this output as well. And, although not shown in the output, the `ifconfig` tool can show you the DNS information configured on the host.

Using the *iptables* utility

The `iptables` firewall utility is built for the Linux operating system. It is a command-line utility that uses what are called chains to allow or disallow traffic. When traffic arrives, `iptables` looks for a rule that addresses that traffic type, and if none exists, it will enforce the default rule. There are three different chain types:

- Input: Controls behavior for incoming connections
- Forward: Used for incoming connections that aren't being delivered locally (like a router would receive)
- Output: Used for outgoing connections

You can set the default action to accept, drop, or reject, with the difference between reject and drop being that reject sends an error message back to the source.

Examples of *iptables*

To block a connection from the device at 192.168.10.1, use this command:

```
iptables -A INPUT -s 192.168.10.1 -j DROP
```

To block all connections from all devices in the 172.16.0.0/16 network, use this command:

```
iptables -A INPUT -s 172.16.0.0/16 -j DROP
```

Here is the command to block SSH connections from 10.110.61.5:

```
iptables -A INPUT -p tcp --dport ssh -s 10.110.61.5 -j DROP
```

Use this command to block SSH connections from any IP address:

```
iptables -A INPUT -p tcp --dport ssh -j DROP
```

The following command is used to save the changes in Ubuntu:

```
sudo /sbin/iptables-save
```

In Red Hat/CentOS, use either of the following commands:

```
/sbin/service iptables save
/etc/init.d/iptables save
```

Using the *ping* Utility

The `ping` utility is the most basic TCP/IP utility, and it's included with most TCP/IP stacks for most platforms. Windows, again, is no exception. In most cases, `ping` is a command-line utility, although there are many GUI implementations available. You use the `ping` utility for two primary purposes:

- To find out if a host is responding
- To find out if you can reach a host

Here's the syntax (you can use either command):

```
ping hostname
ping IP address
```

If you ping any station that has an IP address, the ICMP that's part of that particular host's TCP/IP stack will respond to the request. The ICMP test and response looks something like this:

```
ping 204.153.163.2

Pinging 204.153.163.2 with 32 bytes of data:

Reply from 204.153.163.2: bytes=32 time<10ms TTL=128
Reply from 204.153.163.2: bytes=32 time=1ms TTL=128
Reply from 204.153.163.2: bytes=32 time<10ms TTL=128
Reply from 204.153.163.2: bytes=32 time<10ms TTL=128
```

Because I've received a reply from the destination station (204.153.163.2, in this case), I know that I can reach the host and that it's responding to basic IP requests. Don't forget that you can use name resolution and ping to a name, such as `ping www.sybex.com`, and as long as that name can be resolved, you're golden.

Most versions of `ping` work the same way, but there are some switches you can use to specify certain information, like the number of packets to send, how big a packet to send, and so on. And if you're running the Windows command-line version of `ping`, just use the `/?` or `-?` switch to display a list of the available options like this:

```
C:\Users\tlammle>ping /?

Usage: ping [-t] [-a] [-n count] [-l size] [-f] [-i TTL] [-v TOS]
       [-r count] [-s count] [[-j host-list] | [-k host-list]]
       [-w timeout] [-R] [-S srcaddr] [-4] [-6] target_name
```

The command will also output a table showing what each of the options does, presented here in Table 17.1.

TABLE 17.1 Options for `ping` switches

Option	Description
-t	Pings the specified host until stopped. To see statistics and continue, press Ctrl+Break; to stop, press Ctrl+C.
-a	Resolves addresses to hostnames.
-n *count*	Specifies the number of echo requests to send.
-l *size*	Sends the buffer size.
-f	Sets the Don't Fragment flag in the packet (IPv4 only).
-i *TTL*	Specifies the Time to Live of the packet.
-v *TOS*	Specifies the type of service (IPv4 only).
-r *count*	Records the route for count hops (IPv4 only).
-s *count*	Specifies the time stamp for count hops (IPv4 only).
-j *host-list*	Uses a loose source route along the host list (IPv4 only).

Option	Description
-k *host-list*	Uses a strict source route along the host list (IPv4 only).
-w *timeout*	Specifies the time-out to wait for each reply in milliseconds.
-R	Uses the routing header to test the reverse route also (IPv6 only).
-S *srcaddr*	Specifies the source address to use.
-4	Forces using IPv4.
-6	Forces using IPv6.

You can ping your local TCP/IP interface by typing **ping 127.0.0.1** or **ping localhost**. Understand that both addresses represent the local interface. Really, you can use any address in the 127.0.0.0 network range to provide a loopback test.

As you can see, there's a plethora of options you can use with the ping command from a Windows DOS prompt. But I really want you to focus on a few from the previous output. (I'm going to go over only a few of them, but you can get on your host machine and play with all the options.)

The -a switch is very cool because if you have name resolution (such as a DNS server), you can see the name of the destination host even if you only know its IP address. The -n switch sets the number of echo requests to send, where four is the default, and the -w switch allows you to adjust the time-out in milliseconds. The default ping time-out is 1 second (1,000 ms).

The -6 is also nice if you want to ping an IPv6 host. By the way, unless you really love typing 128-bit addresses, this is a wonderful example of how important name resolution is. And then there's -t, which keeps the ping running. Here's an example of a ping to an IPv6 address:

```
C:\Users\tlammle>ping -6 fe80::1063:16af:3f57:fff9

Pinging fe80::1063:16af:3f57:fff9 from fe80::1063:16af:3f57:fff9%25
with 32 bytes of data:
Reply from fe80::1063:16af:3f57:fff9: time<1ms
Reply from fe80::1063:16af:3f57:fff9: time<1ms
Reply from fe80::1063:16af:3f57:fff9: time<1ms
Reply from fe80::1063:16af:3f57:fff9: time<1ms

Ping statistics for fe80::1063:16af:3f57:fff9:
Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
Minimum = 0ms, Maximum = 0ms, Average = 0ms
C:\Users\tlammle>
```

From a MAC, you can use the ping6 command. Here are the options:

```
$ ping6
usage: ping6 [-DdfHmnNoqrRtvwW] [-a addrtype] [-b bufsiz] [-B boundif]
[-c count][-g gateway] [-h hoplimit] [-I interface] [-i wait] [-l preload][-p
pattern] [-S sourceaddr] [-s packetsize] [-z tclass]
[hops ...] host
```

And if I want to have a continuous ping, I just use that -t option like this:

```
C:\Users\tlammle>ping -t 192.168.0.1

Pinging 192.168.0.1 with 32 bytes of data:
Reply from 192.168.0.1: bytes=32 time=7ms TTL=255
Reply from 192.168.0.1: bytes=32 time=1ms TTL=255
Reply from 192.168.0.1: bytes=32 time=1ms TTL=255
Reply from 192.168.0.1: bytes=32 time=1ms TTL=255
Reply from 192.168.0.1: bytes=32 time=1ms TTL=255
Reply from 192.168.0.1: bytes=32 time=1ms TTL=255

Ping statistics for 192.168.0.1:
Packets: Sent = 6, Received = 6, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
Minimum = 1ms, Maximum = 7ms, Average = 2ms
Control-C
^C
C:\Users\tlammle>
```

This ping will just keep going and going like the Energizer Bunny until you press Ctrl+C. And by the way, it's an awesome tool for troubleshooting links.

Using the Address Resolution Protocol

The *Address Resolution Protocol (ARP)* is part of the TCP/IP protocol stack. It's used to translate TCP/IP addresses to MAC addresses using broadcasts. When a machine running TCP/IP wants to know which machine on an Ethernet network is using a certain IP address, it will send an ARP broadcast that says, in effect, "Hey…exactly who is IP address xxx.xxx.xxx.xxx?" The machine that owns the specific address will respond with its own MAC address, supplying the answer. The machine that made the inquiry will respond by adding the newly gained information to its own ARP table.

In addition to the normal usage, the ARP designation refers to a utility in Windows that you can use to manipulate and view the local workstation's ARP table.

The Windows ARP Table

The *ARP table* in Windows includes a list of TCP/IP addresses and their associated physical (MAC) addresses. This table is cached in memory so that Windows doesn't have to perform ARP lookups for frequently accessed TCP/IP addresses like those of servers and default gateways. Each entry contains an IP address and a MAC address plus a value for TTL that determines how long each entry will remain in the ARP table.

Remember that the ARP table contains two kinds of entries:

- Dynamic
- Static

Dynamic ARP table entries are created whenever the Windows TCP/IP stack performs an ARP lookup but the MAC address isn't found in the ARP table. When the MAC address of the requested IP address is finally found, or *resolved*, that information is then added into the ARP table as a dynamic entry. Whenever a request to send a packet to the host is sent to the Data Link layer, the ARP cache is checked first before an ARP broadcast is sent out. Remember, the ARP request is broadcast on the local segment—it does not go through a router.

NOTE The ARP table is cleared of dynamic entries whose TTL has expired to ensure that the entries are current.

Static ARP table entries serve the same function as dynamic entries but are made manually using the arp utility.

Using the *arp* Utility

You now know that ARP is a protocol included in the TCP/IP suite. You also understand that ARP is used by IP to determine the MAC address of a device that exists on the same subnet as the requesting device. When a TCP/IP device needs to forward a packet to a device on the local subnet, it first looks in its own table, called an *ARP cache* or *mac address lookup table*, for an association between the known IP address of the destination device on the local subnet and that same device's MAC address. The cache is called that because the contents are periodically weeded out.

If no association that includes the destination IP address can be found, the device will then send out an ARP broadcast that includes its own MAC and IP information as well as the IP address of the target device and a blank MAC address field. Filling in that blank is the object of the whole operation—it's the unknown value that the source device is requesting to be returned to it in the form of an ARP reply. Windows includes a utility called arp that allows us to check out the operating system's ARP cache. To view this, from a Windows DOS prompt, use the arp command like this:

```
C:\Uses\tlammle>arp

Displays and modifies the IP-to-Physical address translation tables used
by address resolution protocol (ARP).

ARP -s inet_addr eth_addr [if_addr]
ARP -d inet_addr [if_addr]
ARP -a [inet_addr] [-N if_addr] [-v]
```

Table 17.2 describes the various options that you can use with the arp command.

TABLE 17.2 arp options

Option	Description
-a	Displays current ARP entries by interrogating the current protocol data. If inet_addr is specified, the IP and physical addresses for only the specified computer are displayed. If more than one network interface uses ARP, entries for each ARP table are displayed.
-g	Same as -a.
-v	Displays current ARP entries in verbose mode. All invalid entries and entries on the loopback interface will be shown.
inet_addr	Specifies an Internet address.
-N	Displays the ARP entries for the network interface specified by if_addr.
-d	Deletes the host specified by inet_addr. inet_addr may be wildcarded with * to delete all hosts.
-s	Adds the host, and associates the Internet address inet_addr with the physical address eth_addr. The physical address is given as six hexadecimal bytes separated by hyphens. The entry is permanent.
eth_addr	Specifies a physical address.
if_addr	If present, specifies the Internet address of the interface whose address translation table should be modified. If not present, the first applicable interface will be used.

Sheesh. Looking at that output really makes me wish we were all just running IPv6 because, as you already should know, IPv6 doesn't need ARP as well as many other annoying features and protocols required when running IPv4.

Of note, the Windows arp utility is primarily useful for resolving duplicate IP addresses. For example, let's say your workstation receives its IP address from a DHCP server but it accidentally receives the same address that some other workstation gets. And so, when you try to ping it, you get no response. Your workstation is basically confused—it's trying to determine the MAC address, and it can't because two machines are reporting that they have the same IP address. To solve this little snag, you can use the arp utility to view your local ARP table and see which TCP/IP address is resolved to which MAC address.

To display the entire current ARP table, use the arp command with the -a switch like so to show you the mac address lookup table:

```
C:\Users\tlammle>arp -a

Interface: 192.168.0.6 --- 0xb
Internet Address      Physical Address      Type
192.168.0.1           00-15-05-06-31-b0     dynamic
192.168.0.255         ff-ff-ff-ff-ff-ff     static
224.0.0.22            01-00-5e-00-00-16     static
224.0.0.252           01-00-5e-00-00-fc     static
239.255.255.250       01-00-5e-7f-ff-fa     static
255.255.255.255       ff-ff-ff-ff-ff-ff     static

Interface: 10.100.10.54 --- 0x10
Internet Address      Physical Address      Type
10.100.10.1           00-15-05-06-31-b0     dynamic
10.100.10.255         ff-ff-ff-ff-ff-ff     static
224.0.0.22            01-00-5e-00-00-16     static
224.0.0.252           01-00-5e-00-00-fc     static
239.255.255.250       01-00-5e-7f-ff-fa     static
```

NOTE

By the way, the -g switch will produce the same result.

Now, from this output, you can tell which MAC address is assigned to which IP address. Then, for static assignments, you can tell which workstation has a specific IP address and if it's indeed supposed to have that address by examining your network documentation—you do have that record, right?

For DHCP-assigned addresses, you can begin to uncover problems stemming from multiple DHCP scopes or servers doling out identical addresses and other common configuration issues. And remember that under normal circumstances, you shouldn't see IP addresses in the ARP table that isn't a member of the same IP subnet as the interface.

NOTE If the machine has more than one network card (as may happen in Windows servers and on laptops with both Ethernet and wireless cards), each interface will be listed separately.

It's good to know that in addition to displaying the ARP table, you can use the `arp` utility to manipulate the table itself. To add static entries to the ARP table, you use the `arp` command with the `-s` switch. These static entries will stay in the ARP table until the machine is rebooted. A static entry essentially hardwires a specific IP address to a specific MAC address so that when a packet needs to be sent to that IP address, it will automatically be sent to that MAC address. Here's the syntax:

```
arp -s [IP Address] [MAC Address]
```

Simply replace the *[IP Address]* and *[MAC Address]* sections with the appropriate entries, like so:

```
arp -s 204.153.163.5 00-a0-c0-ab-c3-11
```

Now, take a look at your new ARP table by using the `arp -a` command. You should see something like this:

```
Internet Address        Physical Address        Type
204.153.163.5           00-a0-c0-ab-c3-11       static
```

Finally, if you want to delete entries from the ARP table, you can either wait until the dynamic entries time out or use the `-d` switch with the IP address of the static entry you'd like to delete, like this:

```
arp -d 204.153.163.5
```

Doing so effectively deletes the entry from the ARP table in memory.

NOTE The `arp` utility doesn't confirm successful additions or deletions (use `arp -a` or `arp -g` for that), but it will give you an error message if you use incorrect syntax.

Using the *nslookup* Utility

Whenever you're configuring a server or a workstation to connect to the Internet, you've got to start by configuring DNS if you want name resolution to happen (that is, if you want to be able to type **`www.sybex.com`** instead of an IP address). When configuring DNS, it's a very good thing to be able to test what IP address DNS is returning to ensure that it's working properly. The `nslookup` utility allows you to query a name server and quickly find out which name resolves to which IP address.

NOTE

The Unix `dig` (short for *domain information groper*) utility does the exact same thing as `nslookup`. It's primarily a command-line utility that allows you to perform a single DNS lookup for a specific entity, but it can also be employed in batch mode for a series of lookups. Detailed information on this command is beyond the scope of this study guide, but you can find more information on the Web by searching for "unix dig."

The `nslookup` utility comes with Windows NT and later as well as most versions of Unix and Linux, but not with Windows 95/98. You can run it from a Windows command prompt. At the command prompt, you can start the `nslookup` utility by typing **`nslookup`** and pressing Enter. When you're inside this utility, the command prompt will change from something similar to a `C:\>` sign to a shorter `>` sign. It will also display the name and IP address of the default DNS server you will be querying (you can change it, if necessary). Then you can start using `nslookup`. The following output gives you a sample of the display after the `nslookup` command has been entered at the `C:\>` prompt.

```
C:\Users\tlammle>nslookup
Default Server:  gnt-corpdc1.globalnet.local
Address:  10.100.36.12

>
```

The primary job of `nslookup` is to tell you the many different features of a particular domain name, the names of the servers that serve it, and how they're configured. To get that, just type in a domain name at the `>` prompt, and the `nslookup` utility will then return this information:

```
> lammle.com
Server:  dslmodem.domain.actdsltmp
Address:  192.168.0.1
```

The non-authoritative answer is as follows:

```
Name:    lammle.com
Address:  206.123.114.186
```

What this tells you is that the server that returned the information is not responsible (authoritative) for the zone information of the domain for which you requested an address and that the name server for the domain `lammle.com` is located at the IP address 206.123.114.186.

You can also ask `nslookup` for other information by setting a different option within `nslookup`. Just type ***`set option`*** at the `>` prompt and replace `option` with the actual option you want to use—for example, use `>set type=mx` to determine the IP address of your email server. If you can't decide which one you want, use the question mark (`?`) at the greater than sign (`>`) to see all available options.

If you type in **nslookup** and receive the reply

```
NS request timed out.
    timeout was 2 seconds.
***Can't find server name for address 206.123.114.186: Timed out
Default Server:  UnKnown
Address:  fec0:0:0:ffff::1
```

then you know your DNS servers are not answering. You need to get over to the DNS server, stat!

Resolving Names with the Hosts Table

The Hosts table is really a lot like DNS, except its entries are static for each and every host and server. Within the Hosts table, you'll find a collection of hostnames that devices reference for name-resolution purposes. And even though it works in both IPv4 and IPv6 environments, it's unlikely you will use it these days because the Hosts table is a way-ancient relic left over from old Unix machines.

But just because it's museum quality doesn't mean you won't run into it now and then, which is the main reason I'm showing it to you. You can find the Hosts table in `C:\Windows\System32\drivers\etc`. Just double-click the file, and then choose to open the file in Notepad or another text editor. Here's the default information—it's really nothing more than an explanation of how to use it and the local hosts for both IP and IPv6:

```
# Copyright (c) 1993-2006 Microsoft Corp.
#
# This is a sample HOSTS file used by Microsoft TCP/IP for Windows.
#
# This file contains the mappings of IP addresses to host names. Each
# entry should be kept on an individual line. The IP address should
# be placed in the first column followed by the corresponding host name.
# The IP address and the host name should be separated by at least one
# space.
#
# Additionally, comments (such as these) may be inserted on individual
# lines or following the machine name denoted by a '#' symbol.
#
# For example:
#
```

```
#      102.54.94.97     rhino.acme.com          # source server
#       38.25.63.10     x.acme.com              # x client host

127.0.0.1       localhost
::1             localhost
```

NOTE Any information entered to the right of a pound sign (#) in a Hosts file is ignored, so you can use this space for comments.

Because it's a plain ASCII text file, you add the IP address under the local hosts and then the name to which you want to resolve the IP address. It's a pretty simple configuration, and again, one I don't recommend using because you have to type in the names of every host on every machine in your network. DNS is definitely the name resolution of choice for networks today.

NOTE Do not get the Hosts table confused with the `hostname` command. The `hostname` command doesn't do much but display the name of your host, as shown here:

```
C:\Users\tlammle>hostname /?

Prints the name of the current host.

hostname

C:\Users\tlammle>hostname
globalnet-todd
```

Using the *Mtr* Command *(pathping)*

`Mtr`, or `My traceroute`, is a computer program that combines the functions of the `traceroute` and `ping` utilities in a single network diagnostic tool. It also adds round-trip time and packet loss to the output—very cool.

`Mtr` probes routers on the route path by limiting the number of hops individual packets are allowed to traverse and listening to news of their termination. It will regularly repeat this process (usually once per second) and keep track of the response times of the hops along the path.

`Mtr` is great if you have Linux or Unix, but by default, it's not installed on Windows devices. Third-party applications of `Mtr` are available to install on Windows, but Microsoft did respond with its own version of Mtr—it's called pathping and it provides the same functions as Mtr. Here's a look at the output and the options:

```
C:\Users\tlammle>pathping

Usage: pathping [-g host-list] [-h maximum_hops] [-i address] [-n]
                [-p period] [-q num_queries] [-w timeout]
                [-4] [-6] target_name
```

Table 17.3 lists the options of the Windows pathping command.

TABLE 17.3 pathping options

Option	Description
-g *host-list*	Uses a loose source route along the host list.
-h *maximum_hops*	Specifies the maximum number of hops to search for the target.
-i *address*	Uses the specified source address.
-n	Does not resolve addresses to hostnames.
-p *period*	Waits *period* milliseconds between pings.
-q *num_queries*	Specifies the number of queries per hop.
-w *timeout*	Waits *timeout* milliseconds for each reply.
-4	Forces using IPv4.
-6	Forces using IPv6.

NOTE The Mtr utility is basically the same as traceroute and ping, but it does give you some additional output that can help you troubleshoot your network.

Using the Nmap Utility

Nmap is one of the most popular port scanning tools used today. After performing scans with certain flags set in the scan packets, security analysts (and hackers) can make certain assumptions based on the responses received. These flags are used to control the TCP connection process and so are present only in TCP packets. Figure 17.5 show a TCP header with the important flags circled. Normally flags are "turned on" because of the normal TCP process, but hackers can craft packets to check the flags they wants to check.

FIGURE 17.5 TCP flags

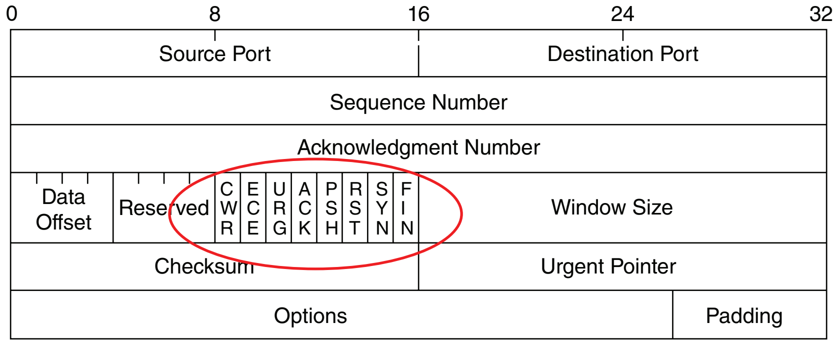


Figure 17.5 shows these flags, among others:

- URG: Urgent pointer field significant
- ACK: Acknowledgment field significant
- PSH: Push function
- RST: Reset the connection
- SYN: Synchronize sequence numbers
- FIN: No more data from sender

While application of a scan and interpretation of the responses are beyond the scope of this book, security analysts and hackers alike can perform scans with these flags set in the scan packets to get responses that allow them to determine the following information:

- If a port is open on a device
- If the port is blocked by a firewall before its gets to the device

Nmap can also be used as follows:

- To determine the live hosts on a network
- To create a logical "map" of the network

Using the *route* Command

I went over static routing in Chapter 9, "Introduction to IP Routing," so you know that Windows devices like routers perform routing. Most of the time, it's a good idea to leave Windows alone, but it's still good to know how to add and delete routes on your Windows machines.

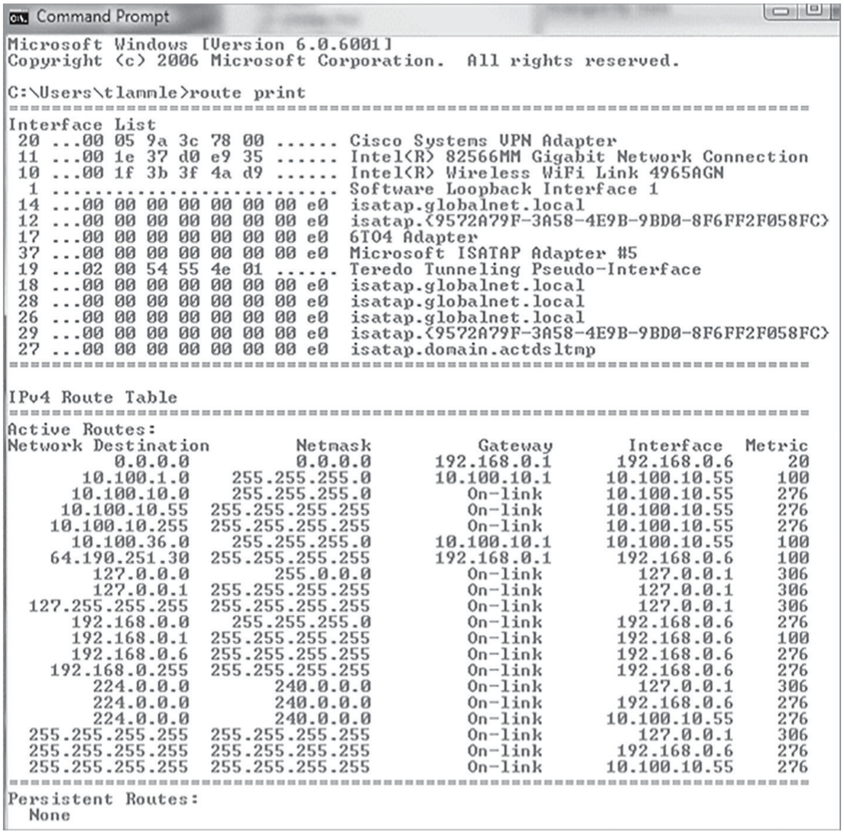
Probably the biggest reason for manipulating the routing table on a Windows server is to create a firewall. For instance, let's say we're running an Application layer firewall on a Windows server located between the demilitarized zone (DMZ) and the internal network.

This scenario would mean the routing that's happening on the server or hosts located in the DMZ wouldn't be able to reach the internal network's hosts and vice versa.

To circumvent this problem, we would need to employ both static and default routing because while Windows 10 and Windows Server versions support some routing protocols, running routing protocols on hosts and servers wouldn't be a good solution for today's networks, and Microsoft knows that.

To view the routing table on a Windows device, use the `route print` command, as shown in Figure 17.6.

FIGURE 17.6 `route print` output



```
Microsoft Windows [Version 6.0.6001]
Copyright (c) 2006 Microsoft Corporation.  All rights reserved.

C:\Users\tlammle>route print
===========================================================================
Interface List
 20 ...00 05 9a 3c 78 00 ...... Cisco Systems VPN Adapter
 11 ...00 1e 37 d0 e9 35 ...... Intel(R) 82566MM Gigabit Network Connection
 10 ...00 1f 3b 3f 4a d9 ...... Intel(R) Wireless WiFi Link 4965AGN
  1 ........................... Software Loopback Interface 1
 14 ...00 00 00 00 00 00 00 e0  isatap.globalnet.local
 12 ...00 00 00 00 00 00 00 e0  isatap.{9572A79F-3A58-4E9B-9BD0-8F6FF2F058FC}
 17 ...00 00 00 00 00 00 00 e0  6TO4 Adapter
 37 ...00 00 00 00 00 00 00 e0  Microsoft ISATAP Adapter #5
 19 ...02 00 54 55 4e 01 ...... Teredo Tunneling Pseudo-Interface
 18 ...00 00 00 00 00 00 00 e0  isatap.globalnet.local
 28 ...00 00 00 00 00 00 00 e0  isatap.globalnet.local
 26 ...00 00 00 00 00 00 00 e0  isatap.globalnet.local
 29 ...00 00 00 00 00 00 00 e0  isatap.{9572A79F-3A58-4E9B-9BD0-8F6FF2F058FC}
 27 ...00 00 00 00 00 00 00 e0  isatap.domain.actdsltmp
===========================================================================

IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0      192.168.0.1      192.168.0.6     20
      10.100.1.0    255.255.255.0      10.100.10.1     10.100.10.55    100
     10.100.10.0    255.255.255.0         On-link      10.100.10.55    276
    10.100.10.55  255.255.255.255         On-link      10.100.10.55    276
   10.100.10.255  255.255.255.255         On-link      10.100.10.55    276
     10.100.36.0    255.255.255.0      10.100.10.1     10.100.10.55    100
   64.190.251.30  255.255.255.255      192.168.0.1      192.168.0.6    100
       127.0.0.0        255.0.0.0         On-link         127.0.0.1    306
       127.0.0.1  255.255.255.255         On-link         127.0.0.1    306
 127.255.255.255  255.255.255.255         On-link         127.0.0.1    306
     192.168.0.0    255.255.255.0         On-link       192.168.0.6    276
     192.168.0.1  255.255.255.255         On-link       192.168.0.6    100
     192.168.0.6  255.255.255.255         On-link       192.168.0.6    276
   192.168.0.255  255.255.255.255         On-link       192.168.0.6    276
       224.0.0.0        240.0.0.0         On-link         127.0.0.1    306
       224.0.0.0        240.0.0.0         On-link       192.168.0.6    276
       224.0.0.0        240.0.0.0         On-link      10.100.10.55    276
 255.255.255.255  255.255.255.255         On-link         127.0.0.1    306
 255.255.255.255  255.255.255.255         On-link       192.168.0.6    276
 255.255.255.255  255.255.255.255         On-link      10.100.10.55    276
===========================================================================
Persistent Routes:
  None
```

In this output, you can see that each of the routes were added automatically when the system booted up. (This is all based on the configuration of your IP stack.) To see all the options available with the `route` command, type the `route` command and then press Enter. To add a route to your routing table, use the following syntax:

```
route [-f] [-p] [Command [Destination] [mask Netmask] [Gateway]
[metric Metric]] [if Interface]]
```

Using the *route* Command Options

Let's start with the switches you can use:

`-f` Using this command with any of the options like `add`, `change`, or `delete` will clear the routing table of all entries that aren't host routes (routes with the subnet mask 255.255.255.255), the loopback network route or routes (routes with a destination of 127.0.0.0 and the subnet mask 255.0.0.0), and any multicast routes (those with a destination of 224.0.0.0 and the subnet mask 240.0.0.0).

`-p` If you use this with the `add` command, the individual route will be added to the Registry and then used to initialize the IP routing table whenever TCP/IP is started. Important to remember is that by default, the routes you've statically added won't remain in the routing table the next time TCP/IP boots. And if you use `-p` with the `print` command, you'll get shown a list of the persistent routes that are stored in the Registry location of `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters\PersistentRoutes`.

Now, let's take a look at how and when you would use the `route` command. Table 17.4 shows the command options available and what they do when you are using the `route` command with them.

TABLE 17.4 `route` command options

Command	Purpose
`add`	Adds a route
`change`	Modifies an existing route
`delete`	Deletes a route (or routes)
`print`	Prints a route (or routes)

Here's a description of some other tasks you can accomplish via the rest of the command's options:

`Destination` This will give you the network destination of a given route. If the host bits of the network address are set to 0, it will be depicted with the destination's IP network address, an IP address for a specific host route, or the default route of 0.0.0.0.

`mask` **`netmask`** This will provide you with the *netmask*—often referred to as the *subnet mask*—that's associated with the destination network. The default destination subnet mask is 0.0.0.0, and typically you'll see 255.255.255.255 representing a host route. It's really important to remember that the destination address can't be more specific than its corresponding subnet mask. What I'm saying is that there absolutely can't be a bit set to 1 in the destination address if the equivalent bit in the subnet mask is a 0.

Gateway The gateway also depends on the network address and subnet mask, but it's even more specific and delimits what's called the *next-hop IP address*. For routes located on a local subnet, the gateway address maps directly to a particular interface. If the destination is on a remote network, the gateway IP address will direct packets to the neighboring router.

***metric* metric** *Metric* refers to the cost of a given route from the sending to the receiving device, and it's a value between 1 and 9999. Devices use this value to choose the best, or most efficient, routes among those in its routing table—the route with the lowest value wins. This decision can also include factors like the number of hops and the speed, reliability, and available bandwidth of the path being considered plus the various administrative aspects associated with it.

***if* interface** This tool depends on information from the gateway address and determines the interface index for the specific interface that needs to receive the data. You can get a list of interfaces along with their relevant interface indexes by typing the `route print` command.

/? Using this will allow you to view help at the command prompt.

Some Examples of the *route* Command

Even though the finer points of the `route` command demand that you use caution when deploying some of the options, I'll still list the basics of the `route` command because it can be really useful. I highly recommend that you spend some time practicing them on a non-production server, though—especially at first.

- To display the entire IP routing table, type **`route print`**.
- To add a default route with the default gateway address 192.168.10.1, type **`route add 0.0.0.0 mask 0.0.0.0 192.168.10.1`**.
- To add a route to the destination 10.1.1.0 with the subnet mask 255.255.255.0 and the next-hop address 10.2.2.2, type **`route add 10.1.1.0 mask 255.255.255.0 10.2.2.2`**.
- If you want to, let's say, add a persistent route to the destination 10.100.0.0 with the subnet mask 255.255.0.0 and the next-hop address 10.2.0.1, type **`route -p add 10.100.0.0 mask 255.255.0.0 10.2.0.1`**. If you want to delete the route to the destination 10.100.0.0 with the subnet mask 255.255.0.0, enter **`route delete 10.100.0.0 mask 255.255.0.0`**.
- And finally, if you want to change the next-hop address of a route with the destination 10.100.0.0 and the subnet mask 255.255.0.0 from 10.2.0.1 to 10.7.0.5, type **`route change 10.100.0.0 mask 255.255.0.0 10.7.0.5`**.

Let's move on to some other important Windows utilities.

Using the *nbtstat* Utility

Microsoft Windows uses an interface called Network Basic Input/Output System (NetBIOS), which relates names with workstations and is an upper-layer interface that requires a transport protocol—usually TCP/IP. But IPv6 can be used as well. Deploying the `nbtstat` utility will achieve these three important things:

- Track NetBIOS over TCP/IP statistics
- Show the details of incoming and outgoing NetBIOS over TCP/IP connections
- Resolve NetBIOS names

Understand that because NetBIOS name resolution is primarily a Windows network utility, the `nbtstat` command is available only in Windows-based operating systems.

To display a basic description of `nbtstat` and its associated options, type **`nbtstat`** at the command line. Then, use these options to get a display of information about NetBIOS over TCP/IP hosts. Here are some of the tools, or *switches*, you can use:

`-a`	`-A`
`-c`	`-n`
`-r`	`-R`
`-S`	`-s`

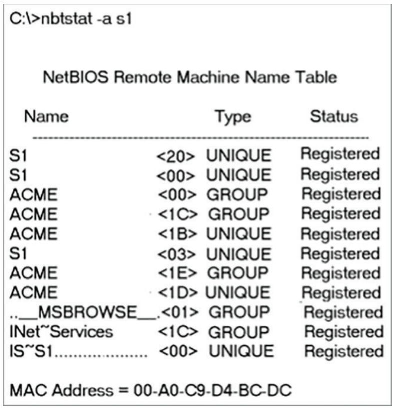
NOTE All `nbtstat` switches are case sensitive. Generally speaking, lowercase switches deal with NetBIOS names of hosts, and the uppercase ones deal with the TCP/IP addresses of hosts.

The –*a* Switch

Making use of the `-a` switch will get you a remote machine's NetBIOS name table consisting of a list of every NetBIOS name the machine from which you've deployed the switch knows of. The `-a` switch produced the output from server S1 shown in Figure 17.7.

So, using this switch arranges the NetBIOS name-table information in table form with output in four columns. The Name column displays the NetBIOS name entry for the remote host machine.

FIGURE 17.7 Sample output of the `nbtstat -a` command



```
C:\>nbtstat -a s1


     NetBIOS Remote Machine Name Table

   Name                 Type        Status
   ---------------------------------------------
S1                  <20>  UNIQUE     Registered
S1                  <00>  UNIQUE     Registered
ACME                <00>  GROUP      Registered
ACME                <1C>  GROUP      Registered
ACME                <1B>  UNIQUE     Registered
S1                  <03>  UNIQUE     Registered
ACME                <1E>  GROUP      Registered
ACME                <1D>  UNIQUE     Registered
..__MSBROWSE__.<01>  GROUP      Registered
INet~Services       <1C>  GROUP      Registered
IS~S1..........     <00>  UNIQUE     Registered

MAC Address = 00-A0-C9-D4-BC-DC
```

The next column gives you a unique two-digit hexadecimal identifier for the NetBIOS name. This identifier represents the last byte of the NetBIOS name depicted in the Name column, and it's important because the same name could actually be used several times for the same machine. Plus, it identifies the specific service on the particular host that the name is referencing. Table 17.5 and Table 17.6 list the hexadecimal identifiers for unique and group hostnames.

TABLE 17.5 Last-byte identifiers for unique names

Hex ID	Description
00	General name for the computer.
03	Messenger service ID used to send messages between a WINS server and a workstation. This is the ID registered with a WINS server.
06	Remote Access Server (RAS) server service ID.
20	File-serving service ID.
21	RAS client.
53	DNS.
123	Network Time Protocol (NTP).
1B	Domain master browser ID. A NetBIOS name with this ID indicates the domain master browser.

Hex ID	Description
1F	Network Dynamic Data Exchange (NetDDE) service ID.
BE	Network monitor agent ID.
BF	Network monitor utility ID.

The Type column refers to (surprise) the type of NetBIOS name being referenced. Unique NetBIOS names refer to individual hosts, and group names refer to logical groupings of workstations—either domains or workgroups.

The Status column gives you information about the status of a host's NetBIOS even if it hasn't been registered with the rest of the network.

TABLE 17.6 Last-byte identifiers for group names

Hex ID	Description
01	Master browser for a domain to other master browsers.
20	Internet group name ID. This ID is registered with the WINS server to indicate which computers are used for administrative purposes.
1C	Domain group name ID.
1D	Master browser name.
1E	Normal group name.

The –*A* Switch

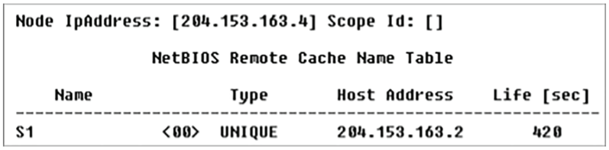
The `-A` switch works just like the `–a` switch and will give you the same output, but the syntax of the command is different. Obviously, you use an uppercase `A` instead of a lowercase one, and you also have to include the host's IP address instead of its NetBIOS name. To use it, type **`nbtstat`** followed by **`–A`** and finally the IP address of the specific host whose NetBIOS table you want to check out:

```
nbtstat -A 199.153.163.2
```

The –*c* Switch

Use the `-c` switch to display the local NetBIOS name cache on the workstation it's running on. Figure 17.8 shows sample output of the *`nbtstat -c`* command.

FIGURE 17.8 Sample output of the `nbtstat -c` command



```
Node IpAddress: [204.153.163.4] Scope Id: []

              NetBIOS Remote Cache Name Table

    Name              Type       Host Address    Life [sec]
------------------------------------------------------------
S1             <00>  UNIQUE      204.153.163.2       420
```

Each entry in this display shows the NetBIOS name, the hex ID for the service that was accessed, the type of NetBIOS name (unique or group), the IP address that the name resolves to, and its life. The Life value shows how many seconds each entry will live in the cache. When this time expires, the entry will be deleted.

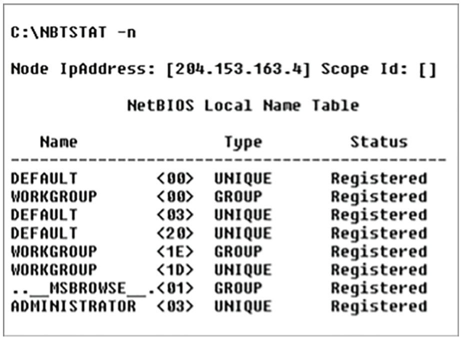
NOTE

Sometimes, deploying `nbtstat` to display the cache will get you the response "No names in the cache" because all entries in the cache have expired. This is what happens if you don't regularly access machines or services with NetBIOS names.

The –*n* Switch

The `-n` switch will give you the local NetBIOS name table on a Windows device. Figure 17.9 shows output that's similar to the output of the `-a` switch except for one important thing: What you're seeing is the NetBIOS name table for the machine you're running the command on instead of that of another host. Check it out.

FIGURE 17.9 Sample output of the `nbtstat -n` command



```
C:\NBTSTAT -n

Node IpAddress: [204.153.163.4] Scope Id: []

            NetBIOS Local Name Table

   Name                  Type         Status
---------------------------------------------
DEFAULT        <00>  UNIQUE      Registered
WORKGROUP      <00>  GROUP       Registered
DEFAULT        <03>  UNIQUE      Registered
DEFAULT        <20>  UNIQUE      Registered
WORKGROUP      <1E>  GROUP       Registered
WORKGROUP      <1D>  UNIQUE      Registered
..__MSBROWSE__.<01>  GROUP       Registered
ADMINISTRATOR  <03>  UNIQUE      Registered
```

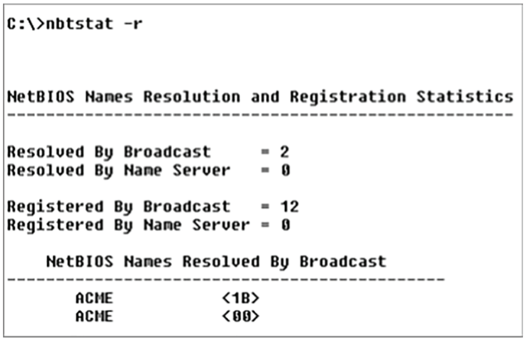
The –*r* Switch

This switch is probably the one you'll use most often when you want to get a hold of NetBIOS over TCP/IP (NBT) statistics because it tells you exactly how many NetBIOS names have been resolved to TCP/IP addresses. Figure 17.10 shows sample output of the `nbtstat -r` command.

What you can see here is that the statistics are divided into two categories. First, there are the NetBIOS names resolution and registration statistics. This is how many names have been resolved or registered either by broadcasts on the local segment or via lookup from a WINS name server.

Next you have the NetBIOS unique and group names and their associated hex IDs that were resolved or registered. In Figure 17.10, you can see that there's a distinct lack of information regarding names resolved by a name server. What this means is that the output is telling you that there's no WINS server operating—instead, all NetBIOS names were resolved by broadcast only.

FIGURE 17.10 Sample output of the `nbtstat -r` command



```
C:\>nbtstat -r


NetBIOS Names Resolution and Registration Statistics
----------------------------------------------------

Resolved By Broadcast     = 2
Resolved By Name Server   = 0

Registered By Broadcast   = 12
Registered By Name Server = 0

    NetBIOS Names Resolved By Broadcast
---------------------------------------------
       ACME           <1B>
       ACME           <00>
```

NOTE

The `-r` switch comes in handy when you want to determine how a workstation is resolving NetBIOS names and whether WINS is configured correctly. If WINS isn't configured correctly or it's simply not being used, the numbers in the Resolved By Name Server and Registered By Name Server categories will always be zero.

The –*R* Switch

Unlike the `-a` and `-A` switches, `-r` and `-R` use the same letter but do *not* have anything in common.

Here's an example. Let's say you have a bad name in the NetBIOS name cache but the right name is in the LMHOSTS file instead. (The LMHOSTS file contains NetBIOS names of stations and their associated IP addresses.) Because the cache is consulted before the LMHOSTS file is, that bad address will remain in the cache until it expires.

This command is used when you want to purge the NetBIOS name table cache and reload the LMHOSTS file into memory. You do that using the `nbtstat` command with the `-R` switch, like so:

```
nbtstat -R
```

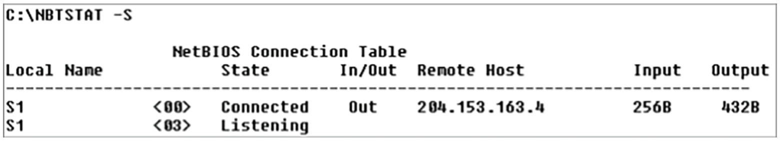
You can practice this `nbtstat -R` command on your host to purge the NBT remote cache table.

The –*S* Switch

Using the -S switch will display the NetBIOS sessions table that lists all NetBIOS sessions to and from the host from which you issued the command. The -S switch displays both workstation and server sessions but lists remote addresses by IP address only.

Figure 17.11 shows sample output of the nbtstat -S command.

FIGURE 17.11 Sample output of the nbtstat -S command



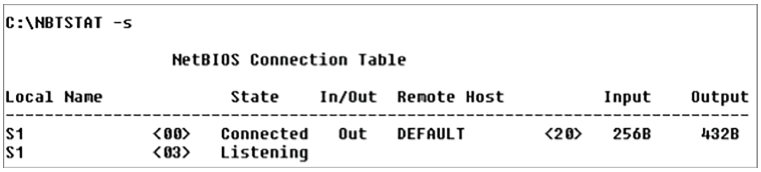
```
C:\NBTSTAT -S

                 NetBIOS Connection Table
Local Name            State       In/Out  Remote Host            Input   Output
----------------------------------------------------------------------------
S1            <00>    Connected    Out    204.153.163.4           256B     432B
S1            <03>    Listening
```

Here you can see the NetBIOS name being displayed along with its hex ID and the status of each session. An entry in the In/Out column determines whether the connection has been initiated from the computer on which you're running nbtstat (outbound) or whether another computer has initiated the connection (inbound). The numbers in the Input and Output columns indicate in bytes the amount of data transferred between the stations.

The –*s* Switch

As with the -A and -a switches, the lowercase -s switch is similar to its uppercase sibling. The nbtstat -s command produces the same output as nbtstat -S except that it will also attempt to resolve remote-host IP addresses into hostnames. Figure 17.12 shows sample output from the nbtstat -s command.

FIGURE 17.12 Sample output of the nbtstat -s command



```
C:\NBTSTAT -s

                 NetBIOS Connection Table

Local Name             State    In/Out  Remote Host          Input    Output
----------------------------------------------------------------------------
S1            <00>   Connected    Out   DEFAULT        <20>   256B      432B
S1            <03>   Listening
```

Note the similarities between Figure 17.11 and Figure 17.12.

As with the netstat command, with the nbtstat command you can place a number for an interval at the end to direct it to deploy once every so many seconds until you press Ctrl+C.

Using the *netstat* Utility

Using `netstat` is a great way to check out the inbound and outbound TCP/IP connections on your machine. You can also use it to view packet statistics like how many packets have been sent and received, the number of errors, and so on.

When used without any options, `netstat` produces output similar to the following, which shows all the outbound TCP/IP connections. This utility is a great tool to use to determine the status of outbound web connections. Take a look:

```
C:\Users\tlammle>netstat

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    10.100.10.54:49545     gnt-exchange:epmap     TIME_WAIT
  TCP    10.100.10.54:49548     gnt-exchange:epmap     TIME_WAIT
  TCP    10.100.10.54:49551     gnt-exchange:1151      ESTABLISHED
  TCP    10.100.10.54:49557     gnt-exchange:1026      ESTABLISHED
  TCP    10.100.10.54:49590     gnt-exchange:epmap     TIME_WAIT
  TCP    127.0.0.1:49174        globalnet-todd:62514   ESTABLISHED
  TCP    127.0.0.1:62514        globalnet-todd:49174   ESTABLISHED
  TCP    192.168.0.6:2492       blugro2relay:2492      ESTABLISHED
  TCP    192.168.0.6:2492       blugro3relay:2492      ESTABLISHED
  TCP    192.168.0.6:49170      64.12.25.26:5190       ESTABLISHED
  TCP    192.168.0.6:49171      oam-d05c:5190          ESTABLISHED
  TCP    192.168.0.6:49473      205.128.92.124:http    CLOSE_WAIT
  TCP    192.168.0.6:49625      64-190-251-21:ftp      ESTABLISHED
  TCP    192.168.0.6:49628      210-11:http            ESTABLISHED
  TCP    192.168.0.6:49629      varp1:http             ESTABLISHED
  TCP    192.168.0.6:49630      varp1:http             ESTABLISHED
  TCP    192.168.0.6:49631      varp1:http             ESTABLISHED
  TCP    192.168.0.6:49632      varp1:http             ESTABLISHED
  TCP    192.168.0.6:49635      199.93.62.125:http     ESTABLISHED
  TCP    192.168.0.6:49636      m1:http                ESTABLISHED
  TCP    192.168.0.6:49638      spe:http               ESTABLISHED
```

The Proto column lists the protocol being used. You can see that I'm connected to my Exchange server and an FTP server and that I have some HTTP sessions open; by the way, all of them use TCP at the Transport layer.

The Local Address column lists the source address and the source port (source socket). The Foreign Address column lists the address of the destination machine (the hostname if it's been resolved). If the destination port is known, it will show up as the well-known port. In the previous output, you see `http` instead of port 80 and `ftp` instead of port 21.

The State column indicates the status of each connection. This column shows statistics only for TCP connections because User Datagram Protocol (UDP) establishes no virtual circuit to the remote device. Usually, this column indicates ESTABLISHED when a TCP connection between your computer and the destination computer has been established. All sessions eventually time out and then close, and you can see that I have all of these listed in my netstat output.

NOTE If the address of either your computer or the destination computer can be found in the HOSTS file on your computer, the destination computer's name, rather than the IP address, will show up in either the Local Address or Foreign Address column.

The output of the netstat utility depends on the switch. By using the netstat /? command, we can see the options available to us.

```
C:\Users\tlammle>netstat /?
```

All of the netstat switch options are listed in Table 17.7.

TABLE 17.7 netstat options

Option	Description
-a	Displays all connections and listening ports.
-b	Displays the executable involved in creating each connection or listening port. In some cases, well-known executables host multiple independent components, and in these cases the sequence of components involved in creating the connection or listening port is displayed. Note that this option can be time consuming and will fail unless you have sufficient permissions.
-e	Displays Ethernet statistics. This may be combined with the -s option.
-f	Displays fully qualified domain names (FQDNs) for foreign addresses.
-n	Displays addresses and port numbers in numerical form.
-o	Displays the owning process ID associated with each connection.
-p *proto*	Shows connections for the protocol specified by *proto*; *proto* may be TCP, UDP, TCPv6, or UDPv6. If used with the -s option to display per-protocol statistics, *proto* may be IP, IPv6, ICMP, ICMPv6, TCP, TCPv6, UDP, or UDPv6.
-r	Displays the routing table.

Option	Description
`-s`	Displays per-protocol statistics. By default, statistics are shown for IP, IPv6, ICMP, ICMPv6, TCP, TCPv6, UDP, and UDPv6; the `-p` option may be used to specify a subset of the default.
`-t`	Displays the current connection offload state. Redisplays selected statistics, pausing interval seconds between each display. Press Ctrl+C to stop redisplaying statistics. If `-t` is omitted, `netstat` will print the current configuration information once.

Simply type **`netstat`** followed by a space and then the particular switch you want to use. Some switches have options, but no matter what, the syntax is basically the same.

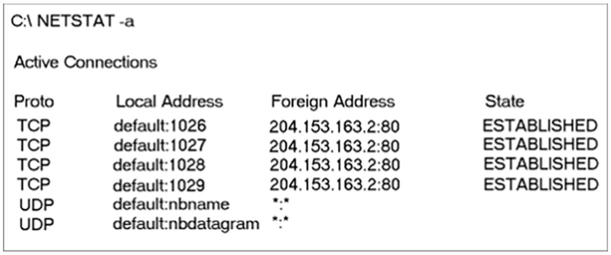
NOTE

Note that with Unix-type switches, the hyphen absolutely must be included. This is common in Microsoft operating systems for TCP/IP utilities that originate from Unix systems. I'm not going to exhaustively go over each and every switch, but make sure you practice all of these on your own Windows machine.

The –*a* Switch

When you use the `-a` switch, the `netstat` utility displays all TCP/IP connections and all UDP connections. Figure 17.13 shows sample output produced by the `netstat -a` command.

FIGURE 17.13 Sample output of the `netstat -a` command



```
C:\ NETSTAT -a

Active Connections

Proto     Local Address        Foreign Address        State
TCP       default:1026         204.153.163.2:80       ESTABLISHED
TCP       default:1027         204.153.163.2:80       ESTABLISHED
TCP       default:1028         204.153.163.2:80       ESTABLISHED
TCP       default:1029         204.153.163.2:80       ESTABLISHED
UDP       default:nbname       *:*
UDP       default:nbdatagram   *:*
```

The last two entries in Figure 17.13 show that the protocol is UDP and give the source-port nicknames nbname and nbdatagram. These are the well-known port numbers of 137 and 138, respectively. These port numbers are commonly seen on networks that broadcast the NetBIOS name of a workstation on the TCP/IP network. You can tell that this is a broadcast because the destination address is listed as *:* (meaning "any address, any port").

NOTE The State column in Figure 17.13 has no entry for the UDP rows because UDP is not a connection-oriented protocol and, therefore, has no connection state.

The most common use for the -a switch is to check the status of a TCP/IP connection that appears to be hung. You can determine if the connection is simply busy or is actually hung and no longer responding.

The –*e* Switch

The -e switch displays a summary of all the packets that have been sent over the Network Interface Card (NIC) as of that instant. The Received and Sent columns show packets coming in as well as being sent:

```
C:\Users\tlammle>netstat -e
Interface Statistics
                           Received            Sent

Bytes                       7426841         7226953
Unicast packets               25784           35006
Non-unicast packets            1115           12548
Discards                          0               0
Errors                            0              71
Unknown protocols                 0
```

You can use the -e switch to display the following categories of statistics:

Bytes The number of bytes transmitted or received since the computer was turned on. This statistic is useful for finding out if data is actually being transmitted and received or if the network interface isn't doing anything at all.

Unicast Packets The number of packets sent from or received at this computer. To register in one of these columns, the packet must be addressed directly from one computer to another and the computer's address must be in either the source or destination address section of the packet.

Non-unicast Packets The number of packets that weren't directly sent from one workstation to another. For example, a broadcast packet is a non-unicast packet. The number of non-unicast packets should be smaller than the number of unicast packets. If the number of non-unicast packets is as high as or higher than that of unicast packets, too many broadcast packets are being sent over your network. Definitely find the source of these packets and make any necessary adjustments to optimize performance.

Discards The number of packets that were discarded by the NIC during either transmission or reception because they weren't assembled correctly.

Errors The number of errors that occurred during transmission or reception. (These numbers may indicate problems with the network card.)

Unknown Protocols The number of received packets that the Windows networking stack couldn't interpret. This statistic only shows up in the Received column because if the computer sent them, they wouldn't be unknown, right?

Unfortunately, statistics don't mean much unless they can be colored with time information. For example, if the Errors row shows 71 errors, is that a problem? It might be if the computer has been on for only a few minutes. But 71 errors could be par for the course if the computer has been operating for several days. Unfortunately, the netstat utility doesn't have a way of indicating how much time has elapsed for these statistics.

The –*r* Switch

You use the -r switch to display the current route table for a workstation so that you can see exactly how TCP/IP information is being routed. This will give you the same output as the route print command that we covered earlier in this chapter.

The –*s* Switch

Using the -s switch displays a variety of TCP, UDP, IP, and ICMP protocol statistics. But be warned—the output you'll get is really long, which may or may not be okay for you. For this book, it's way too long for me to insert. With that in mind, we can add another modifier called the -p switch.

The –*p* Switch

Like the -n switch, the -p switch is a modifier that's usually used with the -s switch to specify which protocol statistics to list in the output (IP, TCP, UDP, or ICMP). For example, if you want to view only ICMP statistics, you use the -p switch like so:

```
netstat -s -p ICMP
```

The netstat utility then displays the ICMP statistics instead of the entire gamut of TCP/IP statistics that the -s switch will typically flood you with. For a different example, let's use the -s and -p switches to retrieve some IPv6 information:

```
C:\Users\tlammle>netstat -s -p IPV6

IPv6 Statistics

  Packets Received                   = 1400
  Received Header Errors             = 0
  Received Address Errors            = 6
  Datagrams Forwarded                = 0
  Unknown Protocols Received         = 0
  Received Packets Discarded         = 451
  Received Packets Delivered         = 10441
  Output Requests                    = 24349
  Routing Discards                   = 0
  Discarded Output Packets           = 3575
  Output Packet No Route             = 41
  Reassembly Required                = 0
  Reassembly Successful              = 0
  Reassembly Failures                = 0
  Datagrams Successfully Fragmented  = 0
  Datagrams Failing Fragmentation    = 0
  Fragments Created                  = 0

C:\Users\tlammle>
```

Nice! Gets right to the point. Now, let's see the TCP connections my host has:

```
C:\Users\tlammle>netstat -s -p tcp

TCP Statistics for IPv4

  Active Opens                        = 7832
  Passive Opens                       = 833
  Failed Connection Attempts          = 1807
  Reset Connections                   = 2428
  Current Connections                 = 11
  Segments Received                   = 1391678
  Segments Sent                       = 1340994
  Segments Retransmitted              = 6246

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    10.100.10.54:54737     gnt-exchange:1151      ESTABLISHED
  TCP    10.100.10.54:54955     gnt-exchange:1026      ESTABLISHED
  TCP    10.100.10.54:55218     gnt-exchange:epmap     TIME_WAIT
  TCP    127.0.0.1:2492         globalnet-todd:54840   ESTABLISHED
  TCP    127.0.0.1:54516        globalnet-todd:62514   ESTABLISHED
  TCP    127.0.0.1:54840        globalnet-todd:2492    ESTABLISHED
  TCP    127.0.0.1:62514        globalnet-todd:54516   ESTABLISHED
  TCP    192.168.0.6:2492       blugro2relay:2492      ESTABLISHED
  TCP    192.168.0.6:2492       blugro3relay:2492      ESTABLISHED
  TCP    192.168.0.6:54527      64.12.25.26:5190       ESTABLISHED
  TCP    192.168.0.6:54531      oam-d05c:5190          ESTABLISHED
  TCP    192.168.0.6:55163      207.123.44.123:http    CLOSE_WAIT

C:\Users\tlammle>
```

This kind of efficiency is exactly why it's good to use the -p modifier with the -s switch.

Because the Network+ exam doesn't cover them, we won't go into detail about what all these statistics mean for most of these commands. You can probably figure out most of them—for instance, Packets Received. For more details, go to Microsoft's support website at `https://support.microsoft.com/en-us`.

The –*n* Switch

The `-n` switch is a modifier for the other switches. When used with them, it reverses the natural tendency of `netstat` to use names instead of network addresses. In other words, when you use the `-n` switch, the output always displays network addresses instead of their associated network names. Following is output from the `netstat` command used with the `netstat -n` command. It's showing the same information but with IP addresses instead of names:

```
C:\Users\tlammle>netstat

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    10.100.10.54:54737     gnt-exchange:1151      ESTABLISHED
  TCP    10.100.10.54:54955     gnt-exchange:1026      ESTABLISHED
  TCP    127.0.0.1:2492         globalnet-todd:54840   ESTABLISHED
  TCP    127.0.0.1:54516        globalnet-todd:62514   ESTABLISHED
  TCP    127.0.0.1:54840        globalnet-todd:2492    ESTABLISHED
  TCP    127.0.0.1:62514        globalnet-todd:54516   ESTABLISHED
  TCP    192.168.0.6:2492       blugro2relay:2492      ESTABLISHED
  TCP    192.168.0.6:2492       blugro3relay:2492      ESTABLISHED
  TCP    192.168.0.6:54527      64.12.25.26:5190       ESTABLISHED
  TCP    192.168.0.6:54531      oam-d05c:5190          ESTABLISHED
  TCP    192.168.0.6:55163      207.123.44.123:http    CLOSE_WAIT

C:\Users\tlammle>netstat -n

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    10.100.10.54:54737     10.100.36.13:1151      ESTABLISHED
  TCP    10.100.10.54:54955     10.100.36.13:1026      ESTABLISHED
  TCP    127.0.0.1:2492         127.0.0.1:54840        ESTABLISHED
  TCP    127.0.0.1:54516        127.0.0.1:62514        ESTABLISHED
  TCP    127.0.0.1:54840        127.0.0.1:2492         ESTABLISHED
  TCP    127.0.0.1:62514        127.0.0.1:54516        ESTABLISHED
  TCP    192.168.0.6:2492       65.55.239.100:2492     ESTABLISHED
  TCP    192.168.0.6:2492       65.55.248.110:2492     ESTABLISHED
  TCP    192.168.0.6:54527      64.12.25.26:5190       ESTABLISHED
  TCP    192.168.0.6:54531      205.188.248.163:5190   ESTABLISHED
  TCP    192.168.0.6:55163      207.123.44.123:80      CLOSE_WAIT

C:\Users\tlammle>
```

Real World Scenario

Uses for *netstat*

You might be saying to yourself, "Fine…I can use lots of cool switches with `netstat`, but really, what for?" I'm always finding uses for `netstat`. For instance, once I found a particularly nasty worm on my PC using `netstat`. I just happened to run `netstat` for giggles one day and noticed a very large number of outbound connections to various places on the Internet. My PC was sending out SYN packets to a large number of hosts (an indication that my computer was involved—unknowingly—in a large-scale denial-of-service attack). Upon further examination, I noticed that this activity would start shortly after bootup.

I tried running `netstat` after bootup and noticed that the first outbound connection was to TCP port 6667, some Internet Relay Chat (IRC) server I'd never heard of—I didn't even have an IRC client on my machine at the time. The worm was particularly nasty to try to get rid of while active, so I turned off port 6667 on my firewall. That prevented the initial connection to the IRC server and, as I found out later, nicely prevented the worm from getting its instructions from the IRC server. I was then able to simply remap without `netstat`. Even my antivirus program missed it.

Using tcpdump

The `tcpdump` utility is used to read either packets captured live from a network or packets that have been saved to a file. Although there is a Windows version called `windump`, `tcpdump` only works on Unix-like operating systems.

Examples of Using *tcpdump*

Use this command to capture traffic on all interfaces:

```
# tcpdump -i any
```

Here is the command to capture traffic on a particular interface:

```
# tcpdump -i eth0
```

And to filter traffic by IP, whether it's the source or the destination, use this command:

```
# tcpdump host 192.168.5.5
```

Using the File Transfer Protocol

You already know that *File Transfer Protocol (FTP)* is a subset of TCP/IP and that FTP is used for the transfer of files. In recent years, FTP has become a truly cross-platform protocol for transferring files. Because Internet (and thus TCP/IP) use has skyrocketed, almost every client and server platform has implemented FTP. Windows is no exception. Its TCP/IP stack comes with a command-line `ftp` utility.

To start the `ftp` utility, enter **`ftp`** at a command prompt. The result is an `ftp` command prompt:

```
C:\Users\tlammle>ftp
ftp>
```

From this prompt, you can open a connection to an FTP server and upload and download files as well as change the way FTP operates. To display a list of all the commands you can use at the `ftp` command prompt, type **`help`** or **`?`** and press Enter. To get help on a specific command, type **`help`**, a space, and then the name of the command. Here is some output from the `help` command:

```
ftp>help
Commands may be abbreviated.  Commands are:

!               delete          literal         prompt          send
?               debug           ls              put             status
append          dir             mdelete         pwd             trace
ascii           disconnect      mdir            quit            type
bell            get             mget            quote           user
binary          glob            mkdir           recv            verbose
bye             hash            mls             remotehelp
cd              help            mput            rename
close           lcd             open            rmdir
ftp>
```

In the following sections, I'll give you an introduction to uploading and downloading files because every network technician and administrator positively needs to know how to do this. As they come up, I'll go over the specific commands necessary to perform those two operations as well as any commands that relate to those processes. But first, let's look at how to begin the process.

NOTE Third-party applications are available that provide a GUI interface for FTP, which is easier to use than a command line.

Starting FTP and Logging In to an FTP Server

Of the two FTP file operations (download and upload), the ability to download files is definitely the more crucial for you to have down as a network technician or sys admin. The reason it's so important for you to master is that network and client operating system drivers and patches are located on FTP servers all over the Internet.

The first steps in starting an FTP download session are to determine the address of the FTP site and start the `ftp` utility. The FTP site typically has the same name as the website except that the first three characters are `ftp` instead of www. For example, Microsoft's website is `www.microsoft.com`. Its FTP site, on the other hand, is `ftp.microsoft.com`. We'll use my personal FTP site as an example for the rest of this section because it works, so I can actually log in to it.

First, start the `ftp` utility as demonstrated earlier, and then follow these steps:

1. At the `ftp` command prompt, type **open**, a space, and the name of the FTP server, like this:

```
C:\Users\tlammle>ftp
ftp>open ftp.lammle.com
Connected to ftp.lammle.com.
220---------- Welcome to Pure-FTPd [TLS] ----------
220-You are user number 1 of 50 allowed.
220-Local time is now 11:45. Server port: 21.
220-IPv6 connections are also welcome on this server.
220 You will be disconnected after 15 minutes of inactivity.
User (ftp.lammle.com:(none)):enter
230 Anonymous user logged in
ftp>
```

As shown here, if the FTP server is available and running, you'll receive a response welcoming you to the server and asking you for a username. Right now, I just have *Anonymous* as the username (enabled by default on the FTP server), which means that anyone can log in to it. (By the way, don't bother trying this on my server because I disabled it for obvious reasons as soon as I finished writing this section.)

You can also start an FTP session by typing **ftp**, a space, and the address of the FTP server (for example, **ftp ftp.globalnettraining.com**). This allows you to start the `ftp` utility and open a connection in one step. Here's an example:

```
C:\Users\tlammle>ftp ftp.globalnettraining.com
Connected to ftp.globalnettraining.com.
220 Microsoft FTP Service
```

```
User (ftp.globalnettraining.com:(none)):todd
331 Password required for todd.
Password:not shown when typed
230 User todd logged in.
ftp>quit
```

2. Enter a valid username, and press Enter.
3. Enter your password, and press Enter. (The password won't show up when you type it.)

NOTE

Most Internet web servers that allow just about anyone to download files also allow the username *anonymous*, as I demonstrated. In addition to *anonymous*, you can use the username *ftp* to gain access to a public FTP server. They are both anonymous usernames. Remember that FTP (and Unix) usernames are case sensitive.

All good, but if you want to access a private FTP server, as I'll demonstrate in a minute, you'll need to use the username and password given to you by the site's administrator. Oh, and sometimes you can use your email address as a password when accessing a public FTP server with a username like *anonymous*.

NOTE

You don't have to enter your entire email address to log in with the *anonymous* username. Most of the time, FTP server software doesn't actually verify the actual email address, only that it is, in fact, an email address. To do this, it checks for an @ sign and two words separated by a period. You just need to enter a very short email address to bypass the password (like `u@me.com`). This is especially helpful if you have a long email address, and it's a really good idea if you don't want to get a ton of junk email.

If you enter the wrong username and/or password, the server will tell you so by displaying the following and leaving you at the `ftp` command prompt:

```
530 Login Incorrect
Login failed.
```

This means you've got to try again and must start the login process over. If you're successful, the FTP server will welcome you and drop you back at the `ftp` command prompt. You're now ready to start uploading or downloading files.

Downloading Files

After you log in to the FTP server, you'll navigate to the directory that contains the files you want. Thankfully, the FTP command-line interface is similar to the DOS command-line interface. This is no surprise because DOS is based on Unix and FTP is a Unix utility. Table 17.8 lists and describes the common navigation commands for FTP. (Remember that these are also case sensitive.)

After you navigate to the directory and find the file you want to download, it's time to set the parameters for the type of file. Files come in two types:

- ASCII, which contains text
- Binary, which is all other files

If you set `ftp` to the wrong type, the file you download will contain gibberish. So if you're in doubt, set `ftp` to download files as binary files. Check out Table 17.8.

TABLE 17.8 Common FTP navigation commands

Command	Description
`ls`	Short for *list*. Displays a directory listing. Very similar to the `DIR` command in MS-DOS.
`cd`	Short for *change directory*. Works almost identically to the MS-DOS `CD` command. Use it to change to a different directory and navigate the server's directory structure.
`pwd`	Short for *print working directory*. Displays the current directory on the server. Useful if you forget where you are when changing to several locations on the server.
`lcd`	Short for *local change directory*. Displays and changes the current directory on the local machine. Useful when you are downloading a file and aren't in the directory where you want to put the file.

To set the file type to ASCII, type **`ascii`** at the `ftp` command prompt. `ftp` will respond by telling you that the file type has been set to A (ASCII):

```
ftp>ascii
Type set to A
```

To set the file type to binary, type **`binary`** at the `ftp` command prompt. `ftp` will respond by telling you that the file type has been set to I (binary):

```
ftp>binary
Type set to I
```

To download the file, just use the `get` command like this:

```
ftp>get lammlepress.exe
200 PORT command successful.
150 Opening BINARY mode data connection for 'scrsav.exe'
(567018 bytes).
```

The file will start downloading to your hard drive. Unfortunately, with its default settings, the `ftp` utility doesn't give you any indication of the progress of the transfer. When the file has downloaded, the `ftp` utility will display the following message and return you to the `ftp` command prompt:

```
226 Transfer complete.
567018 bytes received in 116.27 seconds (4.88 Kbytes/sec)
```

NOTE

You can download multiple files by using the `mget` command. Simply type **`mget`**, a space, and then something known as a *wildcard* that specifies the files you want to get. For example, to download all the text files in a directory, type **`mget *.txt`**.

Uploading Files

To upload a file to an FTP server, you've got to have rights on that specific server. These rights are assigned on a directory-by-directory basis. To upload a file, log in and then follow these steps:

1. At the `ftp` command prompt, type **`lcd`** to navigate to the directory on the local machine where the file resides.
2. Type **`cd`** to navigate to the destination directory.
3. Set the file type to ASCII or binary.
4. Use the `put` command to upload the file.

The syntax of the `put` command looks like this:

```
ftp>put local file destination file
```

Let's say you want to upload a file called `1.txt` on the local server but you want it to be called `my.txt` on the destination server. To accomplish that, use the following command:

```
ftp>put 1.txt my.txt
```

You'll get the following response:

```
200 PORT command successful.
150 Opening BINARY mode data connection for collwin.zip
226 Transfer complete.
743622 bytes sent in 0.55 seconds (1352.04 Kbytes/sec)
```

NOTE

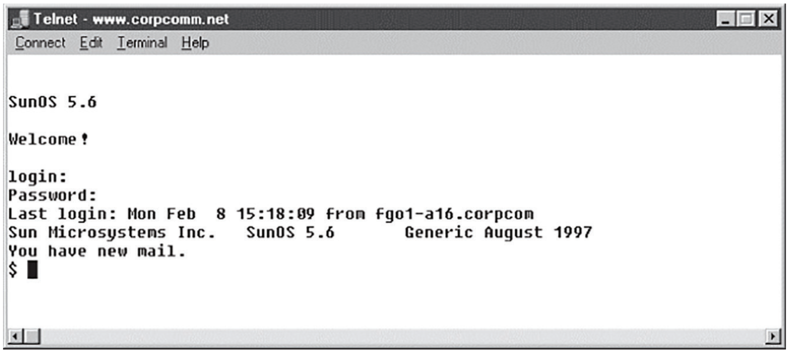
You can upload multiple files using the `mput` command. Simply type **`mput`**, a space, and then a wildcard that specifies the files. For example, to upload all the text files in a directory, type **`mput *.txt`**.

When you're finished with the `ftp` utility, just type `quit` to return to the command prompt.

Using the Telnet Utility

Part of the TCP/IP protocol suite, *Telnet* is a virtual terminal protocol utility that allows you to make connections to remote devices, gather information, and run programs. Telnet was originally developed to open terminal sessions from remote Unix workstations to Unix servers. Although it's still used for that purpose, we now use it as a troubleshooting tool as well. Figure 17.14 shows the basic Telnet interface as it's being used to start a terminal session on a remote Unix host.

FIGURE 17.14 The Telnet utility



```
SunOS 5.6

Welcome!

login:
Password:
Last login: Mon Feb  8 15:18:09 from fgo1-a16.corpcom
Sun Microsystems Inc.   SunOS 5.6       Generic August 1997
You have new mail.
$ █
```

In today's Windows environments, Telnet is a basic command-line tool for testing TCP connections. You can telnet to any TCP port to see if it's responding—something that's especially useful when checking Simple Mail Transfer Protocol (SMTP) and HTTP (web) ports.

As you learned back in Chapter 6, "Introduction to the Internet Protocol," each upper-layer service in a TCP stack has a number for its address. And by default, each network service that uses a particular address will respond to a TCP request on that specific port.

How to Enable Telnet in Windows

Because most people have the Windows 10 operating system running on their PCs these days, it's good to know that, by default, these operating systems install without Telnet available. But there's a way around that one—if you really must have a Telnet client enabled in these operating systems, here's how to do it:

1. Open Control Panel.
2. Select Programs And Features.

3. In the left column, select Turn Windows Features On Or Off (get ready for the annoying User Account Control [UAC] prompt, and then enter your name and password).
4. Select the Telnet check box (and any other obscure services you may want enabled), and wait while Windows thinks for a while and then reboots.

Nice—now you can go to Start and then type **telnet** in the Start search box to get a Telnet window to open for you. You can also open a DOS prompt and just type **telnet** from there. Here are the options that Windows provides with Telnet:

```
Microsoft Telnet> ?
Commands may be abbreviated. Supported commands are:

c    - close                    close current connection
d    - display                  display operating parameters
o    - open hostname [port]     connect to hostname (default port 23).
q    - quit                     exit telnet
set  - set                      set options (type 'set ?' for a list)
sen  - send                     send strings to server
st   - status                   print status information
u    - unset                    unset options (type 'unset ?' for a list)
?/h  - help                     print help information
```

Now that we've finished talking about Telnet, my personal recommendation is that you never use it again. What? Yes, you read that right, and here's why.

Don't Use Telnet, Use Secure Shell

What? I just told you how to use Telnet, and now I am telling you not to use it. That's right, don't use Telnet! Telnet is totally insecure because it sends all data in crystal-clear text—including your name and password. And I'm pretty sure you know that's a really bad thing these days. If Microsoft doesn't even enable it on its latest OSs, then you know it really must be insecure.

So if you shouldn't use Telnet, what should you use instead? Secure Shell (SSH) is your answer. It provides the same options as Telnet, plus a lot more; but most important, it doesn't send any data in clear text. The thing is, your servers, routers, and other devices need to be enabled with SSH, and it's not configured by default on most devices.

Some configuration is usually necessary if you want things to work as they really should, and yes, sometimes it's a little painful to get everything running smoothly, but it's all worth it in the long run. Personally, I disable Telnet on all my routers and use SSH exclusively. No lie—I never use Telnet anymore if I can help it. Even so, you should still understand Telnet and get in some practice with it in case you do ever need it.

NOTE

In my Sybex book *Cisco CCNA Study Guide*, I get into the skinny on how to configure SSH on all Cisco devices and use an SSH client.

Summary

In this chapter, you learned about many of the utilities for using and troubleshooting TCP/IP. These utilities include GUI tools like protocol analyzers, throughput testers, and connectivity software like Remote Desktop, and they include command-line utilities like `tracert`, `ping`, `arp`, `netstat`, `nbtstat`, `ipconfig`, `ifconfig`, and `nslookup`.

You also learned how these utilities are used, including their various options and switches and how they all affect the use of the utilities. Finally, you learned about how these utilities work within the TCP/IP suite.

Exam Essentials

Describe some of the GUI tools available to assist in testing and troubleshooting. These include protocol analyzers, throughput testers, and connectivity software. Understand each product's purpose and how to use it.

Know how to describe and use the troubleshooting information and statistics that `arp`, `nbtstat`, and `netstat` provide for you. The `arp` utility shows whether an IP address is being resolved to your MAC address (or someone else's, in case of conflicts). The `netstat` utility produces TCP/IP statistics, and `nbtstat` produces NetBIOS over TCP/IP statistics.

Know how to diagnose a network by using TCP/IP's troubleshooting commands. The `ping` command echoes back if a machine is alive and active on a network. The `tracert` command shows the path that the ping packets take from source to target. And `telnet` enables a user to participate in a remote text-based session.

Know what the `tracert` utility does. The `tracert` utility finds the route from your computer to any computer on a network.

Know what the `ping` utility does. The `ping` utility determines whether a particular IP host is responding.

Know what the `ftp` utility does. The `ftp` utility allows you to reliably download and upload files from and to an FTP server across the Internet.

Know what the `ipconfig` and `ifconfig` utilities do. The `ipconfig` utility displays TCP/IP configuration information for Windows NT and later operating systems. The `ifconfig` utility performs a similar function in Unix environments, in addition to performing certain interface-configuration tasks.

Know what the `nslookup` and `dig` utilities do. The `nslookup` and `dig` utilities allow you to look up DNS resolution information.

Identify `nmap` and `tcpdump`. While `tcpdump` is a command-line packet capture utility for Linux, `nmap` is a network reconnaissance tool that can identify live hosts, open ports, and the operating systems of devices.

Describe the use of the `iptables` utility. `Iptables` is a firewall utility built for the Linux operating system. It is a command-line utility that uses what are called chains to allow or disallow traffic. When traffic arrives, `iptables` looks for a rule that addresses that traffic type, and if none exists, it will enforce the default rule.

Written Lab

You can find the answers to the written labs in Appendix A. Write the answers to the following questions about command-line tools:

1. What command can you type from a command prompt to see the hops a packet takes to get to a destination host?
2. What tool would you use to verify a complaint about a slow network?
3. You need your IP address, subnet mask, default gateway, and DNS information. What command will you type from a Windows command prompt?
4. You need to log in as a dumb terminal to a server or Unix host and run programs. What application will you use?
5. You need to add a route to your Windows server's routing table. What command will you use?
6. You want to log in to a server and transfer files. What application will you use?
7. You need to check your name-resolution information on your host. What command will you type from the command prompt?
8. You want to use `netstat`, but you want to see only the IP address, not the names of the hosts. Which modifier will you use?
9. You want the IP configuration on a Unix host. What command will you type at the command prompt?
10. Which Windows command will show you the routing table of your host or server?

Review Questions

You will find the answers to the review questions in Appendix B.

1. Which TCP/IP utility is most often used to test whether an IP host is up and functional?
   - **A.** `ftp`
   - **B.** `telnet`
   - **C.** `ping`
   - **D.** `netstat`

2. Which TCP/IP utility will produce the following result?

```
Interface: 199.102.30.152
Internet Address   Physical Address   Type
199.102.30.152     A0-ee-00-5b-0e-ac   dynamic
```

   - **A.** `arp`
   - **B.** `netstat`
   - **C.** `tracert`
   - **D.** `nbtstat`

3. Which Windows utility can you use to connect to a machine 50 miles away to troubleshoot?
   - **A.** Remote Desktop
   - **B.** `netstat`
   - **C.** `arp`
   - **D.** Wireshark

4. Which TCP/IP utility might produce the following output?

```
Reply from 204.153.163.2: bytes=32 time=1ms TTL=128
Reply from 204.153.163.2: bytes=32 time=1ms TTL=128
Reply from 204.153.163.2: bytes=32 time=1ms TTL=128
Reply from 204.153.163.2: bytes=32 time<10ms TTL=128
```

   - **A.** `tracert`
   - **B.** `ping`
   - **C.** `WINS`
   - **D.** `ipconfig`

5. Which utility can you use to find the MAC and TCP/IP addresses of your Windows workstation?
   - **A.** `ping`
   - **B.** `ipconfig`
   - **C.** `ipconfig /all`
   - **D.** `tracert`
   - **E.** `telnet`

6. Which ping commands will verify that your local TCP/IP interface is working? (Choose all that apply.)

   A. `ping 204.153.163.2`

   B. `ping 127.0.0.1`

   C. `ping localif`

   D. `ping localhost`

   E. `ping iphost`

7. Which switch for the Windows `nbtstat` utility will display all NetBIOS name-resolution statistics?

   A. `-r`

   B. `/r`

   C. `-R`

   D. `/R`

8. You need to find a NIC's specific MAC address and IP address. Which command-line tool can you use to find this information without physically going to the computer?

   A. `ping`

   B. `nbtstat`

   C. `arp`

   D. `netstat`

   E. `ftp`

9. Which `nbtstat` utility switch will purge and reload the remote NetBIOS name table cache?

   A. `-r`

   B. `-R`

   C. `/r`

   D. `/R`

10. Wireshark is an example of a ________________?

   A. Throughput tester

   B. Protocol analyzer

   C. Remote connection tool

   D. IDS

11. Which utility produces output similar to the following?

```
1  110 ms  96 ms  107 ms fgo1.corpcomm.net [209.74.93.10]
2  96 ms  126 ms  95 ms someone.corpcomm.net [209.74.93.1]
3  113 ms  119 ms  112 ms Serial5-1-1.GW2.MSP1.alter.net     [157.130.100.185]
4  133 ms  123 ms  126 ms 152.ATM3-0.XR2.CHI6.ALTER.NET      [146.188.209.126]
5  176 ms  133 ms  129 ms 290.ATM2-0.TR2.CHI4.ALTER.NET   [146.188.209.10]
6  196 ms  184 ms  218 ms 106.ATM7-0.TR2.SCL1.ALTER.NET   [146.188.136.162]
```

```
7  182 ms  187 ms  187 ms 298.ATM7-0.XR2.SJC1.ALTER.NET   [146.188.146.61]
8  204 ms  176 ms  186 ms 192.ATM3-0-0.SAN-JOSE9- GW.ALTER.NET [146.188.144.133]
9  202 ms  198 ms  212 ms atm3-0-622M.cr1.sjc.globalcenter.net [206.57.16.17]
10 209 ms  202 ms  195 ms pos3-1-155M.br4.SJC.globalcenter.net [206.132.150.98]
11 190 ms   *   191 ms pos0-0-0-155M.hr3.SNV.globalcenter.net [206.251.5.93]
12 195 ms  188 ms  188 ms pos4-1-0-   155M.hr2.SNV.globalcenter.net [206.132.150.206]
13 198 ms  202 ms  197 ms www10.yahoo.com [204.71.200.75]
```

A. `arp`

B. `tracert`

C. `nbtstat`

D. `netstat`

12. You are the network administrator. A user calls you, complaining that the performance of the intranet web server is sluggish. When you try to ping the server, it takes several seconds for the server to respond. You suspect that the problem is related to a router that is seriously overloaded. Which workstation utility could you use to find out which router is causing this problem?

A. `netstat`

B. `nbtstat`

C. `tracert`

D. `ping`

E. `arp`

13. Which `ipconfig` switch will display the most complete listing of IP configuration information for a station?

A. `/all`

B. `/renew`

C. `/release`

D. `/?`

14. Which utility will display a list of all the routers that a packet passes through on the way to an IP destination?

A. `netstat`

B. `nbtstat`

C. `tracert`

D. `ping`

E. `arp`

15. Which Windows TCP/IP utility could you use to find out whether a server is responding on TCP port 21?

A. `tcp`

B. `port`

C. `ping`

D. `nbtstat`

E. `telnet`

16. Which `arp` command can you use to display the currently cached ARP entries?

A. `arp`

B. `arp -all`

C. `arp -a`

D. `ipconfig -arp`

E. `arp -ipconfig`

17. Which command-line tool would best be used to verify DNS functionality?

A. `netstat`

B. `nbtstat`

C. `dig`

D. `icmp`

E. `arp`

18. Which of the following `arp` utility switches perform the same function? (Choose all that apply.)

A. `-g`

B. `-A`

C. `-d`

D. `-a`

19. Which of the following is NOT a chain type used by `iptables`?

A. Forward

B. Backward

C. Input

D. Output

20. Which command captures traffic on all interfaces?

A. `tcpdump -i any`

B. `tcpdump -i eth0`

C. `tcpdump host 192.168.5.5`

D. `tcpdump host all`

Chapter 18

Software and Hardware Tools

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **3.1 Given a scenario, use appropriate documentation and diagrams to manage the network**

- Network configuration and performance baselines

✓ **3.3 Explain common scanning, monitoring, and patching processes and summarize their expected outputs**

- Processes
    - Log reviewing
    - Port scanning
    - Vulnerability scanning
    - Reviewing baselines
    - Packet/traffic analysis
- Event management
    - Notifications
    - Alerts
    - SIEM
- SNMP monitors
    - MIB
- Metrics
    - Error rate
    - Utilization
    - Bandwidth/throughput

✓ **4.2 Explain authentication and access controls.**

- Auditing and logging

✓ **5.1 Given a scenario, use the appropriate tool**

- Hardware tools
  - Crimper
  - Cable tester
  - Punch-down tool
  - OTDR
  - Light meter
  - Tone generator
  - Loopback adapter
  - Multimeter
  - Spectrum analyzer
- Software tools
  - Packet sniffer
  - Port scanner
  - Protocol analyzer
  - Wi-Fi analyzer
  - Bandwidth speed tester

Specialized tasks require specialized tools, and installing network components is no exception. We use some of these tools, like network scanners, on an everyday basis, but most of the hardware tools I'll be covering in this chapter are used mainly in the telecommunications industry.

Still, in order to meet the CompTIA Network+ objectives, and also because you're likely to run across them in today's networking environments, it's very important that you're familiar with them.

NOTE

To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Understanding Network Scanners

Network scanner has become a broad term often referring to a family of tools used to analyze our networks, but the CompTIA Network+ objectives are much less vague. So with regard to those critical objectives, know that *network scanners* refer to these four tools:

- Packet sniffers
- Intrusion detection system/intrusion prevention system (IDS/IPS) software
- Port scanners
- Wi-Fi analyzers
- Bandwidth speed testers

Packet Sniffers/Network Monitors

Unlike port scanners, *packet sniffers* actually look inside every packet on a network segment. Packet sniffers come in many flavors, and some of them, like Microsoft's Message Analyzer, are even free today. Message Analyzer comes bundled with Windows Server and does allow you to analyze network communications traffic.

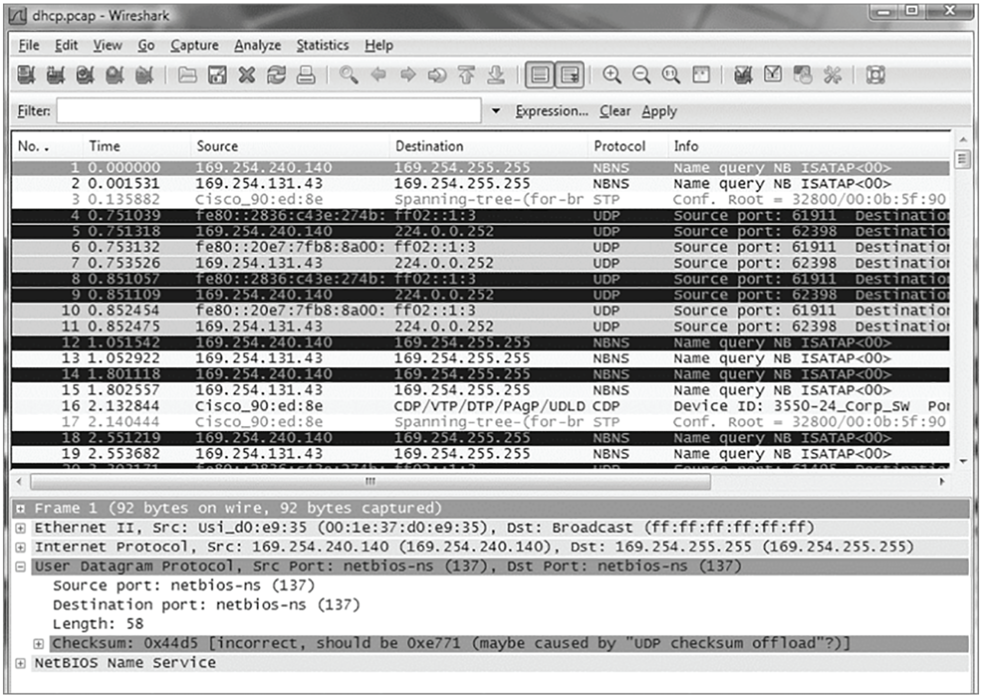
All good, but personally, I use Wireshark instead. It's also free, and you can easily download it from `www.wireshark.org`. A nice feature of Wireshark is that it runs from Windows, OS X, Linux, and Unix platforms. It easily captures data on all my interfaces, including my wireless and virtual private network (VPN) connections, and looks at all traffic on the network segment. There are tons of packet sniffers available, and to get your hands on most of them, you'll have to pony up some cash. Sometimes they're worth it, though, because these higher-end products can even provide solutions to problems you find on your network—nice.

Anyway, free or not, the basic purpose of packet sniffers (or network analyzers) is to collect and analyze each individual packet that is captured on a specific network segment to determine if problems like bottlenecks, retransmissions, and security breaches are happening. Packet sniffers are a must-have for every network administrator to troubleshoot and find problems or security holes in a network. For example, you may discover that users are using an application on the network with usernames and passwords being sent unencrypted over the network.

You can also use packet sniffers to see if there is too much traffic on a segment, to see router or switch interfaces (referred to as interface monitoring), or even to see if a broadcast storm has been created by a bad network interface card (NIC). And remember—I do mean on a network segment—you can't use them to catch packets passing through routers. These network analyzers can also show you top talkers and listeners on your network and provide packet flow monitoring.

Yes, they can help you find a hacker stalking around in there, but you'd really have to be looking closely and constantly to discover this. For that level of monitoring, you'd be better off using a tool known as an IDS/IPS. It can really help you track and even defeat hackers. (We'll talk about IDS/IPS software in the next section.) The more expensive network sniffers can help find anomalies in your network, like a hack, and even alert you to these problems. Figure 18.1 shows output from a packet sniffer. Notice that you can identify both the IP addresses and the MAC addresses associated with any of the packets captured as well as identify the protocol in use.

FIGURE 18.1 Output from a packet sniffer



No.	Time	Source	Destination	Protocol	Info
1	0.000000	169.254.240.140	169.254.255.255	NBNS	Name query NB ISATAP<00>
2	0.001531	169.254.131.43	169.254.255.255	NBNS	Name query NB ISATAP<00>
3	0.135882	Cisco_90:ed:8e	Spanning-tree-(for-br	STP	Conf. Root = 32800/00:0b:5f:90
4	0.751039	fe80::2836:c43e:274b:	ff02::1:3	UDP	Source port: 61911 Destinatio
5	0.751318	169.254.240.140	224.0.0.252	UDP	Source port: 62398 Destinatio
6	0.753132	fe80::20e7:7fb8:8a00:	ff02::1:3	UDP	Source port: 61911 Destinatio
7	0.753526	169.254.131.43	224.0.0.252	UDP	Source port: 62398 Destinatio
8	0.851057	fe80::2836:c43e:274b:	ff02::1:3	UDP	Source port: 61911 Destinatio
9	0.851109	169.254.240.140	224.0.0.252	UDP	Source port: 62398 Destinatio
10	0.852454	fe80::20e7:7fb8:8a00:	ff02::1:3	UDP	Source port: 61911 Destinatio
11	0.852475	169.254.131.43	224.0.0.252	UDP	Source port: 62398 Destinatio
12	1.051542	169.254.240.140	169.254.255.255	NBNS	Name query NB ISATAP<00>
13	1.052922	169.254.131.43	169.254.255.255	NBNS	Name query NB ISATAP<00>
14	1.801118	169.254.240.140	169.254.255.255	NBNS	Name query NB ISATAP<00>
15	1.802557	169.254.131.43	169.254.255.255	NBNS	Name query NB ISATAP<00>
16	2.132844	Cisco_90:ed:8e	CDP/VTP/DTP/PAgP/UDLD	CDP	Device ID: 3550-24_Corp_SW Po
17	2.140444	Cisco_90:ed:8e	Spanning-tree-(for-br	STP	Conf. Root = 32800/00:0b:5f:90
18	2.551219	169.254.240.140	169.254.255.255	NBNS	Name query NB ISATAP<00>
19	2.553682	169.254.131.43	169.254.255.255	NBNS	Name query NB ISATAP<00>

```
⊞ Frame 1 (92 bytes on wire, 92 bytes captured)
⊞ Ethernet II, Src: Usi_d0:e9:35 (00:1e:37:d0:e9:35), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
⊞ Internet Protocol, Src: 169.254.240.140 (169.254.240.140), Dst: 169.254.255.255 (169.254.255.255)
⊟ User Datagram Protocol, Src Port: netbios-ns (137), Dst Port: netbios-ns (137)
    Source port: netbios-ns (137)
    Destination port: netbios-ns (137)
    Length: 58
  ⊞ Checksum: 0x44d5 [incorrect, should be 0xe771 (maybe caused by "UDP checksum offload"?)]
⊞ NetBIOS Name Service
```

You can definitely see that a packet sniffer can provide you with huge amounts of information. This means you really need something to narrow things down and help you to more readily find the needle in the haystack that you're looking for, right?

In this case, help comes in the form of some handy built-in filters that can be used to gather information from just one specific host or server; without them, you'd have to go through possibly thousands of packets to find the problem. For the packet I've highlighted, you can see that there's a probable User Datagram Protocol (UDP) checksum error. And by the way, because UDP is connectionless, this is a pretty common error.

NOTE You should download and start working with a network sniffer right away. As I mentioned, you can download Wireshark at `www.wireshark.org` for free, so what are you waiting for? Go for it!

Now comes the fun stuff—let's take a look at ways we can find and stop hackers dead in their tracks.

Intrusion Detection and Prevention Software

An IDS detects unwanted attempts to manipulate network systems and/or environments, and an IPS is a computer-security device that monitors network and/or system activities for any strange or malicious behavior. It can react in real time to prevent and even block nasty activities. An IDS identifies, detects, and reports attempts of unauthorized access to the network as well as any suspicious activity, and it's the best software type for identifying an attack. However, if you want to stop the attack in its tracks, you need to add an IPS device. So, unlike IDSs, which can identify an attack and report it, an IPS can stop the attack by shutting down ports or dropping certain types of packets.

A bunch of different IDS/IPS software packages are available on the market, and a lot of them are free. Again, predictably, the best ones aren't, and they can be a bit pricey. These high-powered versions run on Linux or other proprietary hardware. But there are still many IDS/IPS software applications available for Windows.

Snort is one of the most popular IDS/IPS software products around. It runs on both Linux and Windows, and it's a free, open-source platform, which happens to be a big reason for its popularity. But that's not the only reason—just because it is free doesn't mean it doesn't offer up some pretty cool features. On the other hand, if you're dealing with a large, corporate environment, you need some serious weaponry, and Cisco offers an Adaptive Security Appliance (ASA) as an enterprise solution that's powerful but definitely far from free. It's worth it, though.

Figure 18.2 shows a picture of a Cisco ASA box I use in my security classes.

Personally, I think the Cisco box is the best IDS/IPS box on the market today. Still, Snort isn't bad (check out Cisco's new acquisition, Sourcefire), so if cost is an issue, rest assured you can use it, as well as several other tools, and be much better equipped than you would be without them working on your network to help you keep it secure.

FIGURE 18.2 A Cisco ASA

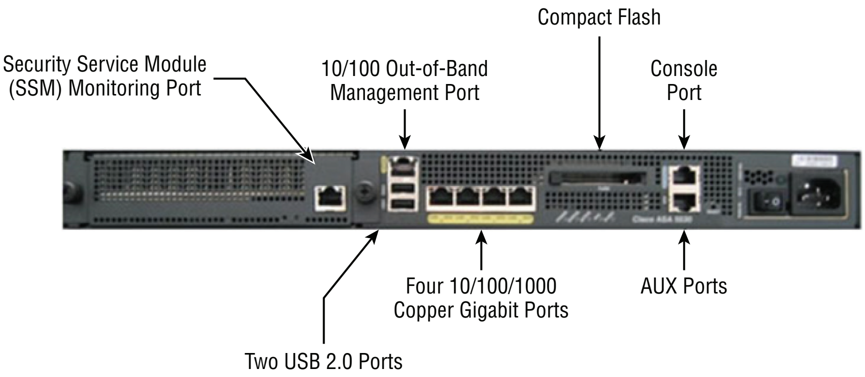
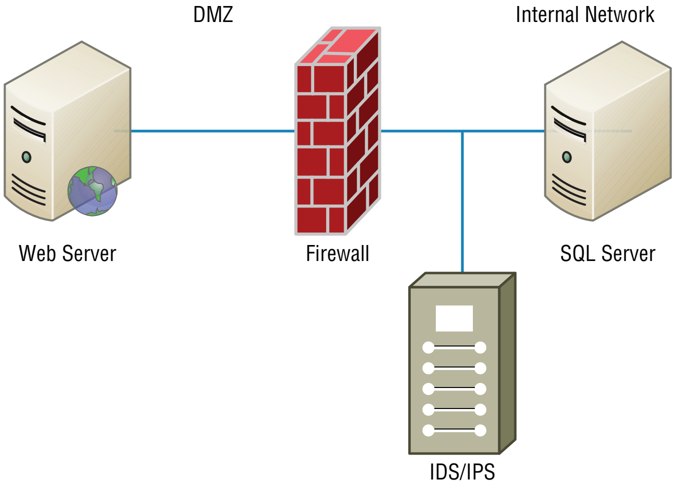


Figure 18.3 shows where you'd find a typical IDS/IPS in a internetwork.

FIGURE 18.3 IDS/IPS placement in an internetwork



To be honest, because of the device's complexity and the many different physical configurations possible, this is a relatively simplistic view of an IDS/IPS working within a network. The important thing I want you to pay attention to is the fact that you would typically find the IDS/IPS software positioned between your internal router and the firewall to the outside network (Internet). If you're using Snort, just add the software to a Linux box, and connect this box between the firewall and the router. This area would typically be your demilitarized zone (DMZ). The Basic Analysis and Security Engine (BASE) displays and reports intrusions and attacks logged in the Snort database in a web browser for convenient analysis.

Port Scanners

A *port scanner* is a software tool designed to search a host for open ports. Those of us administering our networks use port scanners to ensure their security, but bad guys use them to find a network's vulnerabilities and compromise them. To *port scan* means to scan for TCP and UDP open ports on a single target host either to legitimately connect to and use its services for business and/or personal reasons or to find and connect to those ports and subsequently attack the host and steal or manipulate it for nefarious reasons.

In contrast, *port sweeping* means scanning multiple hosts on a network for a specific listening TCP or UDP port, like SQL. (SQL injection attacks are super common today.) This just happens to be a favorite approach used by hackers when trying to invade your network. They port sweep in a broad manner, and then, if they find something—in this case, SQL—they can port scan the particular host they've discovered with the desired service available to exploit and get what they're after. This is why it's a really good idea to turn off any unused services on your servers and routers and to run only the minimum services required on every host machine in your network. Do yourself a big favor and make sure this is in your security policy.

Remember that three-way handshake I discussed in Chapter 6, "Introduction to the Internet Protocol"? Well, it just so happens that a SYN scan is the most popular form of TCP scanning. Rather than use the operating system's network functions, the port scanner actually generates raw IP packets itself and monitors for responses. This scan type is also known as *half-open scanning* because it never really opens a full TCP connection. The port scanner generates a SYN packet, and if the targeted port is open, it will respond with a SYN-ACK packet. The scanner host responds with an RST (reset) packet, closing the connection before the handshake is completed.

NOTE

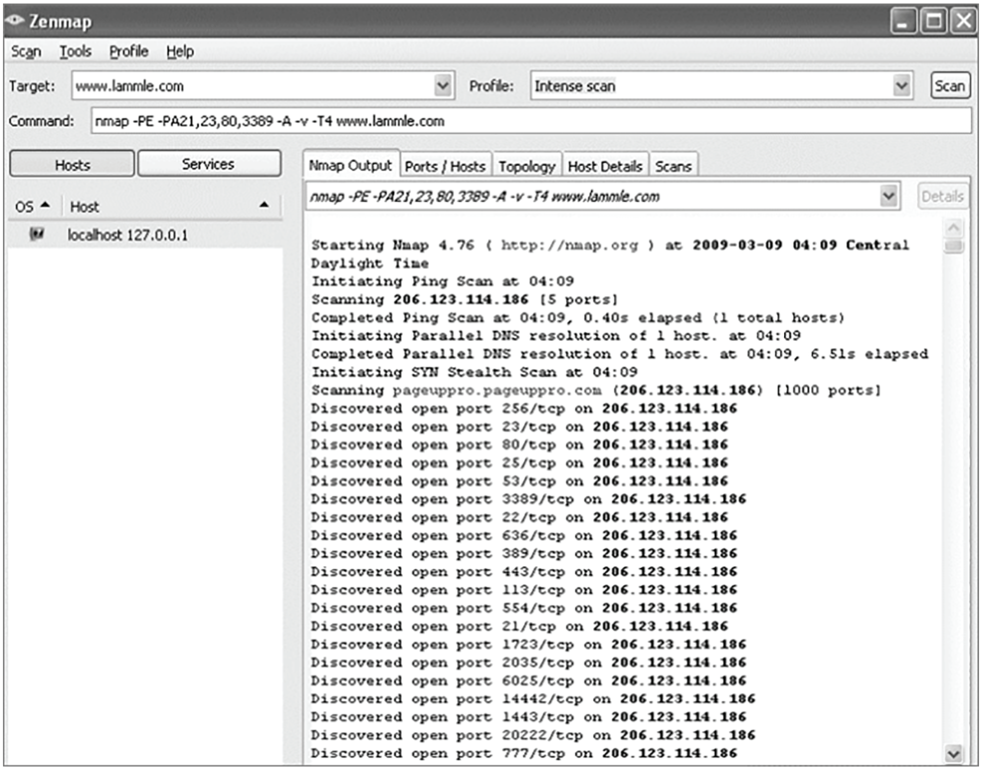
Never use the tools I'm telling you about on computers belonging to any businesses or government agencies without their permission. It's against the law in a big way, and they do monitor and prosecute! Know that I am not exaggerating here, so please do yourself a favor and use the following tools only to test your own network for vulnerabilities.

Although a free program named Network Mapper (Nmap) can be used as a port scanner, you can use it to do so much more. I give it two thumbs up and recommend that you download Nmap (`http://nmap.org`) and play with this cool program.

Nmap, like Snort, is open source. But Nmap runs on all platforms and can provide port-scanning ability, check all the open services running on each host, find firewalls, and even help tremendously with network management.

Figure 18.4 shows Nmap running on a Windows Vista platform, performing a Domain Name Service (DNS) resolution, and then a port scan to the host being monitored (Zenmap is the name of the GUI interface it uses). Pretty chill, right?

FIGURE 18.4 Nmap in action



Target: www.lammle.com

Profile: Intense scan

Command: nmap -PE -PA21,23,80,3389 -A -v -T4 www.lammle.com

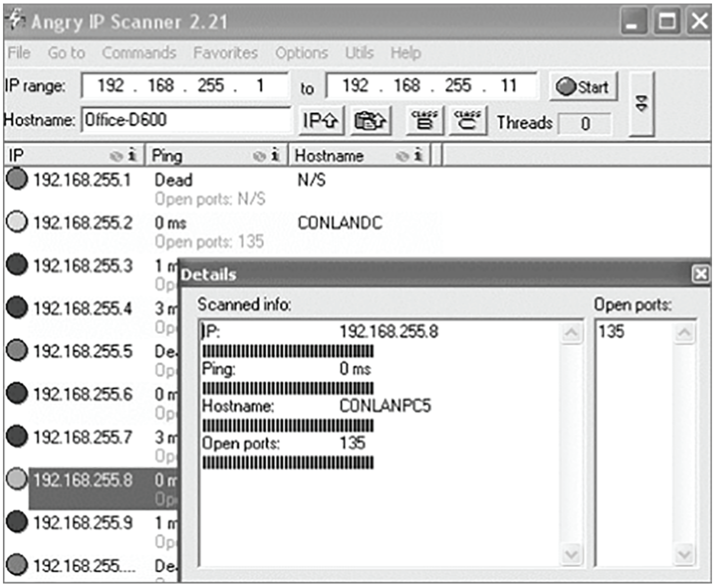
```
nmap -PE -PA21,23,80,3389 -A -v -T4 www.lammle.com

Starting Nmap 4.76 ( http://nmap.org ) at 2009-03-09 04:09 Central
Daylight Time
Initiating Ping Scan at 04:09
Scanning 206.123.114.186 [5 ports]
Completed Ping Scan at 04:09, 0.40s elapsed (1 total hosts)
Initiating Parallel DNS resolution of 1 host. at 04:09
Completed Parallel DNS resolution of 1 host. at 04:09, 6.51s elapsed
Initiating SYN Stealth Scan at 04:09
Scanning pageuppro.pageuppro.com (206.123.114.186) [1000 ports]
Discovered open port 256/tcp on 206.123.114.186
Discovered open port 23/tcp on 206.123.114.186
Discovered open port 80/tcp on 206.123.114.186
Discovered open port 25/tcp on 206.123.114.186
Discovered open port 53/tcp on 206.123.114.186
Discovered open port 3389/tcp on 206.123.114.186
Discovered open port 22/tcp on 206.123.114.186
Discovered open port 636/tcp on 206.123.114.186
Discovered open port 389/tcp on 206.123.114.186
Discovered open port 443/tcp on 206.123.114.186
Discovered open port 113/tcp on 206.123.114.186
Discovered open port 554/tcp on 206.123.114.186
Discovered open port 21/tcp on 206.123.114.186
Discovered open port 1723/tcp on 206.123.114.186
Discovered open port 2035/tcp on 206.123.114.186
Discovered open port 6025/tcp on 206.123.114.186
Discovered open port 14442/tcp on 206.123.114.186
Discovered open port 1443/tcp on 206.123.114.186
Discovered open port 20222/tcp on 206.123.114.186
Discovered open port 777/tcp on 206.123.114.186
```

Nmap is very flexible, and again, I really encourage you to check it out. One of the other nice features of Nmap is its documentation capacity. It comes with a complete set of instructions and equips you with documentation to help you troubleshoot and map your network.

Even though Nmap is pretty simple, there are even simpler tools out there—a whole lot of them. Angry IP is a program I also use that provides both IP-scanning and port-scanning abilities. It's definitely not as complex as Nmap, but because it's extremely easy to use, you might want to try out this free, open-source program as well. Figure 18.5 illustrates port scanning with Angry IP.

You can see right away that this is a much simpler program than some of the other sniffing and port mapping tools we've discussed, but simple doesn't mean it isn't powerful. Angry IP slowed the PC I was scanning way down when I performed a full port scan on the host using this program. Check it out at `http://angryip.org`.

FIGURE 18.5 Angry IP port scanning



IP range: 192 . 168 . 255 . 1 to 192 . 168 . 255 . 11

Hostname: Office-D600

Threads 0

IP	Ping	Hostname
192.168.255.1	Dead Open ports: N/S	N/S
192.168.255.2	0 ms Open ports: 135	CONLANDC
192.168.255.3	1 m Op	
192.168.255.4	3 m Op	
192.168.255.5	De Op	
192.168.255.6	0 m Op	
192.168.255.7	3 m Op	
192.168.255.8	0 m Op	
192.168.255.9	1 m Op	
192.168.255....	De	

Scanned info:

```
IP:            192.168.255.8
Ping:          0 ms
Hostname:      CONLANPC5
Open ports:    135
```

Open ports:

135

Real World Scenario

Hacked and Blamed!

I've already mentioned that you shouldn't port scan on hosts that are not yours, but you need to be careful that someone else does not use your hosts or servers to port scan someone else's servers as well. A few years ago, I had a server at an ISP, and some crackers had hacked into my server and were using it to port scan the Department of Defense (DoD) servers. I received a letter from the DoD informing me of this issue. They were very professional and even mentioned that it probably wasn't me doing the port scanning, but they said that if it happened again, they would prosecute me. They told me that I was responsible for my server and that if I did not stop the attackers, I would be liable.

I was terribly embarrassed, and I was a little freaked out, too! After looking at the server logs, I realized that the crackers were from France and that they had been in my server for three months. Instead of just locking down the ports and getting rid of the hackers, I formatted the server. Why? Because crackers/hackers are notorious for creating many backdoors once they are in a system, in case they get caught, so just locking them out would not have solved the problem. If this happens to you, a reformat is typically what you need to do. I also upgraded to the latest server operating system, which helped with some of the security issues.

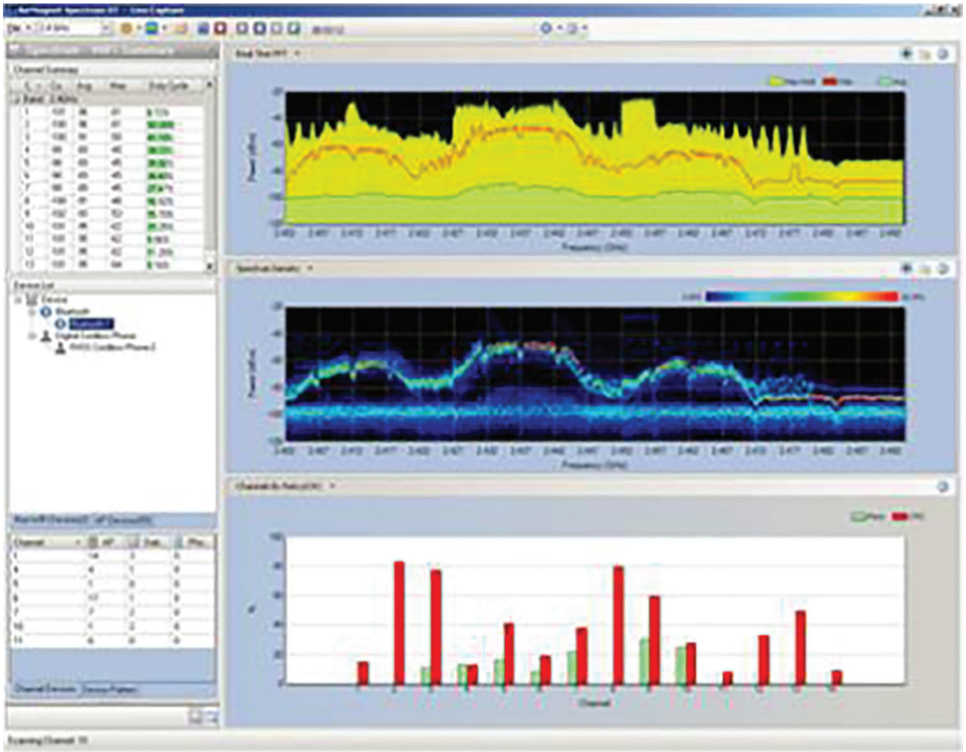
Wi-Fi Analyzer

A Wi-Fi analyzer, or wireless analyzer, is similar to the network analyzers that I've already discussed but is used for sniffing wireless networks. Wi-Fi analyzers can find the channels in use, the amount of clients and bandwidth used, top talkers, and more. On wireless LANs, one can capture traffic on a particular channel or on several channels when using multiple adapters.

Wi-Fi analyzers identify networks by passively collecting packets and detecting standard named networks, detecting (given time) hidden networks, and inferring the presence of nonbeaconing networks via data traffic.

Figure 18.6 shows an output of a wireless analyzer.

FIGURE 18.6 Wireless analyzer

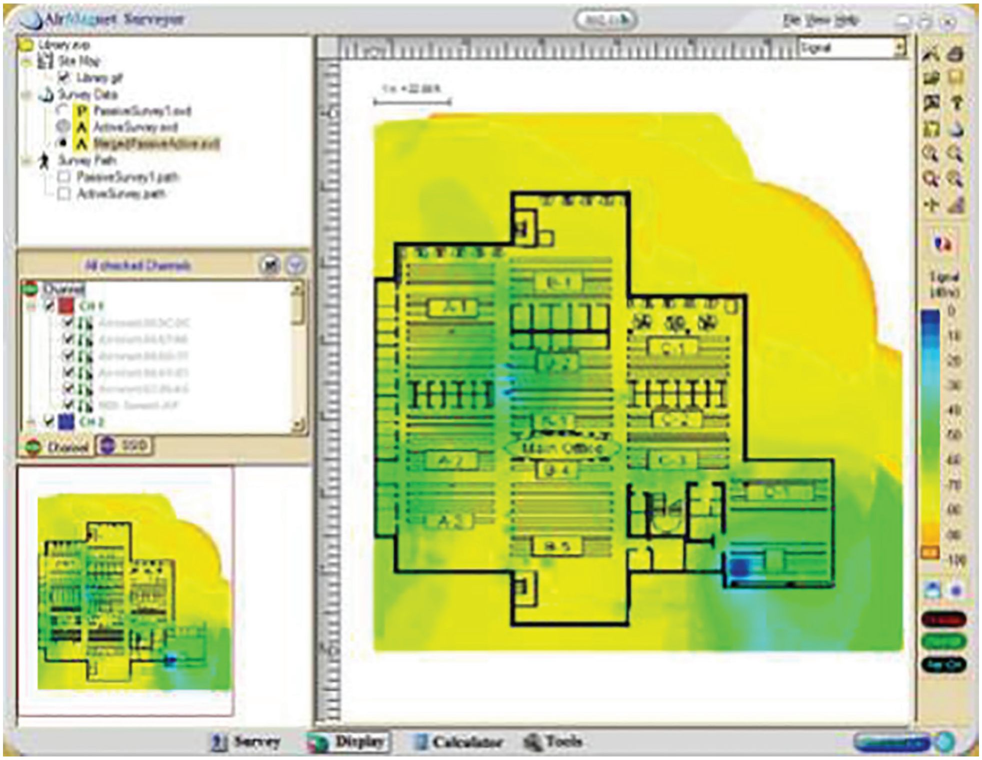


In addition to using a wireless analyzer, to create a good wireless network, you need to do a wireless survey of the floor or building where you are installing your network. To do this, you need a wireless survey tool. Wireless survey tools help you design and deploy the most accurate indoor and outdoor wireless LAN networks (802.11n/a/b/g/ac) correctly the first time and prevent costly rework and IT complaints.

You can collect real-world data by performing unique true end-user experience measurements (wireless LAN throughput, data rates, retries, losses). You can also minimize the (expensive) impact of RF interference sources on wireless 802.11n/a/b/g/ac LAN performance by performing simultaneous wireless spectrum analysis in a single walk-through.

In addition, you can certify the wireless network for any design/application requirements using customer-ready pass/fail assessment reports. Figure 18.7 shows an output of a wireless survey tool.

FIGURE 18.7 Wireless survey tool



Bandwidth Speed Tester

A bandwidth speed test is exactly what it sounds like. It is a device that tests the speed of data transfer in the network. While there are many Internet-based tools for testing the Internet connection to test the performance the LAN, you will need a tool that operates within the network.

An example is LAN Speed Test from Totusoft. It is designed to measure your file transfer and network speeds (wired and wireless). It does this by building a file in memory, then transfers it both ways (removing the effects of windows file caching) while keeping track of the time, and then does the calculations for you.

Baseline

High-quality documentation should include a baseline for network performance because you and your client need to know what "normal" looks like in order to detect problems before they develop into disasters. Don't forget to verify that the network conforms to all internal and external regulations and that you've developed and itemized solid management procedures and security policies for future network administrators to refer to and follow.

In networking, *baseline* can refer to the standard level of performance of a certain device or to the normal operating capacity for your whole network. For instance, a specific server's baseline describes norms for factors like how busy its processors are, how much of the memory it uses, and how much data usually goes through the NIC at a given time.

A network baseline delimits the amount of bandwidth available and when. For networks and networked devices, baselines include information about four key components:

- Processor
- Memory
- Hard-disk (or other storage) subsystem
- Wired/wireless utilization

After everything is up and running, it's a good idea to establish performance baselines on all vital devices and your network in general. To do this, measure things like network usage at three different strategic times to get an accurate assessment. For instance, peak usage usually happens around 8:00 a.m. Monday through Friday, or whenever most people log in to the network in the morning. After hours or on weekends is often when usage is the lowest. Knowing these values can help you troubleshoot *bottlenecks* or determine why certain system resources are more limited than they should be. Knowing what your baseline is can even tell you if someone's complaints about the network running like a slug are really valid—nice!

It's good to know that you can use network-monitoring software to establish baselines. Even some server operating systems come with software to help with network monitoring, which can help find baselines, perform log management, and even do network graphing as well so you can compare the logs and graphs at a later period of time on your network.

In my experience, it's wise to re-baseline network performance at least once a year. And always pinpoint new performance baselines after any major upgrade to your network's infrastructure.

Network Monitoring and Logging

There are a lot of ways to find out what's really going on within your network. Most administrators opt to directly keep tabs on network performance by looking at important factors like data rates and available bandwidth, using the many tools on the market designed to help with that. Another good strategy for assessing a network's health and well-being is via the more indirect route of monitoring the logs that your server operating systems keep. These can help you spot problems on your physical network as well as services or applications that aren't running properly and could eventually bring the network or its resources down and make your users really unhappy.

Network Monitoring

Some key network-monitoring tools and diagnostic utilities around today are software additions that run on an existing server operating system like Windows Server or Unix. Others are stand-alone hardware devices that you plug into your network, but both are basically the packet sniffers we talked about back in Chapter 14. Although it's true that hackers can and do use sniffers to capture network traffic and gather data for an attack, we make good use of them too. And strange but true, being a bit of a hacker yourself can make you a much better sys admin—knowing your enemies and their methods can help you find the same holes they would use for evil, and you can use that knowledge to plug security holes and even optimize your network's performance.

Packet sniffers allow you to examine network traffic down to details of individual packets. You can put the packet's header under the microscope: It contains vital information about the protocol being used to encapsulate it, plus the source and destination IP addresses. This is super-valuable information—if I'm seeing the speed of traffic on a specific segment grind to a crawl, one of first the things I'll look for is one IP address that's spewing tons of data. If that's the case, it could mean that I've got a failing network adapter because a common symptom of a dying NIC is to become extremely "chatty" by sending out broadcast packets and clogging things to the point that legitimate traffic can't get through. It's like getting a deluge of junk mail and being forced to read every last bit of it; a broadcast packet is technically addressed to everyone, meaning that all the other NICs on the segment have to stop and read what's in it—not so good.

NOTE

Good news—routers are, by default, configured to prevent broadcasts from going from one segment to another. Most switches sold today are also able to prevent broadcasts from spreading to multiple network segments, but not by default.

When you hear people refer to things like *load testing*, *connectivity testing*, and *throughput testing*, they're really talking about network monitoring. You'll also hear network monitors referred to as *protocol analyzers*. Microsoft has a graphical utility called Network Monitor that can be used to capture network traffic. The current version is 3.4, and it's supported by Windows Vista, Windows 7/8/10, and Server 2003/2008/2012/. You can download it from Microsoft's website, but for it to work, your network adapter must be able to work in promiscuous mode (yes, you read that right!). Several third parties specialize in producing network monitors, such as, for example, Fluke Networks, which makes some cool tools like the OptiView Network Analyzer.

SNMP

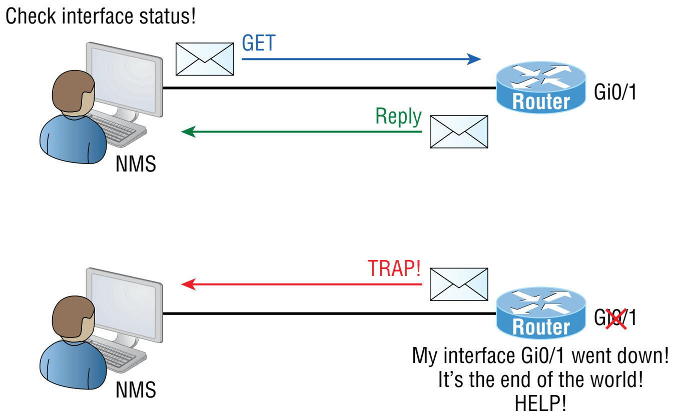
Although *Simple Network Management Protocol (SNMP)* certainly isn't the oldest protocol ever, it's still pretty old, considering it was created way back in 1988 (RFC 1065)!

SNMP is an Application layer protocol that provides a message format for agents on a variety of devices to communicate with network management stations (NMSs)—for example, Cisco Prime or HP Openview. These agents send messages to the NMS station, which then either reads or writes information in the database, stored on the NMS, that's called a Management Information Base (MIB).

The NMS periodically queries or polls the SNMP agent on a device to gather and analyze statistics via GET messages. These messages can be sent to a console or alert you via email or SMS. The command `snmpwalk` uses the SNMP GET NEXT request to query a network for a tree of information.

End devices running SNMP agents would send an SNMP trap to the NMS if a problem occurs. This is demonstrated in Figure 18.8.

FIGURE 18.8 SNMP GET and TRAP messages



Admins can also use SNMP to provide some configuration to agents as well, called SET messages. In addition to polling to obtain statistics, SNMP can be used for analyzing information and compiling the results in a report or even a graph. Thresholds can be used to trigger a notification process when exceeded. Graphing tools are used to monitor the CPU statistics of devices like a core router. The CPU should be monitored continuously, and the NMS can graph the statistics. Notification will be sent when any threshold you've set has been exceeded.

SNMP has three versions, with version 1 being rarely, if ever, implemented today. Here's a summary of these three versions:

SNMPv1 Supports plaintext authentication with community strings and uses only UDP.

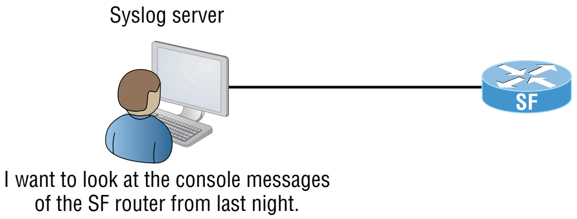
SNMPv2c Supports plaintext authentication with MD5 or SHA with no encryption but provides GET BULK, which is a way to gather many types of information at once and minimize the number of GET requests. It offers a more detailed error message reporting method, but it's not more secure than v1. It uses UDP even though it can be configured to use TCP.

SNMPv3 Supports strong authentication with MD5 or SHA, providing confidentiality (encryption) and data integrity of messages via DES or DES-256 encryption between agents and managers. GET BULK is a supported feature of SNMPv3, and this version also uses TCP.

Syslog

Reading system messages from a switch's or router's internal buffer is the most popular and efficient method of seeing what's going on with your network at a particular time. But the best way is to log messages to a *syslog* server, which stores messages from you and can even time-stamp and sequence them for you, and it's easy to set up and configure! Figure 18.9 shows a syslog server and client in action.

FIGURE 18.9 Syslog server and client


Syslog server
SF
I want to look at the console messages
of the SF router from last night.

Syslog allows you to display, sort, and even search messages, all of which makes it a really great troubleshooting tool. The search feature is especially powerful because you can use keywords and even severity levels. Plus, the server can email admins based on the severity level of the message.

Network devices can be configured to generate a syslog message and forward it to various destinations. These four examples are popular ways to gather messages from Cisco devices:

- Logging buffer (on by default)
- Console line (on by default)
- Terminal lines (using the `terminal monitor` command)
- Syslog server

As you already know, all system messages and debug output generated by the IOS go out only the console port by default and are also logged in buffers in RAM. And you also know that routers aren't exactly shy about sending messages! To send message to the VTY lines, use the `terminal monitor` command.

So, by default, we'd see something like this on our console line:

```
*Oct 21 17:33:50.565:%LINK-5-CHANGED:Interface FastEthernet0/0,
changed state to administratively down
*Oct 21 17:33:51.565:%LINEPROTO-5-UPDOWN:Line protocol on
Interface FastEthernet0/0, changed state to down
```

And the router would send a general version of the message to the syslog server that would be formatted something like this:

```
Seq no:timestamp: %facility-severity-MNEMONIC:description
```

The system message format can be broken down in this way:

`seq no` This stamp logs messages with a sequence number, but not by default. If you want this output, you've got to configure it.

`Timestamp` Date and time of the message or event.

`Facility` The facility to which the message refers.

`Severity` A single-digit code from 0 to 7 that indicates the severity of the message.

`MNEMONIC` Text string that uniquely describes the message.

`Description` Text string containing detailed information about the event being reported.

The severity levels, from the most severe level to the least severe, are explained in Table 18.1. Informational is the default and will result in all messages being sent to the buffers and console.

TABLE 18.1 Severity levels

Severity Level	Explanation
Emergency (severity 0)	System is unusable.
Alert (severity 1)	Immediate action is needed.

Severity Level	Explanation
Critical (severity 2)	Critical condition.
Error (severity 3)	Error condition.
Warning (severity 4)	Warning condition.
Notification (severity 5)	Normal but significant condition.
Information (severity 6)	Normal information message.
Debugging (severity 7)	Debugging message.

NOTE If you are studying for your CompTIA Network+ exam, you need to memorize Table 18.1.

Understand that only emergency-level messages will be displayed if you've configured severity level 0. But if, for example, you opt for level 4 instead, level 0 through 4 will be displayed, giving you emergency, alert, critical, error, and warning messages too. Level 7 is the highest-level security option and displays everything, but be warned that going with it could have a serious impact on the performance of your device. So always use debugging commands carefully with an eye on the messages you really need to meet your specific business requirements!

SIEM

Security information and event management (SIEM) is a term for software products and services combining security information management (SIM) and security event management (SEM). SIEM technology provides real-time analysis of security alerts generated by network hardware and applications. You can get this as a software solution or a hardware appliance, and some businesses sell managed services using SIEM. Any one of these solutions provides log security data and can generate reports for compliance purposes.

The acronyms SEM, SIM, and SIEM are used interchangeably; however, SEM is typically used to describe the management that deals with real-time monitoring and correlation of events, notifications, and console views.

The term *SIM* is used to describe long-term storage, analysis, and reporting of log data. Recently, vSIEM (voice security information and event management) was introduced to provide voice data visibility.

SIEM can collect useful data about the following items:

- Data aggregation
- Correlation

- Alerting
- Dashboards
- Compliance
- Retention
- Forensic analysis

Notifications

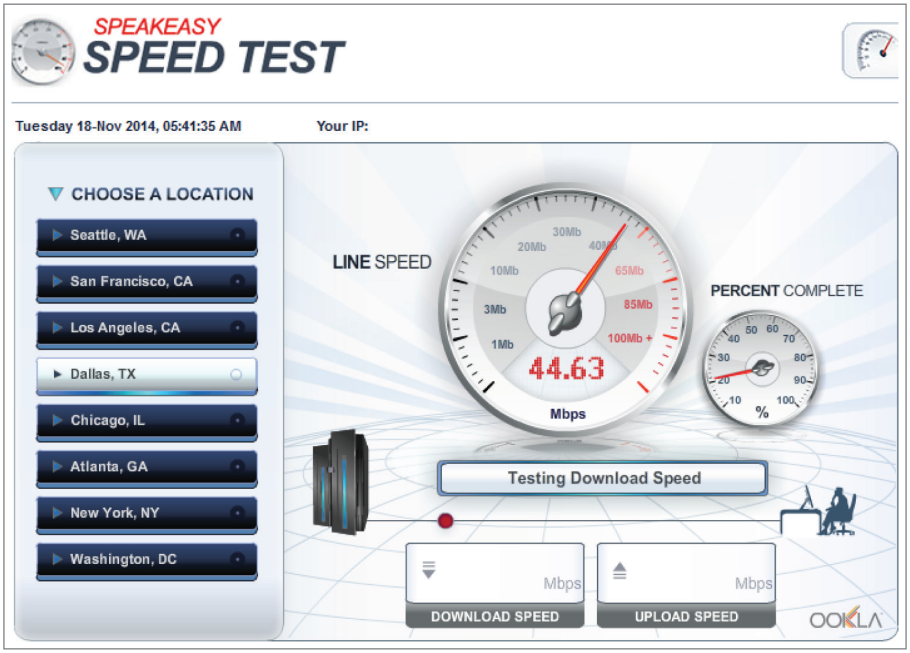
SIEM systems not only assess the aggregated logs in real time, they generate alerts or notifications when an issue is discovered. This allows for continuous monitoring of the environment in a way not possible with other log centralization approaches such as syslog.

Speed Test Sites

Speed test sites are especially helpful for testing the bandwidth of your Internet connection. I typically use Speakeasy's Speed Test, but just search for speed tests, or DSL speed tests, and you'll get a whole host of speed test sites.

Figure 18.10 shows the speed test site that I use.

FIGURE 18.10 Speakeasy Speed Test

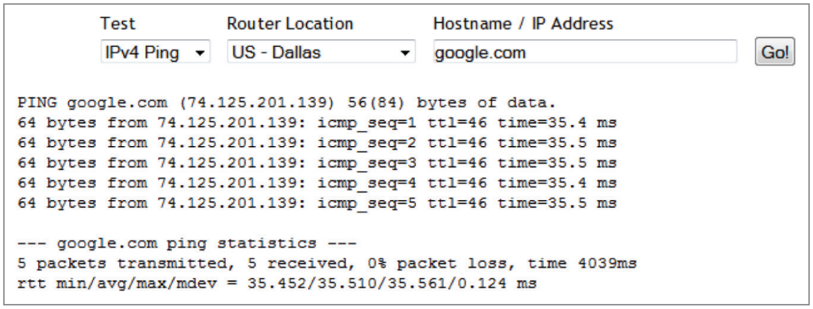


Looking Glass Sites

You can access a Looking Glass (LG) server remotely to view routing information. They are servers on the Internet that run Looking Glass software that is available to the public. The servers are essentially read-only portals to the router belonging to the organizations running them. They are basically just providing a ping or traceroute from a remote location for you.

Figure 18.11 shows an output from a Looking Glass server.

FIGURE 18.11 Looking Glass site output



Test: IPv4 Ping
Router Location: US - Dallas
Hostname / IP Address: google.com

```
PING google.com (74.125.201.139) 56(84) bytes of data.
64 bytes from 74.125.201.139: icmp_seq=1 ttl=46 time=35.4 ms
64 bytes from 74.125.201.139: icmp_seq=2 ttl=46 time=35.5 ms
64 bytes from 74.125.201.139: icmp_seq=3 ttl=46 time=35.5 ms
64 bytes from 74.125.201.139: icmp_seq=4 ttl=46 time=35.4 ms
64 bytes from 74.125.201.139: icmp_seq=5 ttl=46 time=35.5 ms

--- google.com ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4039ms
rtt min/avg/max/mdev = 35.452/35.510/35.561/0.124 ms
```

Server Logs

Windows Server 2016 (and most other Windows operating systems) comes with a tool called Event Viewer that provides you with several logs containing vital information about events happening on your computer. Other server operating systems have similar logs, and many connectivity devices like routers and switches also have graphical logs that gather statistics on what's happening to them. These logs can go by various names, like *history logs*, *general logs*, or *server logs*. Figure 18.12 shows an Event Viewer system log display from a Windows Server 2003 machine.

On Windows servers, a minimum of three separate logs hold different types of information:

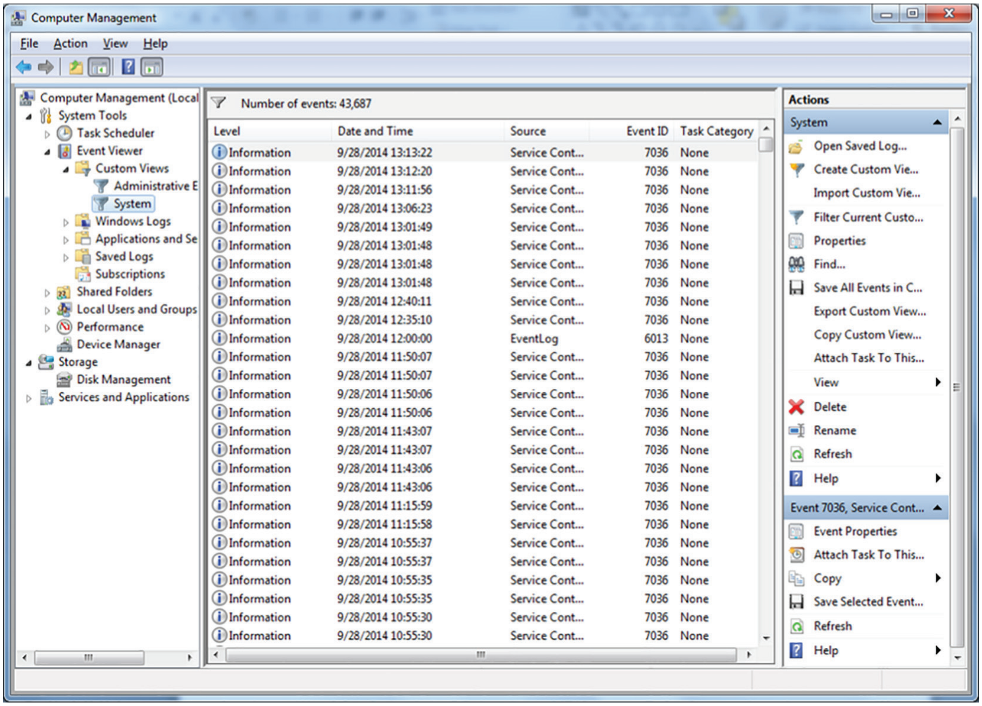
Application Contains events triggered by applications or programs determined by their programmers. Example applications include LiveUpdate, the Microsoft Office suite, and SQL and Exchange servers.

Security Contains security events like valid or invalid logon attempts and potential security problems.

System Contains events generated by Windows system components, including drivers and services that started or failed to start.

The basic "Big Three" can give us lots of juicy information about who's logging on, who's accessing the computer, and which services are running properly (or not). If you want to find out whether your Dynamic Host Configuration Protocol (DHCP) server started up its DHCP service properly, just check out its system log. Because the computer depicted in Figure 18.12 is configured as a domain controller, its Event Viewer serves up three more logs: Directory Service, DNS Server, and File Replication Service, for a total of six.

FIGURE 18.12 Windows Event Viewer system log



Number of events: 43,687

Level	Date and Time	Source	Event ID	Task Category
Information	9/28/2014 13:13:22	Service Cont...	7036	None
Information	9/28/2014 13:12:20	Service Cont...	7036	None
Information	9/28/2014 13:11:56	Service Cont...	7036	None
Information	9/28/2014 13:06:23	Service Cont...	7036	None
Information	9/28/2014 13:01:49	Service Cont...	7036	None
Information	9/28/2014 13:01:48	Service Cont...	7036	None
Information	9/28/2014 13:01:48	Service Cont...	7036	None
Information	9/28/2014 13:01:48	Service Cont...	7036	None
Information	9/28/2014 12:40:11	Service Cont...	7036	None
Information	9/28/2014 12:35:10	Service Cont...	7036	None
Information	9/28/2014 12:00:00	EventLog	6013	None
Information	9/28/2014 11:50:07	Service Cont...	7036	None
Information	9/28/2014 11:50:07	Service Cont...	7036	None
Information	9/28/2014 11:50:06	Service Cont...	7036	None
Information	9/28/2014 11:50:06	Service Cont...	7036	None
Information	9/28/2014 11:43:07	Service Cont...	7036	None
Information	9/28/2014 11:43:07	Service Cont...	7036	None
Information	9/28/2014 11:43:06	Service Cont...	7036	None
Information	9/28/2014 11:43:06	Service Cont...	7036	None
Information	9/28/2014 11:15:59	Service Cont...	7036	None
Information	9/28/2014 11:15:58	Service Cont...	7036	None
Information	9/28/2014 10:55:37	Service Cont...	7036	None
Information	9/28/2014 10:55:37	Service Cont...	7036	None
Information	9/28/2014 10:55:35	Service Cont...	7036	None
Information	9/28/2014 10:55:35	Service Cont...	7036	None
Information	9/28/2014 10:55:30	Service Cont...	7036	None
Information	9/28/2014 10:55:30	Service Cont...	7036	None

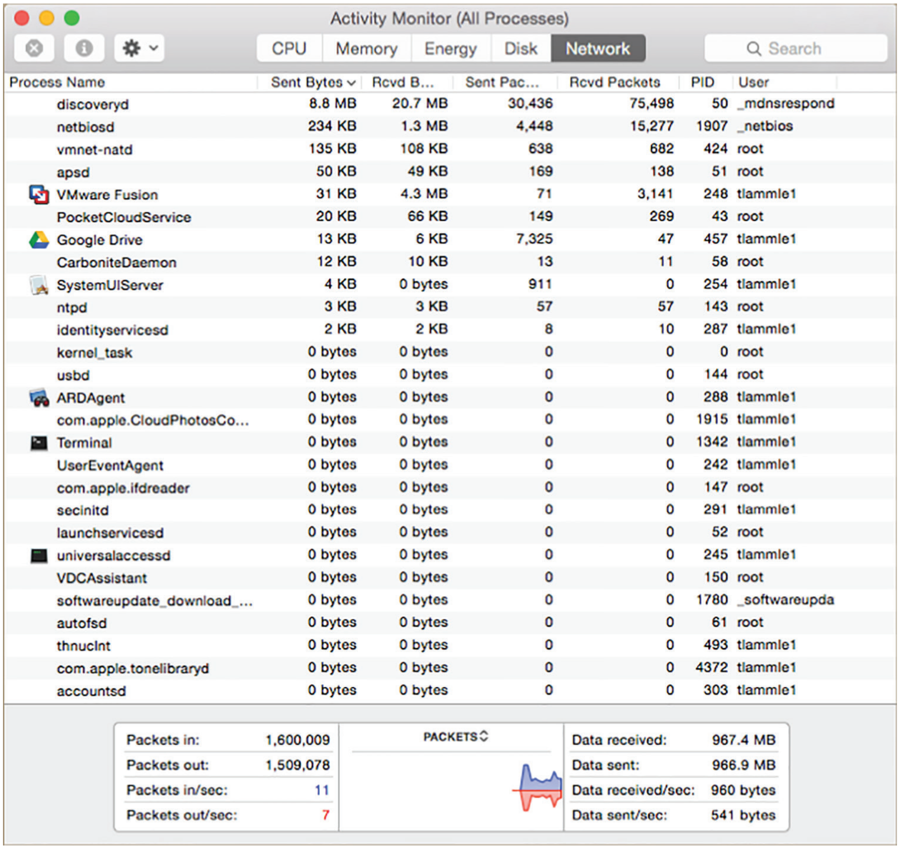
Windows 2000 Server and Windows Server 2003 came with System Monitor—another graphical tool used to create network baselines, provide performance logs, and identify bottlenecks. Windows Server 2008 R2 offered an optional monitoring and optimization tool called System Center Operations Manager 2010.

Utilization

Wired and wireless analyzers can show you the bandwidth used on your network segments or wireless area. There are tools to help you find the stats on storage, network device CPU, and device memory for your servers and hosts.

For example, if you have a Mac, you can use the built-in activity monitor, which provides the CPU usage, memory statistics, energy used by the applications, disk usage, and network bytes sent and received, as shown in Figure 18.13.

FIGURE 18.13 Mac Activity Monitor



Process Name	Sent Bytes	Rcvd B...	Sent Pac...	Rcvd Packets	PID	User
discoveryd	8.8 MB	20.7 MB	30,436	75,498	50	_mdnsrespond
netbiosd	234 KB	1.3 MB	4,448	15,277	1907	_netbios
vmnet-natd	135 KB	108 KB	638	682	424	root
apsd	50 KB	49 KB	169	138	51	root
VMware Fusion	31 KB	4.3 MB	71	3,141	248	tlammle1
PocketCloudService	20 KB	66 KB	149	269	43	root
Google Drive	13 KB	6 KB	7,325	47	457	tlammle1
CarboniteDaemon	12 KB	10 KB	13	11	58	root
SystemUIServer	4 KB	0 bytes	911	0	254	tlammle1
ntpd	3 KB	3 KB	57	57	143	root
identityservicesd	2 KB	2 KB	8	10	287	tlammle1
kernel_task	0 bytes	0 bytes	0	0	0	root
usbd	0 bytes	0 bytes	0	0	144	root
ARDAgent	0 bytes	0 bytes	0	0	288	tlammle1
com.apple.CloudPhotosCo...	0 bytes	0 bytes	0	0	1915	tlammle1
Terminal	0 bytes	0 bytes	0	0	1342	tlammle1
UserEventAgent	0 bytes	0 bytes	0	0	242	tlammle1
com.apple.ifdreader	0 bytes	0 bytes	0	0	147	root
secinitd	0 bytes	0 bytes	0	0	291	tlammle1
launchservicesd	0 bytes	0 bytes	0	0	52	root
universalaccessd	0 bytes	0 bytes	0	0	245	tlammle1
VDCAssistant	0 bytes	0 bytes	0	0	150	root
softwareupdate_download_...	0 bytes	0 bytes	0	0	1780	_softwareupda
autofsd	0 bytes	0 bytes	0	0	61	root
thnuclnt	0 bytes	0 bytes	0	0	493	tlammle1
com.apple.tonelibraryd	0 bytes	0 bytes	0	0	4372	tlammle1
accountsd	0 bytes	0 bytes	0	0	303	tlammle1

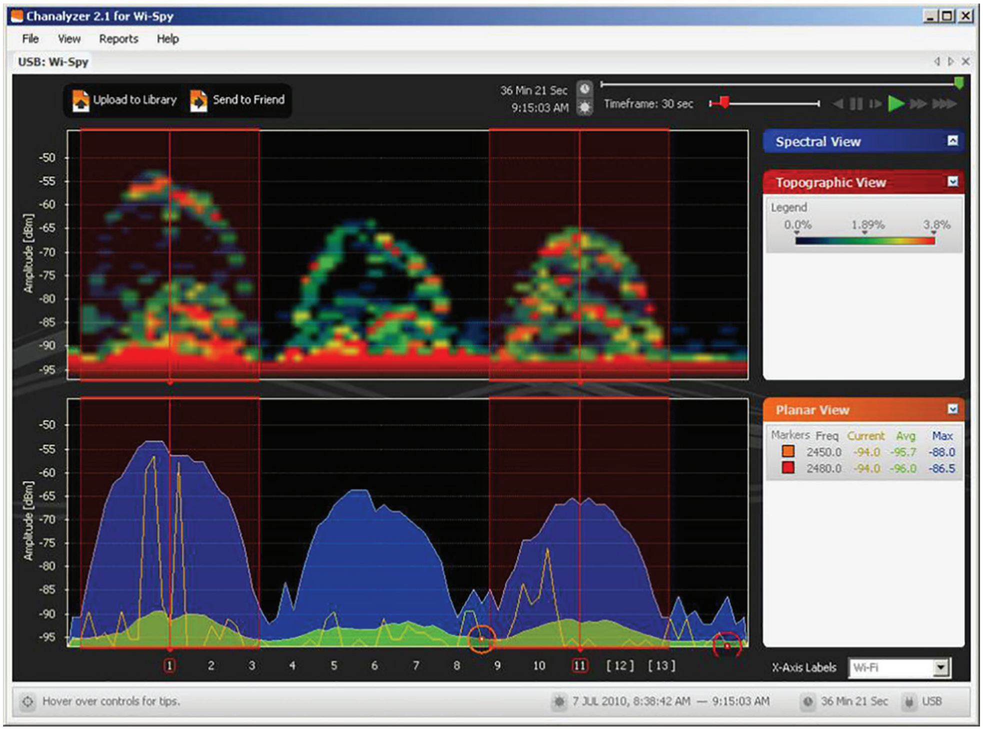
Packets in:	1,600,009
Packets out:	1,509,078
Packets in/sec:	11
Packets out/sec:	7

Data received:	967.4 MB
Data sent:	966.9 MB
Data received/sec:	960 bytes
Data sent/sec:	541 bytes

In addition to utilization information for your hosts, servers, networks, and so on, you need information about the wireless channel utilization on your network. To get it, you need to use a wireless analyzer, which I've already discussed.

The wireless analyzer in Figure 18.14 is showing channel utilization. Notice that three channels—1, 6, and 11—are in use.

FIGURE 18.14 Wireless channel utilization



Markers	Freq	Current	Avg	Max
🟧	2450.0	-94.0	-95.7	-88.0
🟥	2480.0	-94.0	-96.0	-86.5

Hover over controls for tips.

7 JUL 2010, 8:38:42 AM — 9:15:03 AM   36 Min 21 Sec   USB

Identifying Hardware Tools

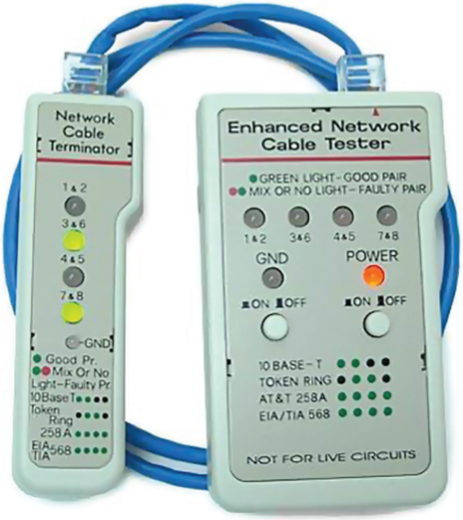
A great example of when the hardware tools and testers I'm about to cover would come in really handy is if you're dealing with failed fiber links between structures. As a system administrator running a network with a server, routers, and switches, it's entirely possible you'll never find yourself in a situation that calls for these tools. But if you're in network design or a field that requires installing cabling, then these hardware tools are going to be really valuable to you. Unlike the software tools we just talked about, none of these goodies are free, but they do come in a variety of flavors that run the gamut from real bargains to "You're joking—how much?" Some of them can indeed free you of thousands of dollars!

Cable testers are the most widely used hardware tool in today's LANs, so let's start with them.

Cable Testers

The best way to deal with a faulty cable installation is to avoid the problem in the first place by purchasing high-quality components and installing them carefully. Still, this isn't a perfect world—no matter how careful you are, problems are bound to arise anyway. The tools that I'm going to cover can be used to test cables at the time of their installation and afterward, if and when you need to troubleshoot cabling problems. Cable-testing tools can range from simple, inexpensive mechanical devices to elaborate electronic testers that automatically supply you with a litany of test results in an easy-to-read pass/fail format. Figure 18.15 shows an example of an inexpensive cable tester for twisted-pair wiring testing.

FIGURE 18.15 An inexpensive cable tester



This little box can verify the connection through the cable and tell you if the cable is straight-through or crossover. It can also identify problems such as grounding issues. Sometimes the problem is not a complete lack of connectivity. Sometimes performance is slow, which can also be a cabling issue that a cable tester can identify. This tool is as cheap as they come.

Let's focus on the types of tools available for both copper and fiber-optic cable testing. This is not to say that you need all of the tools listed here. In fact, I'll try to steer you away from certain types of tools. Sometimes you'll get lucky and have the luxury of choosing between high-tech and low-tech devices that perform roughly the same function. You can choose which ones you prefer according to the requirements of your network, your operational budget, even your temperament and time constraints. Some of the tools are extremely complicated and require extensive training to use effectively, whereas others can be used by pretty much anybody equipped with a functioning brain.

Other important considerations to keep in mind when selecting the types of tools you need are based on the descriptions of cable tests given earlier in this chapter, the test results required by the standards you're using to certify your network, and the capabilities of the people who will be doing the actual work. And don't forget the potentially painful cost of some of them.

Loopback Adaptor (Plug)

A loopback test is a diagnostic procedure in which a signal is transmitted and returned to the sending device after passing through all or a portion of a network or circuit. The returned signal is compared with the transmitted signal to evaluate the integrity of the equipment or transmission path. A computer needs a loopback plug that is inserted into a port in order to perform a loopback test.

Loopback plugs are made for both Ethernet and fiber applications. Figure 18.16 shows an Ethernet loopback plug and Figure 18.17 shows a plug for fiber applications.

FIGURE 18.16 Ethernet loopback plug

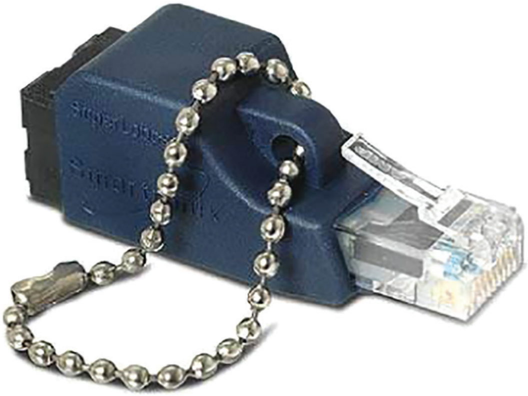
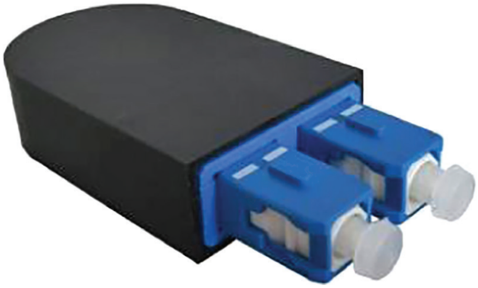


FIGURE 18.17 Fiber loopback plug



Wire-Map Testers

A *wire-map tester* is a device that transmits signals through each wire in a copper twisted-pair cable to determine if it's connected to the correct pin at the other end. Wire mapping is the most basic test for twisted-pair cables because the eight separate wire connections involved in each cable run are a common source of installation errors. Wire-map testers detect transposed wires, opens (broken or unconnected wires), and shorts (wires or pins improperly connected to each other). All of these problems can render a cable run completely inoperable.

Wire-map testing is nearly always included in multifunction cable testers, but sometimes it's just not worth spending serious cash on a comprehensive device. Dedicated wire-map testers that run about two to three hundred bucks are relatively inexpensive options that enable you to test your installation for the most common faults that occur during installations and afterward. If, say, you're installing voice-grade cable, a simple wire-mapping test is probably all that's needed.

A wire-map tester essentially consists of a remote unit that you attach to the far end of a connection and a battery-operated, handheld main unit that displays the results. Typically, the tester displays various codes that indicate the specific type of fault that it finds. You can also purchase a tester with multiple remote units that are numbered so that one person can test several connections without constantly traveling back and forth from one end of the connections to the other to move the remote unit.

NOTE

The one wiring fault that is not detectable by a dedicated wire-map tester is something known as *split pairs*. This fault flies under the radar because even though the pinouts are incorrect, the cable is still wired straight through. To detect split pairs, you must use a device that tests the cable for the near-end crosstalk that split pairs cause.

Continuity Testers

A *continuity tester*, or *line tester*, is an even simpler and less-expensive device than a wire-map tester; it's designed to check a copper cable connection for basic installation problems like opens, shorts, and crossed pairs. It will set you back only a few dollars, but such a device usually can't detect the more complicated twisted-pair wiring faults. It's still a nice option for basic cable testing, especially for coaxial cables that have only two conductors and so don't easily confuse whoever is installing them.

Like a wire-map tester, a continuity tester consists of two separate units that you connect to each end of the cable you want to test. Most of the time, the two units can snap together for storage and easy testing of patch cables. But remember, a continuity tester simply tests continuity, equivalent to data at one bit per minute (or slower), and cannot tell you whether or not a cable will reliably pass Ethernet data at network speeds. For that, you need a real cable tester that can test cables up to Gigabit speeds or higher.

Protocol Analyzer

A *protocol analyzer* is often confused with a packet sniffer because some products really are both. Remember—a packet sniffer looks at all traffic on a network segment. On the other hand, a protocol analyzer (surprise!) analyzes protocols. These tools come in both software and hardware versions, but compared to the products I listed earlier in this chapter, a network protocol analyzer is likely to give you more information and help than a sniffer will. This is because a bona fide protocol analyzer can actually help you troubleshoot problems, whereas most sniffers just provide information for you to have a ball deciphering.

A network protocol analyzer can perform the following functions:

- Help troubleshoot hard-to-solve problems
- Help you detect and identify malicious software (malware)
- Help gather information such as baseline traffic patterns and network-utilization metrics
- Help you identify unused protocols so that you can remove them from the network
- Provide a traffic generator for penetration testing
- Possibly even work with an IDS

And last, and perhaps most important for you, they can really help you learn about networking in general. This means if you just want to find out why a network device is functioning in a certain way, you can use a protocol analyzer to sniff (there's that word again) the traffic and expose the data and protocols that pass along the wire.

Free Network Analyzers

I've found a whole bunch of network analyzers you can use for free at the following location:

`www.snapfiles.com/freeware/network/fwpacketsniffer.html`

But understand that there's no way I can verify the validity of this link after this book is published. Again, the terms *sniffer* and *analyzer* are used to define the same products found at this link. For example, both Microsoft's Network Monitor (NetMon) and Wireshark are called sniffers and analyzers, and they both are—at least to some degree.

Certifiers

Certification testers—or *certifiers*—are used to determine whether your network meets specific International Organization for Standardization (ISO) or Telecommunications Industry Association (TIA) standards (Cat 5e, Cat 6, or Cat 7). They are the only option for you in this case. Also, if your network is wired with both copper and fiber, you really must use a certification tester.

Basically, a certifier is a combination cable tester and network analyzer, only better because it comes with more options. This is wonderful because it makes your job easier and makes you seem smarter to everyone around you—you're only as good as your tools, right? A good certifier will test the performance and response times of network resources like web, file, email, and even DNS and Dynamic Host Configuration Protocol (DHCP) servers. And, at the same time, it will certify your full Category 6 cable installation. After it finishes all this, you can provide your boss with a detailed network test report complete with dazzling, colorful graphics to make it simple to explain and understand—voilà! You're instantly the genius of the day.

To get these smarts, all you need is a lot of money. These products are not for the small office, home office (SOHO) market because they cost literally thousands of dollars, starting at about $5,000.

Time-Domain Reflectometer

A *time-domain reflectometer (TDR)* is a tool that finds and describes faults in metallic cables like twisted wire pairs and coaxial cables. The equivalent device for optical fiber is an optical time-domain reflectometer (OTDR), which I'll talk about in a minute.

A TDR works in the same basic way that radar does. It transmits a short rise time pulse along the conductor, and if it turns out to be of a uniform impedance and properly terminated, the entire transmitted pulse is absorbed in the far-end termination; no signal is reflected back to the TDR. Any impedance interruptions will cause some of the incident signal to be sent back toward the source, letting you know all is not well.

So basically, any increases in the impedance create a reflection that reinforces the original pulse and decreases the impedance, thereby creating a reflection that opposes the original pulse. The resulting reflected pulse that's measured at the output/input to the TDR is displayed or plotted in measures of time. And because the speed of signal propagation is pretty consistent for a given type of transmission medium, the reading can also tell you about the cable length.

Because of this sensitivity to any variation in impedance, you can use a TDR to verify these things:

- Speed and condition of the cable
- How long it takes to send a signal down a cable and how long it takes to come back
- Cable impedance characteristics
- Splice and connector locations and their associated loss amounts
- Estimated cable lengths

Now, let's take a look at a device that tests fiber-optic cables.

Optical Time-Domain Reflectometer

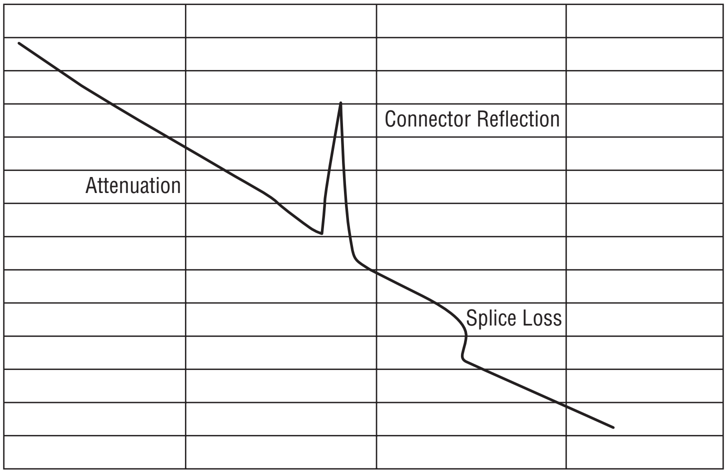
An *optical time-domain reflectometer (OTDR)* is an optoelectronic instrument used to give you the skinny on optical fibers, typically referred to as light meters. It works by putting out a series of optical pulses into the specific fiber you want to test. From the same end that sent these impulses, it collects and measures the light that is scattered and reflected along the length of the fiber. It then records the change in the amount of refraction at various points. This is a lot like the way an electronic TDR measures reflections caused by impedance changes in a cable that you're testing. The strength of the return pulses is incorporated into a measure of time, which also conveniently gives you the fiber's length.

We use OTDRs to give us the following information:

- The fiber's estimated length
- Its overall attenuation, including splice and mated-connector losses
- The location faults, such as breaks

Figure 18.18 shows the output from an OTDR testing a fiber connection.

FIGURE 18.18 Sample OTDR output



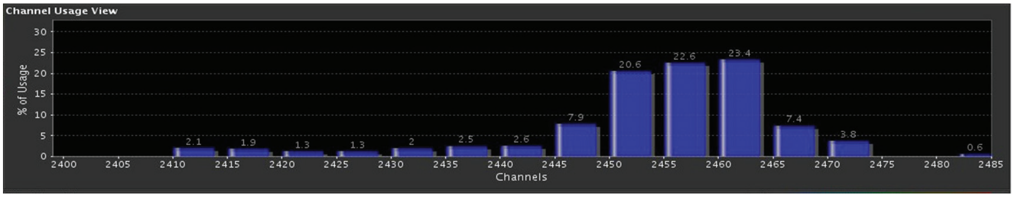
The spike shows where a splice in the fiber is located, which has resulted in the signal being degraded. This is a very typical output. As the signal attenuates, you see a gradual but quick drop in decibels (db). Any connector will actually show a reflection, which, as mentioned, shows up as a spike in the OTDR output. The connector then creates more attenuation and loss of more db. The more splices, the less distance you can run with fiber.

Multimeter

A *multimeter*, or a multitester (also called a volt/ohm meter [VOM]), is a multitasking electronic measuring instrument. Your average multimeter typically includes features like the ability to measure voltage, current, and resistance. Multimeters come in analog and digital versions, and they range from basic handheld devices useful for simple fault-finding and field-service work to more complex bench instruments that will give you measurements with a very high degree of accuracy.

They can be used to troubleshoot electrical problems in a wide array of electrical devices like batteries, motor controls, appliances, power supplies, and wiring systems. Figure 18.19 shows output of the multimeter that I use to help troubleshoot my networks.

FIGURE 18.19 A multimeter

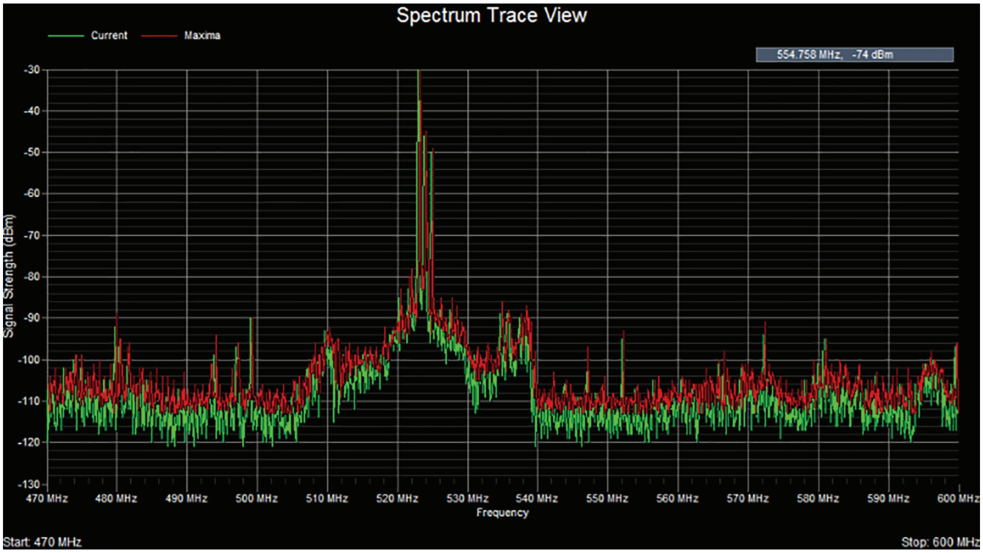


Multimeters come in lots of flavors with different ranges of features and prices. Cheap ones cost less than 10 bucks, but the top-of-the-line models can set you back up to 5 thousand bucks.

Spectrum Analyzer

A spectrum analyzer is a tool that focuses on the Physical layer, which will vary based on the type of analyzer. Although vendors make these analyzers for both audio and optical signals, in most cases spectrum analyzers are used to analyze wireless or radio frequency signals. Spectrum analyzers is primarily used to identify and measure the strength of radio signals that are present in the area. It can visually display these signals by frequency on the device. These devices are used to locate sources of inference that may impact the operation of a wireless network. Figure 18.20 is a shot taken from the screen of a spectrum analyzer showing the relative use of each channel in the area.

FIGURE 18.20 Spectrum analyzer output



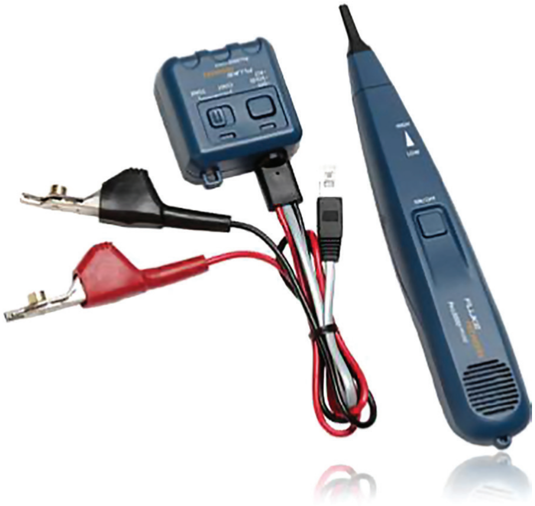
Toner Generator (Probe)

A *toner probe*, also called a tone generator, is a simple copper cable tester that is simple to use and can be used to trace a wire in a wall. It is a two-piece unit that's basically a tone generator and probe, sometimes called a "fox and hound" wire tracer. This type of device consists of one part that you connect to a cable with a standard jack—or to an individual wire with alligator clips that transmit a signal over the cable or wire—and another part that's a penlike probe that emits an audible tone when it touches the other end of the cable, the wire, or even its insulating sheath.

Most often, you will use a toner probe to locate a specific connection in a punch-down block because (annoyingly) some installers run all the cables for a network to the central punch-down block without labeling them. They (or you, if you're unlucky enough) then have to use a tone generator to identify which block is connected to which wall plate and label the punch-down block accordingly. This tool can identify a particular cable at any point between the two ends, and because the probe can detect the cable containing the tone signal through its sheath, it can help you to locate one specific cable out of a massive cable-spaghetti bundle in a ceiling conduit or other type of raceway.

Just connect the tone generator to one end, and touch the probe to each cable in the bundle until you hear the tone. Figure 18.21 shows a picture of my toner and the probe I use to find the tone on the other end of the cable.

FIGURE 18.21 A toner probe



Also, by testing the continuity of individual wires using alligator clips, you can use a tone generator and probe to find opens, shorts, and miswires. An open wire won't produce a tone at the other end, a short will produce a tone on two or more wires at the other end, and an improperly connected wire will produce a tone on the wrong pin at the other end.

Sound like fun to you? Well, not so much—it takes a really long time, and it's super tedious. Worse, the whole process is almost as prone to errors as the cable installation itself. You have to either continually travel from one end of the cable to the other to move the tone generator unit or use a partner to test each connection, keeping in close contact using radios or some other means of communication to avoid confusion. So, considering the time and effort involved, investing in a wire-map tester is just a much more practical solution unless you're numbingly bored or really easily amused.

Metrics

When using any the tools discussed in the preceding sections, especially the network testing tools, collecting and comparing metrics over time is a valuable exercise. Once a baseline has been established for these metrics, you can determine when an issue has gotten better or worse over time. It also allows you to determine if measures you have taken to improve a scenario have done so.

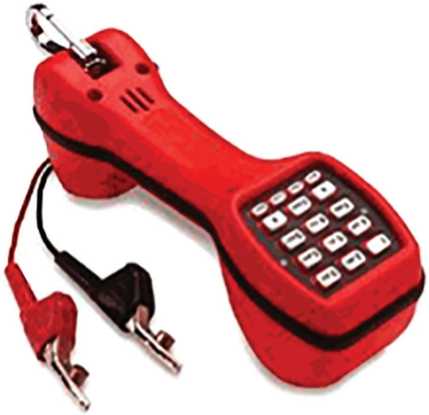
Error Rate

One of the key metrics for which a baseline should be established is network error rate. Since network errors typically lead to retransmissions, they typically result in reduced throughput because each retransmission represents a lost opportunity to use that time slot to send new data.

Butt Set

A *butt set* is essentially a portable telephone that allows you to test analog wet or dry lines and is used to monitor those lines. The most common type, shown in Figure 18.22, can both monitor and transmit.

FIGURE 18.22 A butt set



You see these all the time with telco guys up on the telephone poles. They use their butt sets to connect to telephone lines, test them, and even make phone calls.

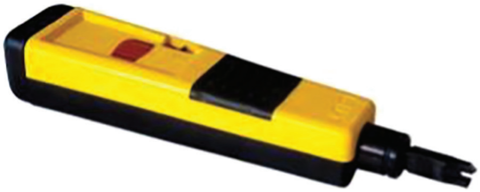
Another handy tool that will take the place of a butt set is a *hound*. This noncanine device is nothing more than an inductively coupled amplifier with a small speaker in a handheld tool. It's used to monitor the audio on a given line to verify that you have the right pair before connecting it and typically used with a toner probe. It will also monitor for noise.

Punch-Down Tool

Most networks today are built using twisted-pair cable of some sort. This cable is usually terminated in wiring closets using a tool known as a *punch-down tool*. It's called that because that's exactly what the tool does—punches down the wire into some kind of insulation displacement connector (IDC).

There are different types of punch-down tools. The most common is a punch-down with replaceable blades for the different types of connectors (either 66 or 110). Figure 18.23 shows an example of this type of punch-down tool.

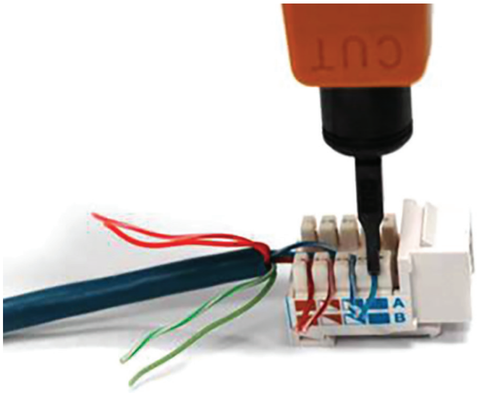
FIGURE 18.23 An example of a punch-down tool



IDCs make contact by cutting through, or displacing, the insulation around a single conductor inside a twisted-pair cable.

As shown in Figure 18.24, the punch-down tool pushes a conductor between the sides of a V inside an IDC, in this example a keystone connector, allowing the small metal blade inside the connector to make contact with the inner conductor deep inside the wire.

FIGURE 18.24 Using a punch-down tool on a small keystone connector



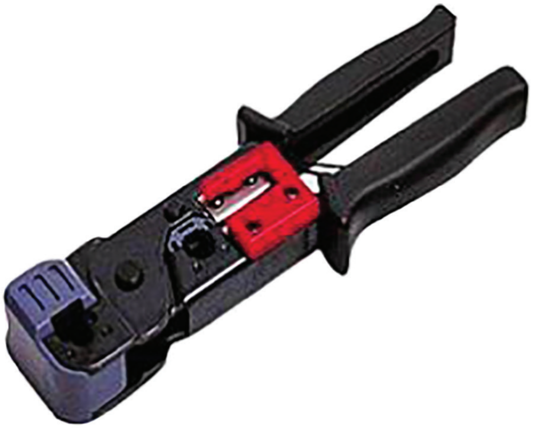
Now let's take a look at how to put a cable end together.

Cable Stripper/Snips

A *wire crimper*, often simply called a crimper, is a handy tool found in most network technicians' tool bags. Crimpers are primarily used for attaching ends onto different types of network cables via a process known as—that's right—*crimping*. Crimping involves using your hands to apply a certain amount of force to press some kind of metal teeth into the inner conductors of a cable. Before you can crimp a connector onto the end, you've got to strip the cable with a type of *cable stripper* (or snip) and then properly put the wires into the connector.

Figure 18.25 shows what a cable stripper and snip looks like (this particular tool also includes a crimper).

FIGURE 18.25 A combination cable stripper, crimper, and snippers



Often, network technicians will make patch cables with a crimper. They'll take a small piece of Category 5e unshielded twisted-pair (UTP), strip the cable, and crimp two RJ-45 ends onto it to create the cable. Snips will create the type of cable needed to connect a host to a wall jack connection, for example. There are strippers and crimpers for the other types of cable as well—even specialized crimpers for fiber-optic ends.

Voltage Event Recorder (Power)

Alternating current (AC) is basically the food that PCs and other network devices require in specific amounts to function properly. In the United States, it's normally 110 volts and changes polarity 60 cycles a second (60 hertz). These values are referred to as *line voltage*. Any deviation from these values can create some major problems for your PC or other electronics—like death. While we're on the subject, you should also know that when a telephone rings, the phone company central office puts 140 VAC on the line to ring that bell; telephone lines are not always the "low-voltage" devices we think they are. Do all phone systems do this, even PBX systems within buildings? Are you willing to bet your life that they don't? Didn't think so.

This is why we have *surge protectors*. These little saviors use a special electronic circuit that monitors the incoming voltage level and trips a circuit breaker when the voltage level reaches critical mass, which is known as the *overvoltage threshold*. Even though having a surge protector is definitely better than nothing, they too can fall victim to overvoltage events—I'm reminded of a friend whose home was struck by lightning during a thunderstorm and he found his surge protectors literally melted into the carpet! But they're still cool because even though they're really only somewhat protective, they are multiple-outlet strips that give us a lot more places to plug in our stuff.

By contrast, a quality *voltage event recorder* can troubleshoot and even provide preventative maintenance on your entire electrical system, whether it's for a home or a huge factory. Although they do big things, they're typically small devices that just plug into a wall and record, over time, the power quality of a given circuit. You would typically use a voltage event recorder for the following applications:

Recording Voltage The voltage event recorder monitors and records the supply voltage and checks whether the socket outlet is providing voltage within specifications.

Measuring Distortion The device measures frequency and harmonics, and it checks whether your uninterruptible power supply (UPS) system is functioning correctly.

Measuring Flicker It checks the switching loads on lighting systems.

Capturing Voltage Transients It can help you find intermittent, momentary events that may be affecting your equipment; the full waveform is captured with date, time stamp, and duration.

But you still have to do more to ensure the vitality of your electronic devices because they're very sensitive to temperature as well. This means you also need a way to monitor the temperature of the place(s) where your equipment is stored.

Environmental Monitors

Environmental monitors are designed to monitor the temperature, humidity, power, and air flow in an area or in a device. Temperature and humidity are both critical factors in the health of computing equipment. High temperatures lead to CPU overheating, and shortly thereafter, systems start rebooting.

High humidity cannot be tolerated because it leads to corrosion of electrical parts followed by shorts and other failures. Low humidity sounds good on paper, but with it comes static electricity buildup in the air, which can fry computer parts if it reaches them. Both of these conditions should be monitored.

A *temperature and humidity monitor* can save you and your precious devices from a total meltdown. By their very nature, networks often include lots of machines placed close together in one or several location(s)—like server rooms. Clearly, these devices, all humming along at once, generate quite a bit of heat.

Just like us, electronics need to "breathe," and they're also pretty sensitive to becoming overheated, which is why you'll often need a jacket in a chilly server room. It's also why we need to set up and use temperature-monitoring devices. Twenty years ago or so, these devices didn't send alerts or give off any kind of alarms; they were just little plastic boxes that had pieces of round graph paper to graph temperature. The paper was good for a month, and for that duration, it would just spin around in a circle. As the temperature moved up or down, the pen attached to the temperature coil moved in or out, leaving a circle line around the paper. All of this allowed you to manually monitor the temperature modulation in the server room over time. Although intended to "alert" you when and if there were climate changes, it usually did so after the fact, and therefore, too late.

Today, these temperature/humidity systems can provide multiple sensors feeding data to a single control point—nice. Now we can much more accurately track the temperature in our server rooms dynamically in real time. The central control point is usually equipped with HTTP software that can send alerts and provide alarms via a browser should your server room experience a warming event.

Temperature/humidity monitors also come in a variety of flavors. They vary in size and cost and come in hardware and/or software varieties. The kind you need varies and is based on the size of the room and the number of devices in it. You can even get one that will just monitor your PC's internal heat.

What else will indicate you have a temperature problem in your server room? When you install new servers in a rack and you have network instability and other issues across all the servers in the rack but the power resources and bandwidth have been tested, this would be a good time to check your temperature monitor and verify that the servers are staying cool enough. Another red flag when it comes to environmental issues is a problem that occurs every day at the same time. This could be the time of day when the room temperature reaches the problematic stage.

Summary

You need network tools, and you need to know how to use them. And as I said, you can get your hands on many of them for free; so download them and use them as soon as possible to get the experience you'll need to pass the CompTIA Network+ exam.

This chapter covered network scanners, including packet sniffers, IDS and IPS software, and port scanners. I also covered hardware tools, which are rarely free. The good news is that you don't need many of them yourself, but the company that owns all the equipment definitely does. Even though I've used all of the tools I talked about in this chapter, I don't own most of them personally—only the ones that are free or relatively inexpensive.

In the hardware tools section, I covered cable testers, analyzers, certifiers, TDR/OTDRs, and other critical tools that help you test the cables and devices in your network, monitor them, and keep them up and running smoothly.

Exam Essentials

Understand what network scanners are and how to use each one. Network scanners are described as packet sniffers, IDS/IPS software, and port scanners. These devices can help you both troubleshoot and fix your network as well as find and stop hackers in their tracks.

Remember the basic purpose of a packet sniffer. The basic purpose of packet sniffers or network analyzers is to collect and analyze each individual packet that is captured on a specific network segment to determine if problems are happening.

Remember the main purpose of IDS/IPS software. The IDS detects unwanted attempts to manipulate network systems and/or environments, and the IPS is a computer security device that monitors network and/or system activities for malicious behavior and can react in real time to stop attacks.

Understand what an OTDR is used for. An optical time-domain reflectometer (OTDR) is an optoelectronic instrument used to test fiber-optic cabling. You can learn the cable's estimated length and attenuation (loss in db) and the location of faults.

Understand the difference between cable testers and certifiers. Cable testers simply tell you if the cable will function. Cable certifiers run much more sophisticated tests that determine if the cable performs according to specifications called for in the standard.

Understand the value of temperature and humidity monitors. These devices can monitor environmental conditions and alert you if either the temperature or the humidity in a server room or area falls below or rises above the prescribed range of safe values.

Written Lab

You can find the answers to the written labs in Appendix A. Answer the following questions about software and hardware tools:

1. True/False: An IDS box can find and fix a problem as the attack occurs.
2. True/False: A TDR is used to test fiber connections.
3. True/False: An IDS box will report an attack but not fix it.
4. True/False: An OTDR is used to test fiber connections.
5. True/False: A network analyzer will see every packet on every segment of your network at the same time.
6. What type of device determines if a cable meets standards specifications?
7. True/False: It is okay to scan the DoD network servers with a port scanner.
8. You need to monitor the temperature of your server room. What device should you use?
9. You want to monitor your UPS systems and make sure they are functioning correctly. What device should you use?
10. What type of device is used to put an RJ-45 end on a Cat 5e cable?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which is a tool in the network scanner category? (Choose all that apply.)
   - A. Packet sniffers
   - B. IDS/IPS software
   - C. Port scanners
   - D. None of the above
2. What is the purpose of packet sniffers?
   - A. Discarding frames
   - B. Sending transmissions from one port to another port
   - C. Looking inside every packet on a network segment
   - D. Stopping malicious behavior on the network
3. You need to trace cables in multiple-pair wiring. What tool will you use?
   - A. Toner probe
   - B. IDS
   - C. Cable tester
   - D. Butt set
4. What tool would you use to both find a break in a fiber-optic connection and test the fiber connectivity on the network?
   - A. Multimeter
   - B. OTDR
   - C. Butt set
   - D. Toner probe
5. You need to create a cable that will connect your host to a wall jack connection. Which of the following will you use?
   - A. IDS/IPS
   - B. Snips
   - C. Coax cable strippers
   - D. Multimeter
6. Where is the IDS/IPS software typically placed within a network?
   - A. Between the internal router and the firewall connected to the ISP
   - B. Between the printer and the router connected to the ISP
   - C. Between the computer and the switch configured with VLANs
   - D. Between the firewall and the router connected to the email server

7. What is the purpose of a port scanner?

A. Scan UDP for closed ports

B. Sweep TCP for closed ports

C. Search the network host for open ports

D. None of the above

8. What is the purpose of wire-map testers?

A. Check copper cable for crossed pairs only

B. Analyze protocols in software

C. Help find unused protocols and remove them from the network

D. Detect transposed wires, opens, and shorts in twisted-pair cables

9. Which of the following can check the speed and condition of the signal on a cable, measure the time it takes to send a signal down the wire and back, and find the exact location of a break?

A. Multimeter

B. TDR

C. Tone generator

D. Event recorder

10. Which device should be used if you need to determine whether your network meets ISO or TIA standards?

A. Angry IP

B. Certifiers

C. Nmap

D. Routing table

11. Which software tool is used to view network traffic at the frame level?

A. TDR

B. Multimeter

C. Port scanner

D. Packet sniffer

12. Which of the following options is not a function of a TDR?

A. Estimate cable lengths

B. Find splice and connector locations and their associated loss amounts

C. Display unused services

D. Determine cable-impedance characteristics

E. Send a signal down a cable and measure how long it takes to come back

13. Which device would be used to measure voltage?

- **A.** Multimeter
- **B.** OTDR
- **C.** Butt set
- **D.** Toner probe

14. Which device would most likely be used to locate a specific connection in an unlabeled punch-down block?

- **A.** VOM
- **B.** Certifier
- **C.** TDR
- **D.** Toner probe

15. Which tool would be used to connect wire between two punch-down block blades?

- **A.** Punch-down tool
- **B.** Crimper
- **C.** Snips
- **D.** Strippers

16. Which tool is used to attach an RJ-45 connector to a Cat 5 cable?

- **A.** Punch-down tool
- **B.** Crimper
- **C.** Snips
- **D.** Strippers

17. On which of the following would a technician use a punch-down tool?

- **A.** RJ-45 connector
- **B.** CSU/DSU
- **C.** 110 block
- **D.** Fiber ST connector

18. Which device monitors incoming voltage levels and overvoltage thresholds?

- **A.** Repeater
- **B.** Toner probe
- **C.** VOM
- **D.** Surge protector

19. Which of the following tools can test a port on a device?

    A. Cable certifier

    B. Loopback plug

    C. Butt set

    D. Toner probe

20. You install new switches in your server room and are now experiencing network instability and other issues across all servers in the rack. Which device would be used to alert you of a system overheating?

    A. Voltage event recorder

    B. Temperature monitor

    C. Surge protector

    D. Probe

Network Troubleshooting

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **3.2 Compare and contrast business continuity and disaster recovery concepts.**

- NIC teaming

✓ **5.1 Explain the network troubleshooting methodology**

- Identify the problem
  - Gather information
  - Duplicate the problem, if possible
  - Question users
  - Identify symptoms
  - Determine if anything has changed
  - Approach multiple problems individually
- Establish a theory of probable cause
  - Question the obvious
  - Consider multiple approaches
    - Top-to-bottom/bottom-to-top
    - OSI model
    - Divide and conquer
- Test the theory to determine the cause
  - Once the theory is confirmed, determine the next steps to resolve the problem
  - If the theory is not confirmed, reestablish a new theory or escalate
- Establish a plan of action to resolve the problem and identify potential effects
- Implement the solution or escalate as necessary

- Verify full system functionality and, if applicable, implement preventive measures
- Document findings, actions, and outcomes

✓ **5.3 Given a scenario, troubleshoot common wired connectivity and performance issues**

- Attenuation
- Latency
- Jitter
- Crosstalk
- EMI
- Open/short
- Incorrect pin-out
- Incorrect cable type
- Bad port
- Transceiver mismatch
- TX/RX reverse
- Duplex/speed mismatch
- Damaged cables
- Bent pins
- Bottlenecks
- VLAN mismatch
- Network connection LED status indicators

✓ **5.4 Given a scenario, troubleshoot common wireless connectivity and performance issues**

- Reflection
- Refraction
- Absorption
- Latency
- Jitter
- Attenuation
- Incorrect antenna type

- Interference
- Incorrect antenna placement
- Channel overlap
- Overcapacity
- Distance limitations
- Frequency mismatch
- Wrong SSID
- Wrong passphrase
- Security type mismatch
- Power levels
- Signal-to-noise ratio

✓ 5.5 Given a scenario, troubleshoot common network service issues

- Names not resolving
- Incorrect gateway
- Incorrect netmask
- Duplicate IP addresses
- Duplicate MAC addresses
- Expired IP address
- Rogue DHCP server
- Untrusted SSL certificate
- Incorrect time
- Exhausted DHCP scope
- Blocked TCP/UDP ports
- Incorrect host-based firewall settings
- Incorrect ACL settings
- Unresponsive service
- Hardware failure

There is no way around it. Troubleshooting computers and networks is a combination of art and science, and the only way to get really good at it is by doing it—a lot! So it's practice, practice, and practice with the basic yet vitally important skills you'll attain in this chapter. Of course, I'm going to cover all the troubleshooting topics you'll need to sail through the Network+ exam, but I'm also going to add some juicy bits of knowledge that will really help you to tackle the task of troubleshooting successfully in the real world.

First, you'll learn to check quickly for problems in the "super simple stuff" category, and then we'll move into a hearty discussion about a common troubleshooting model that you can use like a checklist to go through and solve a surprising number of network problems. We'll finish the chapter with a good briefing about some common troubleshooting resources, tools, tips, and tricks to keep up your sleeve and equip you even further.

I won't be covering any new networking information in this chapter because you've gotten all the foundational background material you need for troubleshooting in the previous chapters. But no worries. I'll go through each of the issues described in this chapter's objectives, one at a time, in detail, so that even if you've still got a bit of that previous material to nail down yet, you'll be good to get going and fix some networks anyway.

NOTE To find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Narrowing Down the Problem

When initially faced with a network problem in its entirety, it's easy to get totally overwhelmed. That's why it's a great strategy to start by narrowing things down to the source of the problem. To help you achieve that goal, it's always wise to ask the right questions. You can begin doing just that with this list of questions to ask yourself:

- Did you check the super simple stuff (SSS)?
- Is hardware or software causing the problem?
- Is it a workstation or server problem?
- Which segments of the network are affected?
- Are there any cabling issues?

Did You Check the Super Simple Stuff?

Yes—it sounds like a snake's hiss (appropriate for a problem, right?), but exactly what's on the SSS list that you should be checking first, and why? Well, as the saying goes, "All things being equal, the simplest explanation is probably the correct one," so you probably won't be stunned and amazed when I tell you that I've had people call me in and act like the sky is falling when all they needed to do was check to make sure their workstation was plugged in or powered on. (I didn't say "super simple stuff" for nothing!) Your SSS list really does include things that are this obvious—sometimes so obvious no one thinks to check for them. Even though anyone experienced in networking has their own favorite "DUH" events to tell about, almost everyone can agree on a few things that should definitely be on the SSS list:

- Check to verify login procedures and rights.
- Look for link lights and collision lights.
- Check all power switches, cords, and adapters.
- Look for user errors.

The Correct Login Procedure and Rights

You know by now that if you've set up everything correctly, your network's users absolutely have to follow the proper login procedure to the letter (or number, or symbol) in order to successfully gain access to the network resources they're after. If they don't do that, they will be denied access, and considering that there are truly tons of opportunities to blow it, it's a miracle, or at least very special, that anyone manages to log in to the network correctly at all.

Think about it. First, a user must enter their username and password flawlessly. Sounds easy, but as they say, "in a perfect world . . ." In this one, people mess up, don't realize it, and freak out at you about the "broken network" or the imaginary IT demon that changed their password on them while they went to lunch and now they can't log in. (The latter could be true—you may have done exactly that. If you did, just gently remind them about that memo you sent about the upcoming password-change date and time that they must have spaced about due to the tremendous demands on them.)

Anyway, it's true. By far, the most common problem is bad typing—people accidentally enter the wrong username or password, and they do that a lot. With some operating systems, a slight brush of the Caps Lock key is all it takes: The user's username and password are case sensitive, and suddenly, they're trying to log in with what's now all in uppercase instead—oops.

Plus, if you happen to be running one of the shiny new operating systems around today, you can also restrict the times and conditions under which users can log in, right? So, if your user spent an unusual amount of time in the bathroom upon returning from lunch, or if they got distracted and tried to log in from their BFF's workstation instead of their own, the network's operating system would've rejected their login request even though they still can type impressively well after two martinis.

And remember—you can also restrict how many times a user can log in to the network simultaneously. If you've set that up, and your user tries to establish more connections than you've allowed, access will again be denied. Just know that most of the time, if a user is denied access to the network and/or its resources, they're probably going to interpret that as a network problem even though the network operating system is doing what it should.

Real World Scenario

Can the Problem Be Reproduced?

The first question to ask anyone who reports a network or computer problem is, "Can you show me what 'not working' looks like?" This is because if you can reproduce the problem, you can identify when it happens, which may give you all the information you need to determine the source of the problem and maybe even solve it in a snap. The hardest problems to solve are those of the random variety that occur intermittently and can't be easily reproduced.

Let's pause for a minute to outline the steps to take during any user-oriented network problem-solving process:

1. Make sure the username and password is being entered correctly.
2. Check that Caps Lock key.
3. Try to log in yourself from another workstation, assuming that doing this doesn't violate the security policy. If it works, go back to the user-oriented login problems, and go through them again.
4. If none of this solves the problem, check the network documentation to find out whether any of the aforementioned kinds of restrictions are in place; if so, find out whether the user has violated any of them.

NOTE

Remember, if intruder detection is enabled on your network, a user will get locked out of their account after a specific number of unsuccessful login attempts. If this happens, either they'll have to wait until a predetermined time period has elapsed before their account will unlock and give them another chance or you'll have to go in and manually unlock it for them.

Network Connection LED Status Indicators

The link light is that little light-emitting diode (LED) found on both the network interface card (NIC) and the switch. It's typically green and labeled Link or some abbreviation of that. If you're running 100BaseT, a link light indicates that the NIC and switch are making a logical (Data Link layer) connection. If the link lights are lit up on both the workstation's

NIC and the switch port to which the workstation is connected, it's usually safe to assume that the workstation and switch are communicating just fine.

NOTE The link lights on some NICs don't activate until the driver is loaded. So, if the link light isn't on when the system is first turned on, you'll just have to wait until the operating system loads the NIC driver. But don't wait forever!

The *collision light* is also a small LED, but it's typically amber in color, and it can usually be found on both Ethernet NICs and hubs. When lit, it indicates that an Ethernet collision has occurred. If you've got a busy Ethernet network on which collisions are somewhat common, understand that this light is likely to blink occasionally; if it stays on continuously, though, it could mean that there are way too many collisions happening for legitimate network traffic to get through. Don't assume this is really what's happening without first checking that the NIC, or other network device, is working properly because one or both could simply be malfunctioning.

NOTE Don't confuse the collision light with the network-activity or network-traffic light (which is usually green) because the latter just indicates that a device is transmitting. This particular light *should* be blinking on and off continually as the device transmits and receives data on the network.

The Power Switch

Clearly, to function properly, all computer and network components must be turned on and powered up first. Obvious, yes, but if I had a buck for each time I've heard, "My computer is on, but my monitor is all dark," I'd be rolling in money by now.

When this kind of thing happens, just keep your cool and politely ask, "Is the monitor turned on?" After a little pause, the person calling for help will usually say, "Ohhh . . . ummmm . . . thanks," and then hang up ASAP. The reason I said to be nice is that, embarrassing as it is, this, or something like it, will probably happen to you, too, eventually.

Most systems include a power indicator (a Power or PWR light). The power switch typically has an On indicator, but the system or device could still be powerless if all the relevant power cables aren't actually plugged in—including the power strip.

NOTE Remember that every cable has two ends, and both must be plugged into something. If you're thinking something like, "Sheesh—a four-year-old knows that," you're probably right. But again, I can't count the times this has turned out to be the root cause of a "major system failure."

The best way to go about troubleshooting power problems is to start with the most obvious device and work your way back to the power-service panel. There could be a number of power issues between the device and the service panel, including a bad power cable, bad outlet, bad electrical wire, tripped circuit breaker, or blown fuse, and any of these things could be the actual cause of the problem that appears to be device-death instead.

Operator Error

Or, the problem may be that you've got a user who simply doesn't know how to be one. Maybe you're dealing with someone who doesn't have the tiniest clue about the equipment they're using or about how to perform a certain task correctly—in other words, the problem may be due to something known as *operator error (OE)*. Here's a short list of the most common types of OEs and their associated acronyms:

- Equipment exceeds operator capability (EEOC)
- Problem exists between chair and keyboard (PEBCAK)
- ID Ten T error (an ID10T)

A word of caution here, though—assuming that all your problems are user related can quickly make an ID10T error out of you.

Although it can be really tempting to take the easy way out and blow things off, remember that the network's well-being and security are ultimately your responsibility. So, before you jump to the operator-error conclusion, ask the user in question to reproduce the problem in your presence, and pay close attention to what they do. Understand that doing this can require a great deal of patience, but it's worth your time and effort if you can prevent someone who doesn't know what they're doing from causing serious harm to pricey devices or leaving a gaping hole in your security. You might even save the help desk crew's sanity from the relentless calls of a user with the bad habit of flipping off the power switch without following proper shutdown procedures. You just wouldn't know they always do that if you didn't see it for yourself, right?

And what about finding out that that pesky user was, in fact, trained really badly by someone and that they aren't the only one? This is exactly the kind of thing that can turn the best security policy to dust and leave your network and its resources as vulnerable to attack as that goat in *Jurassic Park*.

The moral here is, always check out the problem thoroughly. If the problem and its solution aren't immediately clear to you, try the procedure yourself, or ask someone else at another workstation to do so. Don't just leave the issue unsettled or make the assumption that it is user error or a chance abnormality because that's exactly what the bad guys out there are hoping you'll do.

NOTE

This is only a partial list of super simple stuff. No worries. Rest assured you'll come up with your own expanded version over time.

Is Hardware or Software Causing the Problem?

A hardware problem often rears its ugly head when some device in your computer skips a beat and/or dies. This one's pretty easy to discern because when you try to do something requiring that particular piece of hardware, you can't do it and instead get an error telling you that you can't do it. Even if your hard disk fails, you'll probably get warning signs before it actually kicks, like a Disk I/O error or something similar.

Other problems drop out of the sky and hit you like something from the wrong end of a seagull. No warning at all—just splat! Components that were humming along fine a second ago can and do suddenly fail, usually at the worst possible time, leaving you with a mess of lost data, files, everything—you get the idea.

Solutions to hardware problems usually involve one of three things:

- Changing hardware settings
- Updating device drivers
- Replacing dead hardware

If your hardware has truly failed, it's time to get out your tools and start replacing components. If this isn't one of your skills, you can either send the device out for repair or replace it. Your mantra here is "back up, back up, back up," because in either case, a system could be down for a while—anywhere from an hour to several days—so it's always good to keep backup hardware around. And I know everyone and your momma has told you this, but here it is one more time: Back up all data, files, hard drive, everything, and do so on a regular basis.

Software problems are muddier waters. Sometimes you'll get General Protection Fault messages, which indicate a Windows or Windows program (or other platform) error of some type, and other times the program you're working in will suddenly stop responding and hang. At their worst, they'll cause your machine to randomly lock up on you. When this type of thing happens, I'd recommend visiting the manufacturer's support website to get software updates and patches or searching for the answer in a knowledge base.

Sometimes you get lucky and the ailing software will tell the truth by giving you a precise message about the source of the problem. Messages saying the software is missing a file or a file has become corrupt are great because you can usually get your problem fixed fast by providing that missing file or by reinstalling the software. Neither solution takes very long, but the downside is that whatever you were doing before the program hosed will probably be at least partially lost; so again, back up your stuff, and save your data often.

NOTE

Please reread Chapter 17, "Troubleshooting Tools," and Chapter 18, "Software and Hardware Tools," and use the software and hardware tools discussed in those two chapters to help you troubleshoot network problems.

It's time for you to learn how to troubleshoot your workstations and servers.

Is It a Workstation or a Server Problem?

The first thing you've got to determine when troubleshooting this kind of problem is whether it's only one person or a whole group that's been affected. If the answer is only one person (think, a single workstation), solving the issue will be pretty straightforward. More than that, and your problem probably involves a chunk of the network, like a segment. A clue that the source of your grief is the latter case is if there's a whole bunch of users complaining that they can't discover neighboring devices/nodes.

So either way, what do you do about it? Well, if it's the single-user situation, your first line of defense is to try to log in from another workstation within the same group of users. If you can do that, the problem is definitely the user's workstation, so look for things like cabling faults, a bad NIC, power issues, and OSs.

But if a whole department can't access a specific server, take a good, hard look at that particular server, and start by checking all user connections to it. If everyone is logged in correctly, the problem may have something to do with individual rights or permissions. If no one can log in to that server, including you, the server probably has a communication problem with the rest of the network. And if the server has totally crashed, either you'll see messages telling you all about it on the server's monitor or you'll find its screen completely blank—screaming indicators that the server is no longer running. And keep in mind that these symptoms do vary among network operating systems.

Which Segments of the Network Are Affected?

Figuring this one out can be a little tough. If multiple segments are affected, you may be dealing with a network-address conflict. If you're running Transmission Control Protocol/Internet Protocol (TCP/IP), remember that IP addresses must be unique across an entire network. So, if two of your segments have the same static IP subnet addresses assigned, you'll end up with duplicate IP errors—an ugly situation that can be a real bear to troubleshoot and can make it tough to find the source of the problem.

If all of your network's users are experiencing the problem, it could be a server everyone accesses. Thank the powers that be if you nail it down to that because if not, other network devices like your main router or hub may be down, making network transmissions impossible and usually meaning a lot more work on your part to fix.

Adding wide area network (WAN) connections to the mix can complicate matters exponentially, and you don't want to go there if you can avoid it, so start by finding out if stations on both sides of a WAN link can communicate. If so, get the champagne—your problem isn't related to the WAN—woo hoo! But if those stations can't communicate, it's not a happy thing: You've got to check everything between the sending station and the receiving one, including the WAN hardware, to find the culprit. The good news is that most of the time, WAN devices have built-in diagnostics that tell you whether a WAN link is working okay, which really helps you determine if the failure has something to do with the WAN link itself or with the hardware involved instead.

Is It Bad Cabling?

Back to hooking up correctly . . . Once you've figured out whether your plight is related to one workstation, a network segment, or the whole tamale (network), you must then examine the relevant cabling. Are the cables properly connected to the correct port? More than once, I've seen a Digital Subscriber Line (DSL) modem connection to the wall cabled all wrong—it's an easy mistake to make and an easy one to fix.

And you know that nothing lasts forever, so check those patch cables running between a workstation and a wall jack. Just because they don't come with expiration dates written on them doesn't mean they don't expire. They do go bad—especially if they get moved, trampled on, or tripped over a lot. (I did tell you that it's a bad idea to run cabling across the office floor, didn't I?) Connection problems are the tell here—if you check the NIC and there is no link light blinking, you may have a bad patch cable to blame.

It gets murkier if your cable in the walls or ceiling is toast or hasn't been installed correctly. Maybe you've got a user or two telling you the place is haunted because they only have problems with their workstations after dark when the lights go on. Haunted? No . . . some genius probably ran a network cable over a fluorescent light, which is something that just happens to produce lots of electromagnetic interference (EMI), which can really mess up communications in that cable.

Next on your list is to check the medium dependent interface/medium dependent interface-crossover (MDI/MDI-X) port setting on small, workgroup hubs and switches. This is a potential source of trouble that's often overlooked, but it's important because this port is the one that's used to uplink to a switch on the network's backbone.

First, understand that the port setting has to be set to either MDI or MDI-X depending on the type of cable used for your hub-to-hub or switch-to-switch connection. For instance, the crossover cables I talked about way back in Chapter 3, "Networking Topologies, Connectors, and Wiring Standards," require that the port be set to MDI, and a standard network patch cable requires that the port be set to MDI-X. You can usually adjust the setting via a regular switch or a dual inline package (DIP) switch, but to be sure, if you're still using hubs, check out the hub's documentation. (You did keep that, right?)

Other Important Cable Issues You Need to Know About

They may be basic, but they're still vital—an understanding of the physical issues that can happen on a network when a user is connected via cable (usually Ethernet) is critical information to have in your troubleshooting repertoire.

Because many of today's networks still consist of large amounts of copper cable, they suffer from the same physical issues that have plagued networking since the very beginning. Newer technologies and protocols have helped to a degree, but they haven't made these issues a thing of the past yet. Some physical issues that still affect networks are listed and defined next:

Incorrect Pinout/TX/RX Reverse/Damaged Cable The first things to check when working on cabling are the cable connectors to make sure they haven't gone bad. After that, look to make sure the wiring is correct on both ends by physically checking the cable pinouts. Important to remember is that if you have two switches, you need a crossover cable where you cross pins 1 and 2 with 3 and 6. On the other hand, if you have a PC going into a switch, you need a straight-through cable where pins 1 and 2 correspondingly connect to pins 1 and 2 on each side—the same with 3 and 6. Finally, make sure the termination pins on both ends are the correct type for the kind of cable you're using.

Bad Port In some cases, the issue is not the cable but the port into which the cable is connected. On many devices ports have LEDs that can alert you to a bad port. For example, a Cisco router or switch will have an LED for each port and the color of the LED will indicate its current state. In most cases, a lack of any light whatsoever indicates an issue with the port. Loopback plugs can be used to test the functionality of a port. These devices send a signal out and then back in the port to test it.

Transceiver Mismatch Interfaces that send and receive are called transceivers. When a NIC is connected to a port, the two transceivers must have certain settings the same or issues will occur. These settings are the duplex and the speed setting. If the speed settings do not match, there will be no communication. If the duplex settings are incorrect, there may be functionality but the performance will be poor.

Crosstalk Again, looking back to Chapter 3, remember that crosstalk is what happens when there's signal bleed between two adjacent wires that are carrying a current. Network designers minimize crosstalk inside network cables by twisting the wire pairs together, putting them at a 90-degree angle to each other. The tighter the wires are twisted, the less crosstalk you have, and newer cables like Cat 6 cable really make a difference. But like I said, not completely—crosstalk still exists and affects communications, especially in high-speed networks. This is often caused by using the wrong category of cable or by mismatching the member of one pair with a member of another when terminating a cable.

Near-End/Far-End Crosstalk Near-end crosstalk is a specific type of crosstalk measurement that has to do with the EMI bled from a wire to adjoining wires where the current originates. This particular point has the strongest potential to create crosstalk issues because the crosstalk signal itself degrades as it moves down the wire. If you have a problem with it, it's probably going to show up in the first part of the wire where it's connected to a switch or a NIC. Far-end crosstalk is the interference between two pairs of a cable measured at the far end of the cable with respect to the interfering transmitter.

This condition is often caused by improperly terminating a cable. For example, it's important to maintain the twist right up to the punch-down or crimp connector. In the case of crimp connectors, it's critical to select the correct grade of connector even though one grade may look identical to another.

Attenuation/Db Loss/Distance Limitation As a signal moves through any medium, the medium itself will degrade the signal—a phenomenon known as *attenuation* that's common in all kinds of networks. True, signals traversing fiber-optic cable don't attenuate as fast as those on copper cable, but they still do eventually. You know that all copper twisted-pair cables have a maximum segment distance of 100 meters before they'll need to be amplified, or *repeated*, by a hub or a switch, but single-mode fiber-optic cables can sometimes carry signals for miles before they begin to attenuate (degrade). If you need to go far, use fiber, not copper. Although there is attenuation/Db loss in fiber, it can go much farther distances than copper cabling can before being affected by attenuation.

Latency Latency is the delay typically incurred in the processing of network data. A low-latency network connection is one that generally experiences short delay times, while a high-latency connection generally suffers from long delays. Many security solutions may negatively affect latency. For example, routers take a certain amount of time to process and forward any communication. Configuring additional rules on a router generally increases latency, thereby resulting in longer delays. An organization may decide not to deploy certain security solutions because of the negative effects they will have on network latency.

Auditing is a great example of a security solution that affects latency and performance. When auditing is configured, it records certain actions as they occur. The recording of these actions may affect the latency and performance.

Jitter Jitter occurs when the data flow in a connection is not consistent; that is, it increases and decreases in no discernable pattern. Jitter results from network congestion, timing drift, and route changes. Jitter is especially problematic in real-time communications like IP telephony and videoconferencing.

Collisions A network *collision* happens when two devices try to communicate on the same physical segment at the same time. Collisions like this were a big problem in the early Ethernet networks, and a tool known as *Carrier Sense Multiple Access with Collision Detection* (CSMA/CD) was used to detect and respond to them in Ethernet_II. Nowadays, we use switches in place of hubs because they can separate the network into multiple collision domains, learn the Media Access Control (MAC) addresses of the devices attached to them, create a type of permanent virtual circuit between all network devices, and prevent collisions.

Shorts Basically, a *short circuit*, or *short*, happens when the current flows through a different path within a circuit than it's supposed to; in networks, they're usually caused by some type of physical fault in the cable. You can find shorts with circuit-testing equipment, but because sooner is better when it comes to getting a network back up and running, replacing the ailing cable until it can be fixed (if it can be) is your best option.

Open Impedance Mismatch (echo) Open impedance on cable-testing equipment tells you that the cable or wires connect into another cable and there is an impedance mismatch. When that happens, some of the signal will bounce back in the direction it came from, degrading the strength of the signal, which ultimately causes the link to fail.

Interference/Cable Placement EMI and *radio frequency interference (RFI)* occur when signals interfere with the normal operation of electronic circuits. Computers happen to be really sensitive to sources of this, such as TV and radio transmitters, which create a specific radio frequency as part of their transmission process. Two other common culprits are two-way radios and cellular phones.

Your only way around this is to use shielded network cables like shielded twisted-pair (STP) and coaxial cable (rare today) or to run EMI/RFI-immune but pricey fiber-optic cable throughout your entire network.

Split Pairs A split pair is a wiring error where two connections that are supposed to be connected using the two wires of a twisted pair are instead connected using two wires from different pairs. Such wiring causes errors in high-rate data lines. If you buy your cables precut, you won't have this problem.

TX/RX Reverse When connecting from a PC-type device into a switch, for the PC use pins 1 and 2 to transmit and 3 and 6 for receiving a digital signal. This means that the pins must be reversed on the switch, using pins 1 and 2 for receiving and 3 and 6 for transmitting the digital signal. If your connection isn't working, check the cable end pinouts.

Bent Pins Many of the connectors you will encounter have small pins on the end that must go into specific holes on the interface to which they plug. If these pins get bent, either they won't go into the correct hole or they won't go into a hole period. When this occurs, the cable either will not work at all or will not work correctly. Taking care not to bend these fragile pins when working with these cable types will prevent this issue from occurring.

Bottlenecks Bottlenecks are areas of the network where the physical infrastructure is not capable of handling the traffic. In some cases, this is a temporary issue caused by an unusual burst of traffic. In other scenarios, it is a wake-up call to upgrade the infrastructure or reorganize the network to alleviate the bottleneck. The obvious result of a bottleneck is poor performance.

Fiber Cable Issues

Fiber is definitely the best kind of wiring to use for long-distance runs because it has the least attenuation at long distances compared to copper. The bad news is that it's also the hardest to troubleshoot. Here are some common fiber issues to be aware of.

SFP/GBIC (Cable Mismatch) The small form-factor pluggable (SFP) is a compact, hot-pluggable transceiver used for networking and other types of equipment. It interfaces a network device motherboard for a switch, router, media converter, or similar device to a fiber-optic or copper networking cable. Due to its smaller size, SFP obsolesces the formerly ubiquitous gigabit interface converter (GBIC), so SFP is sometimes referred to as a mini-GBIC. Always make sure you have the right cable for each type of connector type and that they are not mismatched.

Bad SFP/GBIC (Cable or Transceiver) If your link is down, verify that your cable or transceiver hasn't gone bad. I covered the pricey equipment you need to get this done in Chapter 18. It can provide exact locations the problem has originated.

Wavelength Mismatch One of the more confusing terms used regarding fiber networks is *wavelength*. Though it sounds very complicated and scientific, it's actually just the term used to define what we think of as the color of light. Wavelength mismatch occurs when two different fiber transmitters at each end of the cable are using either a longer or shorter wavelength. This means you've got to make sure your transmitters match on both ends of the cable.

Fiber Type Mismatch Fiber type mismatches, at each of the transceivers, can cause wavelength issues, massive attenuation, and Db loss.

Dirty Connectors It's important to verify your connectors to make sure no dirt or dust has corrupted the cable end. You need to polish your cable ends with a soft cloth, but do not look into the cable if the other end is transmitting—it could damage your eyes!

Connector Mismatch Just because it fits doesn't mean it works. Make sure you have precisely the right connectors for each type of cable end or transceiver.

Bend Radius Limitations Fiber, whether it is made of glass or plastic, can break. You need to make sure you understand the bend radius limitations of each type of fiber you purchase and that you don't exceed the specifications when installing fiber in your rack.

Distance Limitations The pros of fiber are that it's completely immune to EMI and RFI, and that it can transmit up to 40 kilometers—about 25 miles! Add some repeater stations and you can go between continents. But all fiber types aren't created equally. For example, single mode can perform at much greater distances than multi-mode can. And again, make sure you have the right cable for the distance you'll require to run your fiber!

Unbounded Media Issues (Wireless)

Now let's say your problem-ridden user is telling you they only use a wireless connection. Well, you can definitely take crosstalk and shorts off the list of suspects, but don't get excited, because with wireless, you've got a whole new bunch of possible Physical layer problems to sort through.

Wireless networks are really convenient for the user but not so much for administrators. They can require a lot more configuration, and understand that with wireless networks, you don't just get to substitute one set of challenges for another—you pretty much add all those fresh new issues on top of the wired challenges you already have on your plate.

The following list includes some of those new wireless challenges:

Interference Because wireless networks rely on radio waves to transmit signals, they're more subject to interference, even from other wireless devices like Bluetooth keyboards, mice, or cell phones that are all close in frequency ranges. Any of these—even microwave ovens!—can cause signal bleed that can slow down or prevent wireless communications. Factors like the distance between a client and a wireless access point (WAP) and the stuff between the two can also affect signal strength and even intensify the interference from other signals. So, careful placement of that WAP is a must.

Device Saturation/Bandwidth Saturation Clearly it's important to design and implement your wireless network correctly. Be sure to understand the number of hosts that will be connecting to each AP that you'll be installing. If you have too much device saturation on an AP, it will result in low available bandwidth. Just think about when you're in a hotel and how slow the wireless is. This is directly due to device/bandwidth saturation for each AP. And more APs don't always solve the problem—you need to design correctly!

Simultaneous Wired/Wireless Connections It's not unusual to find that a laptop today will have both a wired and wireless connection at the same time. Typically this doesn't create a problem, but don't think you get more bandwidth or better results because of it. It's possible that the configurations can cause a problem, although that's rare today. For instance, if each provides a DNS server with a different address, it can cause name resolution issues, or even default gateway issues. Most of the time, it just causes confusion in your laptop, which will make it work harder to determine the correct DNS or default gateway address to use. And it's possible for the laptop to give up and stop communicating completely! Because of this, you need to remind the user to turn off their wireless when they take it into their office and connect it to their dock.

Configurations Mistakes in the configuration of the wireless access point or wireless router or inconsistencies between the settings on the AP and the stations can also be the source of problems. The following list describes some of the main sources of configuration problems.

Incorrect Encryption/Security Type Mismatch You know that wireless networks can use encryption to secure their communications and that different encryption flavors are used for wireless networks, like Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access 2 (WPA2) with Advanced Encryption Standard (AES). To ensure the tightest security, configure your wireless networks with the highest encryption protocol that both the WAP and the clients can support. Oh, and make sure the AP and its clients are configured with the same type of encryption. This is why it's a good idea to disable security before troubleshooting client problems, because if the client can connect once you've done that, you know you're dealing with a security configuration error.

Incorrect, Overlapping, or Mismatched Channels Wireless networks use many different frequencies within the 2.4 GHz or 5 GHz band, and I'll bet you didn't know that these frequencies are sometimes combined to provide greater bandwidth for the user. You actually do know about this—has anyone heard of something called a *channel*? Well, that's exactly what a channel is, and it's also the reason some radio stations come in better than others—they have more bandwidth because their channel has more combined frequencies. You also know what happens when the AP and the client aren't quite matching up. Have you ever hit the scan button on your car's radio and only kind of gotten a station's static-ridden broadcast? That's because the AP (radio station) and the client (your car's radio) aren't quite on the same channel. Most of the time, wireless networks use channel 1, 6, or 11, and because clients auto-configure themselves to any channel the AP is broadcasting on, it's not usually a configuration issue unless someone has forced a client onto an incorrect channel. Also, be sure not to use the same channel on APs within the same area. Overlapping channels cause your signal-to-noise ratio to drop because you'll get a ton of interference and signal loss!

Incorrect Frequency/Incompatibilities So, setting the channel sets the frequency or frequencies that wireless devices will use. But some devices, such as an AP running 802.11g/n, allow you to tweak those settings and choose a specific frequency such as 2.4 GHz or 5 GHz. As with any relationship, it works best if things are mutual. So if you do this on one device, you've got to configure the same setting on all the devices with which you want to communicate, or they won't—they'll argue, and you don't want that. Incorrect-channel and frequency-setting problems on a client are rare, but if you have multiple APs and they're in close proximity, you need to make sure they're on different channels/frequencies to avoid potential interference problems.

Wrong Passphrase When a passphrase is used as an authentication method, the correct passphrase must be entered when authenticating to the AP or to the controller. When an incorrect passphrase is provided, access will be denied. This is another issue that will impair functionality.

SSID Mismatch When a wireless device comes up, it scans for service set identifiers (SSIDs) in its immediate area. These can be basic service set identifiers (BSSIDs) that identify an individual access point or extended service set identifiers (ESSIDs) that identify a set of APs. In your own wireless LAN, you clearly want the devices to find the ESSID that you're broadcasting, which isn't usually a problem: Your broadcast is closer than the neighbor's, so it should be stronger—unless you're in an office building or apartment complex that has lots of different APs assigned to lots of different ESSIDs because they belong to lots of different tenants in the building. This can definitely give you some grief because it's possible that your neighbor's ESSID broadcast is stronger than yours, depending on where the clients are in the building. So if a user reports that they're connected to an AP but still can't access the resources they need or authenticate to the network, you should verify that they are, in fact, connected to your ESSID and not your neighbor's. This is very typical in an open security wireless network. You can generally just look at the information tool tip on the wireless software icon to find this out. However, you can easily solve this problem today by making the office SSID the preferred network in the client software.

Wireless Standard Mismatch As you found out in Chapter 12, "Wireless Networking," wireless networks have many standards that have evolved over time, like 802.11a, 802.11b, 802.11g, and 802.11n. Standards continue to develop that make wireless networks even faster and more powerful. The catch is that some of these standards are backward compatible and others aren't. For instance, most devices you buy today can be set to 802.11a/b/g/n, which means they can be used to communicate with other devices of all four standards. So, make sure the standards on the AP match the standards on the client, or that they're at least backward compatible. It's either that or tell all your users to buy new cards for their machines. Be sure to understand the throughput, frequency, distance capabilities, and available channels for each standard you use.

Untested Updates It's really important to push updates to the APs in your wireless network, but not before you test them. Just like waiting for an update from Microsoft or Apple to become available for weeks or months before you update, you need to wait for the OS or patch updates for your AP. Then, you need to test the updates thoroughly on your bench before pushing them to your live network.

Distance/Signal Strength/Power Levels Location, location, location. You've got only two worries with this one: Your clients are either not far enough away or too far from the AP. If your AP doesn't seem to have enough power to provide a connectivity point for your clients, you can move it closer to them, increase the distance that the AP can transmit by changing the type of antenna it uses, or use multiple APs connected to the same switch or set of switches to solve the problem. If the power level or signal is too strong, and it reaches out into the parking area or farther out to other buildings and businesses, place the AP as close as possible to the center of the area it's providing service for. And don't forget to verify that you've got the latest security features in place to keep bad guys from authenticating to and using your network.

Latency and Overcapacity When wireless users complain that the network is slow (latency) or that they are losing their connection to applications during a session, it is usually a capacity or distance issue. Remember, 802.11 is a shared medium, and as more users connect, all user throughput goes down. If this becomes a constant problem as opposed to the occasional issue where 20 guys with laptops gather for a meeting every six months in the conference room, it may be time to consider placing a second AP in the area. When you do this, place the second AP on a different non-overlapping channel from the first and make sure the second AP uses the same SSID as the first. In the 2.4 GHz frequency (802.11b and 802.11g), the three non-overlapping channels are 1, 6, and 11. Now the traffic can be divided between them and users will get better performance. It is also worth noting that when clients move away from the AP, the data rate drops until at some point it is insufficient to maintain the connection.

Bounce For a wireless network spanning large geographical distances, you can install repeaters and reflectors to bounce a signal and boost it to cover about a mile. This can be a good thing, but if you don't tightly control signal bounce, you could end up with a much bigger network than you wanted. To determine exactly how far and wide the signal will bounce, make sure you conduct a thorough wireless site survey. However, bounce can also refer to multipath issues, where the signal reflects off objects and arrives at the client degraded because it is arriving out of phase. The solution is pretty simple. APs use two antennas, both of which sample the signal and use the strongest signal and ignore the out-of-phase signal. However, 802.11n takes advantage of multipath and can combine the out-of-phase signals to increase the distance hosts can be from the AP.

Incorrect Antenna Type or Switch Placement Most of the time, the best place to put an AP and/or its antenna is as close to the center of your wireless network as possible. But you can position some antennas a distance from the AP and connect to it with a cable—a method used for a lot of the outdoor installations around today. If you want to use multiple APs, you've also got to be a little more sophisticated about deciding where to put them all; you can use third-party tools like the packet sniffers Wireshark and AirMagnet on a laptop to survey the site and establish how far your APs are actually transmitting. You can also hire a consultant to do this for you—there are many companies that specialize in assisting organizations with their wireless networks and the placement of antennas and APs. This is important because poor placement can lead to interference and poor performance, or even no performance at all.

Environmental Factors It's vital to understand your environmental factors when designing and deploying your wireless network. Do you have concrete walls, window film, or metal studs in the walls? All of these will cause a degradation of Db or power level and result in connectivity issues. Again—plan your wireless network carefully!

Reflection When a wave hits a smooth object that is larger than the wave itself, depending on the media the wave may bounce in another direction. This behavior is categorized as reflection.

Reflection can be the cause of serious performance problems in a WLAN. As a wave radiates from an antenna, it broadens and disperses. If portions of this wave are reflected, new wave fronts will appear from the reflection points. If these multiple waves all reach the receiver, the multiple reflected signals cause an effect called multipath.

Multipath can degrade the strength and quality of the received signal or even cause data corruption or canceled signals. APs mitigate this behavior by using multiple antennas and constantly sampling the signal to avoid a degraded signal.

Refraction Refraction is the bending of an RF signal as it passes through a medium with a different density, thus causing the direction of the wave to change. RF refraction most commonly occurs as a result of atmospheric conditions.

In long-distance outdoor wireless bridge links, refraction can be an issue. An RF signal may also refract through certain types of glass and other materials that are found in an indoor environment.

Absorption Some materials will absorb a signal and reduce its strength. While there is not much that can be done about this, this behavior should be noted during a site survey, and measures such as additional APs or additional antenna types may be called for.

Signal-to-Noise Ratio Signal-to-noise ratio (SNR) is the difference in decibels between the received signal and the background noise level (noise floor).

If the amplitude of the noise floor is too close to the amplitude of the received signal, data corruption will occur and result in Layer 2 retransmissions, negatively affecting both throughput and latency. An SNR of 25 dB or greater is considered good signal quality, and an SNR of 10 dB or lower is considered very poor signal quality.

Now that you know all about the possible physical network horrors that can befall you on a typical network, it's a good time for you to memorize the troubleshooting steps that you've got to know to ace the CompTIA Network+ exam.

Troubleshooting Steps

In the Network+ troubleshooting model, there are seven steps you've got to have dialed in:

1. Identify the problem.
2. Establish a theory of probable cause.
3. Test the theory to determine cause.
4. Establish a plan of action to resolve the problem and identify potential effects.
5. Implement the solution or escalate as necessary.
6. Verify full system functionality, and if applicable, implement preventative measures.
7. Document findings, actions, and outcomes.

To get things off to a running start, let's assume that the user has called you yet again, but now they're almost in tears because they can't connect to the server on the intranet and they also can't get to the Internet. (By the way, this happens a lot, so pay attention—it's only a matter of time before it happens to you!)

NOTE

Absolutely, positively make sure you memorize this seven-step troubleshooting process in the right order when studying for the Network+ exam!

Step 1: Identify the Problem

Before you can solve the problem, you've got to figure out what it is, right? Again, asking the right questions can get you far along this path and really help clarify the situation. Identifying the problem involves steps that together constitute *information gathering.*

Gather Information by Questioning Users

A good way to start is by asking the user the following questions:

- Exactly which part of the Internet can't you access? A particular website? A certain address? A type of website? None of it at all?
- Can you use your web browser?
- Is it possible to duplicate the problem?
- If the hitch has to do with an internal server to the company, ask the user if they can ping the server and talk them through doing that.
- Ask the user to try to telnet or FTP to an internal server to verify local network connectivity; if they don't know how, talk them through it.
- If there are multiple complaints of problems occurring, look for the big stuff first, then isolate and approach each problem individually.

Here's another really common trouble ticket that just happens to build on the last scenario: Now let's say you've got a user who's called you at the help desk. By asking the previous questions, you found out that this user can't access the corporate intranet or get out to any sites on the Internet. You also established that the user can use their web browser to access the corporate FTP site, but only by IP address, not by the FTP server name. This information tells you two important things: that you can rule out the host and the web browser (application) as the source of the problem and that the physical network is working.

Duplicate the Problem, If Possible

When a user reports an issue, you should attempt to duplicate the issue. When this is possible, it will aid in discovering the problem. When you cannot duplicate the issue, your challenge becomes harder because you are dealing with an intermittent problem. These issues are difficult to solve because they don't happen consistently.

Determine If Anything Has Changed

Moving right along, if you can reproduce the problem, your next step is to verify what has changed and how. Drawing on your knowledge of networking, you ask yourself and your user questions like these:

Were you ever able to do this? If not, then maybe it just isn't something the hardware or software is designed to do. You should then tell the user exactly that, as well as advise them that they may need additional hardware or software to pull off what they're trying do.

If so, when did you become unable to do it? If, once upon a time, the computer was able to do the job and then suddenly could not, whatever conditions surrounded and were involved in this turn of events become extremely important. You have a really good shot at unearthing the root of the problem if you know what happened right before things changed. Just know that there's a high level of probability that the cause of the problem is directly related to the conditions surrounding the change when it occurred.

Has anything changed since the last time you could do this? This question can lead you right to the problem's cause. Seriously—the thing that changed right before the problem began happening is almost always what caused it. It's so important that if you ask it and your user tells you, "Nothing changed…it just happened," you should rephrase the question and say something like, "Did anyone add anything to your computer?" or "Are you doing anything differently from the way you usually do it?"

Were any error messages displayed? These are basically arrows that point directly at the problem's origin; error messages are designed by programmers for the purpose of pointing them to exactly what it is that isn't working properly in computer systems. Sometimes error messages are crystal clear, like Disk Full, or they can be cryptically annoying little puzzles in and of themselves. If you pulled the short straw and got the latter variety, it's probably best to hit the software or hardware vendor's support site, where you can usually score a translation from the "programmerese" in which the error message is written into plain English so you can get back to solving your riddle.

Are other people experiencing this problem? You've got to ask this one because the answer will definitely help you target the cause of the problem. First, try to duplicate the problem from your own workstation because if you can't, it's likely that the issue is related to only one user or group of users—possibly their workstations. (A solid hint that this is the case is if you're being inundated with calls from a bunch of people from the same workgroup.)

Is the problem always the same? It's good to know that when problems crop up, they're almost always the same each time they occur. But their symptoms can change slightly as the conditions surrounding them change. A related question would be, "If you do *x*, does the problem get better or worse?" For example, ask a user, "If you use a different file, does the problem get better or worse?" If the symptoms lighten up, it's an indication that the problem is related to the original file that's being used. It's important to try to duplicate the problem to find the source of the issue as soon as possible!

NOTE Understand that these are just a few of the questions you can use to get to the source of a problem.

Okay, so let's get back to our sample scenario. So far, you've determined that the problem is unique to one user, which tells you that the problem is specific to this one host. Confirming that is the fact that you haven't received any other calls from other users on the network.

And when watching the user attempt to reproduce the problem, you note that they're typing the address correctly. Plus, you've got an error message that leads you to believe that the problem has something to with Domain Name Service (DNS) lookups on the user's host. Time to go deeper…

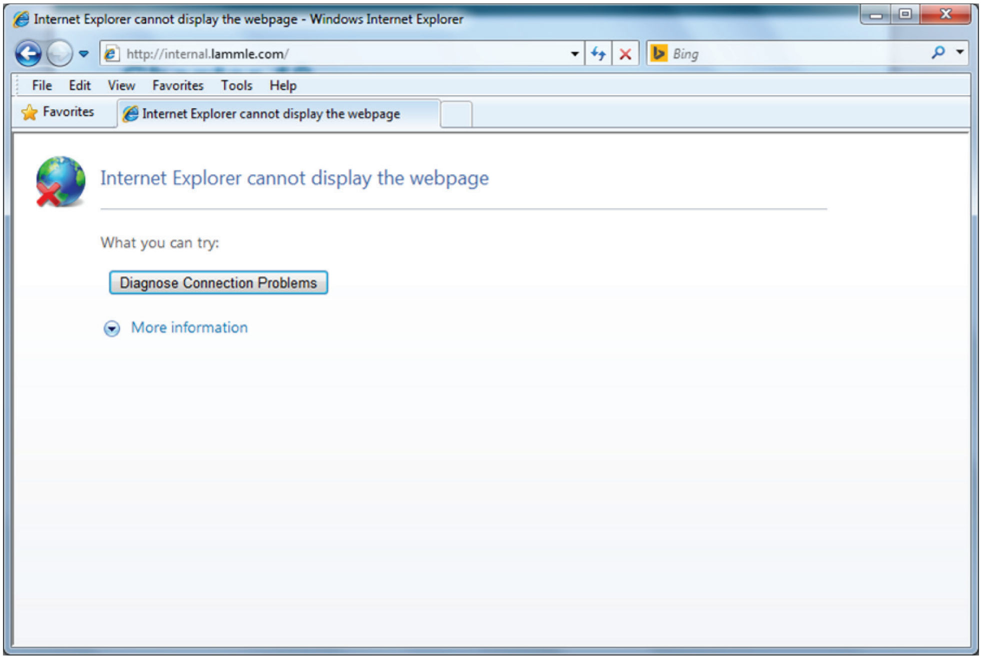
Identify Symptoms

I probably don't need to tell you that computers and networks can be really fickle—they can hum along fine for months, suddenly crash, and then continue to work fine again without ever seizing in that way again. That's why it's so important to be able to reproduce the problem and identify the affected area to narrow things down so you can cut to the chase and fix the issue fast. This really helps—when something isn't working, try it again, and write down exactly what is and is not happening.

Most users' knee-jerk reaction is to straight up call the help desk the minute they have a problem. This is not only annoying but also inefficient, because you're going to ask them exactly what they were doing when the problem occurred and most users have no idea what they were doing with the computer at the time because they were focused on doing their jobs instead. This is why if you train users to reproduce the problem and jot down some notes about it *before* calling you, they'll be much better prepared to give you the information you need to start troubleshooting it and help them.

So with that, here we go. The problem you've identified results in coughing out an error message to your user when they try to access the corporate intranet. It looks like Figure 19.1.

FIGURE 19.1 Cannot connect


Internet Explorer cannot display the webpage - Windows Internet Explorer

http://internal.lammle.com/

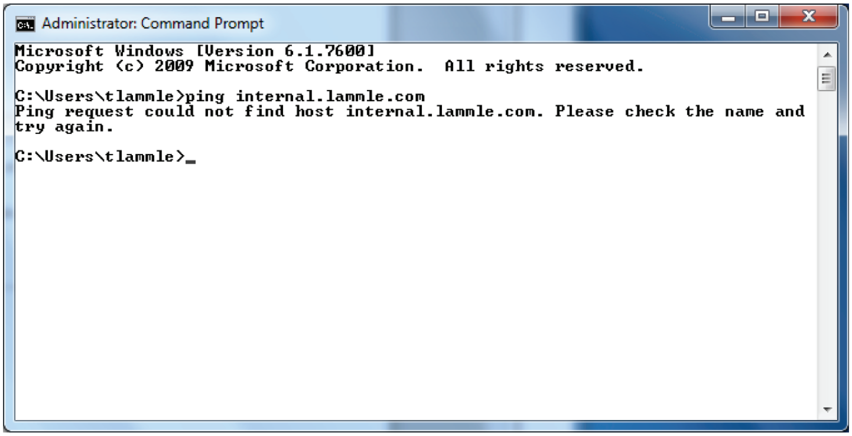
Internet Explorer cannot display the webpage

What you can try:

Bing
File
Edit
View
Favorites
Tools
Help
Favorites
Internet Explorer cannot display the webpage
Diagnose Connection Problems
More information

And when this user tries to ping the server using the server's hierarchical web name, it fails, too (see Figure 19.2).

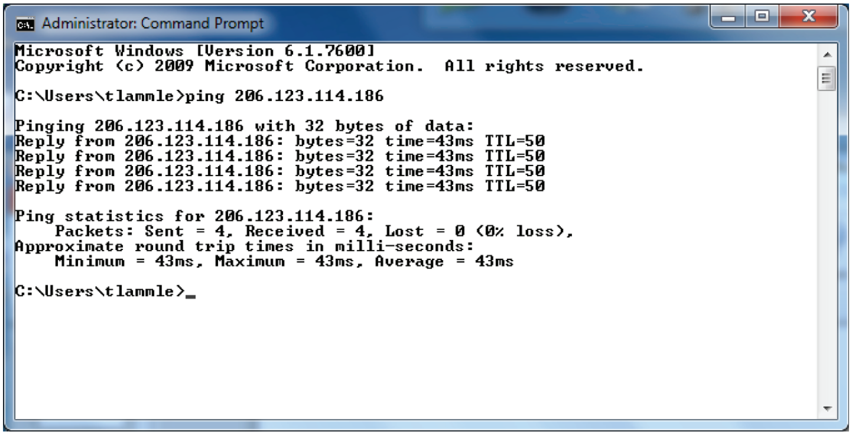
FIGURE 19.2 Host could not be found.



```
Microsoft Windows [Version 6.1.7600]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\tlammle>ping internal.lammle.com
Ping request could not find host internal.lammle.com. Please check the name and
try again.

C:\Users\tlammle>_
```

You're going to respond by checking to see whether the server is up by pinging the server by its IP address (see Figure 19.3).

FIGURE 19.3 Successful ping



```
Microsoft Windows [Version 6.1.7600]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\tlammle>ping 206.123.114.186

Pinging 206.123.114.186 with 32 bytes of data:
Reply from 206.123.114.186: bytes=32 time=43ms TTL=50
Reply from 206.123.114.186: bytes=32 time=43ms TTL=50
Reply from 206.123.114.186: bytes=32 time=43ms TTL=50
Reply from 206.123.114.186: bytes=32 time=43ms TTL=50

Ping statistics for 206.123.114.186:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 43ms, Maximum = 43ms, Average = 43ms

C:\Users\tlammle>_
```

Nice—that worked, so the server is up, but you could still have a server problem. Just because you can ping a host, it doesn't mean that host is 100 percent up and running, but in this case, it's a good start.

And you're in luck because you've been able to re-create this problem from this user's host machine. By doing that, you now know that the URL name is not being resolved from Internet Explorer, and you can't ping it by the name either. But you can ping the server

IP address from your limping host, and when you try this same connection to the `internal.lammle.com` server from another host nearby, it works fine, meaning the server is working fine. So, you've succeeded in isolating the problem to this specific host—yes!

NOTE It is a huge advantage if you can watch the user try to reproduce the problem themselves because then you know for sure whether the user is performing the operation correctly. It's a really bad idea to assume the user is typing in what they say they are.

Approach Multiple Problems Individually

You should never mix possible solutions when troubleshooting. When multiple changes are made, interactions can occur that muddy the results. Always attack one issue at a time and make only a single change at a time. When a change does not have a beneficial effect, reverse the change before making another change.

Great—now you've nailed down the problem. This leads us to step 2

Step 2: Establish a Theory of Probable Cause

After you observe the problem and identify the symptoms, next on the list is to establish its most probable cause. (If you're stressing about it now, don't, because though you may feel overwhelmed by all this, it truly does get a lot easier with time and experience.)

You must come up with at least one possible cause, even though it may not be completely on the money. And you don't always have to come up with it yourself. Someone else in the group may have the answer. Also, don't forget to check online sources and vendor documentation.

Again, let's get back to our scenario, in which you've determined the cause is probably an improperly configured DNS lookup on the workstation. The next thing to do is to verify the configuration (and probably reconfigure DNS on the workstation; we'll get to this solution later, in step 4).

Understand that there are legions of problems that can occur on a network—and I'm sorry to tell you this, but they're typically not as simple as the example we've been using. They can be, but I just don't want you to expect them to be. Always consider the physical aspects of a network, but look beyond them into the realm of logical factors like the DNS lookup issue we've been using.

Question the Obvious

The probable causes that you've got to thoroughly understand to meet the Network+ objectives are as follows:

- Port speed
- Port duplex mismatch
- Mismatched MTU
- Incorrect virtual local area network (VLAN)

- Incorrect IP address/duplicate IP address
- Wrong gateway
- Wrong DNS
- Wrong subnet mask
- Incorrect interface/interface misconfiguration
- Duplicate MAC addresses
- Expired IP address
- Rogue DHCP server
- Untrusted SSL certificate
- Incorrect time
- Exhausted DHCP scope
- Blocked TCP/UDP ports
- Incorrect host-based firewall settings
- Incorrect ACL settings
- Unresponsive service

Let's talk about these logical issues, which can cause an abundance of network problems. Most of these happen because a device has been improperly configured.

Port Speed Because networks have been evolving for many years, there are various levels of speed and sophistication mixed into them—often within the same network. Most of the newest NICs can be used at 10 Mbps, 100 Mbps, and 1,000 Mbps. Most switches can support at least 10 Mbps and 100 Mbps, and an increasing number of switches can also support 1,000 Mbps. Plus, many switches can also autosense the speed of the NIC that's connected and use different speeds on various ports. As long as the switches are allowed to autosense the port speed, it's rare to have a problem develop that results in a complete lack of communication. But if you decide to set the port speed manually, make positively sure to set the same speed on both sides of a link.

Port Duplex Mismatch There are generally three duplex settings on each port of a network switch: full, half, and auto. In order for two devices to connect effectively, the duplex setting has to match on both sides of the connection. If one side of a connection is set to full and the other is set to half, they're mismatched. More elusively, if both sides are set to auto but the devices are different, you can also end up with a mismatch because the device on one side defaults to full and the other one defaults to half.

Duplex mismatches can cause lots of network and interface errors, and even the lack of a network connection. This is partially because setting the interfaces to full duplex disables the CSMA/CD protocol. This is definitely not a problem in a network that has no hubs (and therefore no shared segments in which there could be collisions), but it can make things really ugly in a network where hubs are still being used. This means the settings you choose are based on the type of devices you have populating your network. If you have all switches and no hubs, feel free to set all interfaces to full duplex, but if you've got hubs in the mix, you have shared networks, so you're forced to keep the settings at half duplex. With all new switches produced today, leaving the speed and duplex setting to auto (the default on both switches and hosts) is the recommended way to go.

Mismatched MTU Ethernet LANs enforce what is called a maximum transmission unit (MTU). This is the largest size packet that is allowed across a segment. In most cases, this is 1,500 bytes. Left alone this is usually not a problem, but it is possible to set the MTU on a router interface, which means it is possible for a mismatch to be present between two router interfaces. This can cause problems with communications between the routers, resulting in the link failing to pass traffic. To check the MTU on an interface, execute the command `show interface`.

Incorrect VLAN Switches can have multiple VLANs each, and they can be connected to other switches using trunk links. As you now know, VLANs are often used to represent departments or the occupations of a group of users. This makes the configurations of security policies and network access lists much easier to manage and control. On the other hand, if a port is accidentally assigned to the wrong VLAN in a switch, it's as if that client was magically transported to another place in the network. If that happens, the security policies that should apply to the client won't anymore, and other policies will be applied to the client that never should have been. The correct VLAN port assignment of a client is as important as air; when I'm troubleshooting a single-host problem, this is the first place I look.

NOTE

It's pretty easy to tell if you have a port configured with a wrong VLAN assignment. If this is the case, it won't be long before you'll get a call from some user screaming something at you that makes the building shake, like, "I can get to the Internet but I can't get to the Sales server, and I'm about to lose a huge sale. DO SOMETHING!" When you check the switch, you will invariably see that this user's port has a membership in another VLAN like Marketing, which has no access to the Sales server.

Incorrect IP Address/Duplicate IP Address The most common addressing protocol in use today is IPv4, which provides a unique IP address for each host on a network. Client computers usually get their addresses from Dynamic Host Configuration Protocol (DHCP) servers. But sometimes, especially in smaller networks, IP addresses for servers and router interfaces are statically assigned by the network's administrator. An incorrect or duplicate IP address on a client will keep that client from being able to communicate and may even cause a conflict with another client on the network, and a bad address on a server or router interface can be disastrous and affect a multitude of users. This is exactly why you need to be super careful to set up DHCP servers correctly and also when configuring the static IP addresses assigned to servers and router interfaces.

Wrong Gateway A *gateway*, sometimes called a *default gateway* or an *IP default gateway*, is a router interface's address that's configured to forward traffic with a destination IP address that's not in the same subnet as the device itself. Let me clarify that one for you: If a device compares where a packet wants to go with the network it's currently on and finds that the packet needs to go to a remote network, the device will send that packet to the gateway to be forwarded to the remote network. Because every device needs a valid gateway to obtain communication outside its own network, it's going to require some careful planning when considering the gateway configuration of devices in your network.

NOTE If you're configuring a static IP address and default gateway, you need to verify the router's address. Not doing so is a really common "wrong gateway" problem that I see all the time.

Wrong DNS DNS servers are used by networks and their clients to resolve a computer's hostname to its IP addresses and to enable clients to find the server they need to provide the resources they require, like a domain controller during the login and authentication process. Most of the time, DNS addresses are automatically configured by a DHCP server, but sometimes these addresses are statically configured instead. Because lots of applications rely on hostname resolution, a botched DNS configuration usually causes a computer's network applications to fail just like the user's applications in our example scenario.

NOTE If you can ping a host using its IP address but not its name, you probably have some type of name-resolution issue. It's probably lurking somewhere within a DNS configuration.

Wrong Subnet Mask When network devices look at an IP address configuration, they see a combination of the IP address and the subnet mask. The device uses the subnet mask to establish which part of the address represents the network address and which part represents the host address. So clearly, a subnet mask that is configured wrong has the same nasty effect as a wrong IP address configuration does on communications. Again, a subnet mask is generally configured by the DHCP server; if you're going to enter it manually, make sure the subnet mask is tight or you'll end up tangling with the fallout caused by the entire address's misconfiguration.

Incorrect Interface/Interface Misconfiguration If a host is plugged into a misconfigured switch port, or if it's plugged into the wrong switch port that's configured for the wrong VLAN, the host won't function correctly. Make sure the speed, duplex, and correct Ethernet cable is used. Get any of that wrong and either you'll get interface errors on the host and switch port or, worse, things just won't work at all!

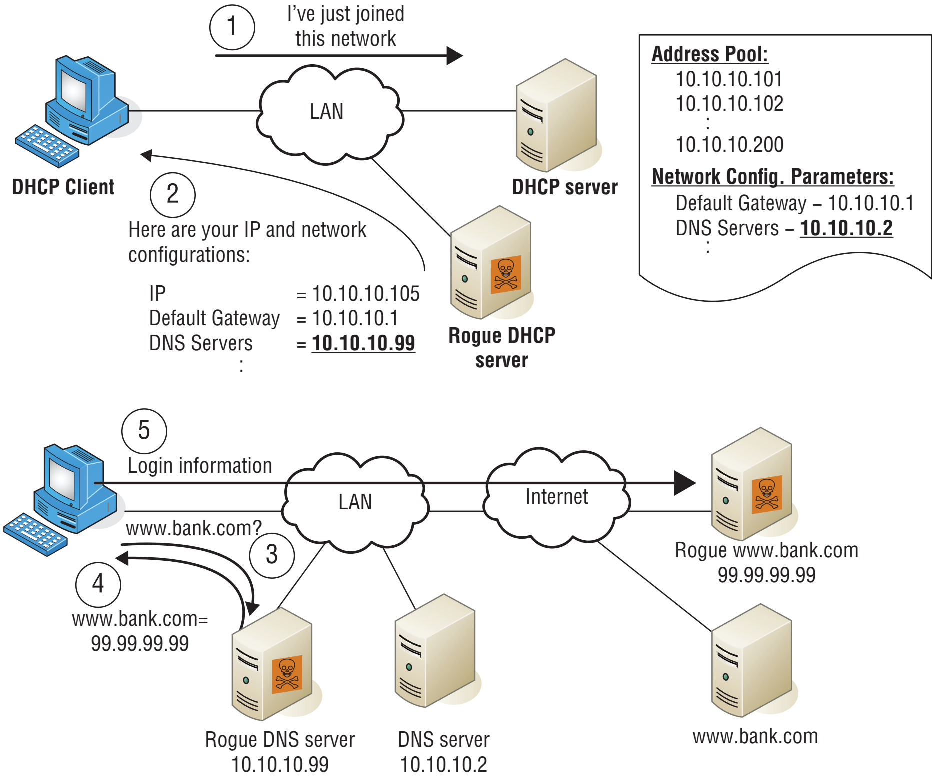
Duplicate MAC Addresses There should never be duplicate MAC addresses in your environment. Each interface vendor is issued an organizationally unique identifier (OUI), which will match on all interfaces produced by that vendor, and then the vendor is responsible for ensuring unique MAC addresses. That means duplicate MAC addresses usually indicate a MAC spoofing attack, in which some malicious individual changes their MAC address, which can be done quite easily in the properties of the NIC.

Expired IP Address In almost all cases, when DHCP is used to allocate IP configurations to devices, the configuration is supplied to the DHCP client is on a temporary basis. The lease period is configurable, and when the lease period and a grace period transpire, the lease is expired. The effect of an expired lease is the next time that client computer starts, it must enter the initialization state and obtain new TCP/IP configuration information from a DHCP server. There is nothing, however, to prevent the client from obtaining a new lease for the same IP address.

Rogue DHCP Server Dynamic Host Configuration Protocol (DHCP) is used to automate the process of assigning IP configurations to hosts. When configured properly, it reduces administrative overload, reduces the human error inherent in manual assignment, and enhances device mobility. But it introduces a vulnerability that when leveraged by a malicious individual can result in an inability of hosts to communicate (constituting a DoS attack) and peer-to-peer attacks.

When an illegitimate DHCP server (called a rogue DHCP server) is introduced to the network, unsuspecting hosts may accept DHCP Offer packets from the illegitimate DHCP server rather than the legitimate DHCP server. When this occurs, the rogue DHCP server will not only issue the host an incorrect IP address, subnet mask, and default gateway address (which makes a peer-to-peer attack possible), it can also issue an incorrect DNS server address, which will lead to the host relying on the attacker's DNS server for the IP addresses of websites (such as major banks) that lead to phishing attacks. An example of how this can occur is shown in Figure 19.4.

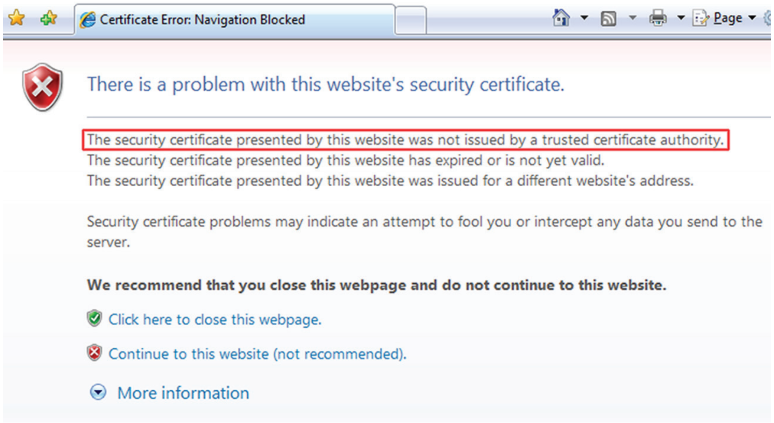
FIGURE 19.4 Rogue DHCP



In Figure 19.4, after receiving an incorrect IP address, subnet mask, default gateway, and DNS server address from the rogue DHCP server, the DHCP client uses the attacker's DNS server to obtain the IP address of his bank. This leads the client to unwittingly connect to the attacker's copy of the bank's website. When the client enters his credentials to log in, the attacker now has the client's bank credentials and can proceed to empty out his account.

Untrusted SSL Certificate Reception of an untrusted SSL certificate error message can be for several reasons. In Figure 19.5, the possible reasons for the warning message are shown. The first reason, "The Security certificate presented by this website was not issued by a trusted certificate authority," means the CA that issued the certificate is not trusted by the local machine. This will occur if the certificate of the CA that issued the certificate is not found in the Trusted Root Certification Authorities Folder on the local machine.

FIGURE 19.5 Certificate error



There is a problem with this website's security certificate.

The security certificate presented by this website was not issued by a trusted certificate authority.
The security certificate presented by this website has expired or is not yet valid.
The security certificate presented by this website was issued for a different website's address.

Security certificate problems may indicate an attempt to fool you or intercept any data you send to the server.

We recommend that you close this webpage and do not continue to this website.

Click here to close this webpage.

Continue to this website (not recommended).

More information

The second reason this might occur is that the certificate is not valid. It may be that the certificate was presented before the validity period begins, or it may have expired, meaning the validity period is over.

The third reason is that the name on the certificate does not match the name listed on the certificate.

Incorrect Time Incorrect time on a device can be the cause of several issues. First, in a Windows environment using Active Directory, a clock skew of more than 5 minutes between a client and server will prevent communication between the two.

Second, when certificates are in use, proper time synchronization is critical for successful operation.

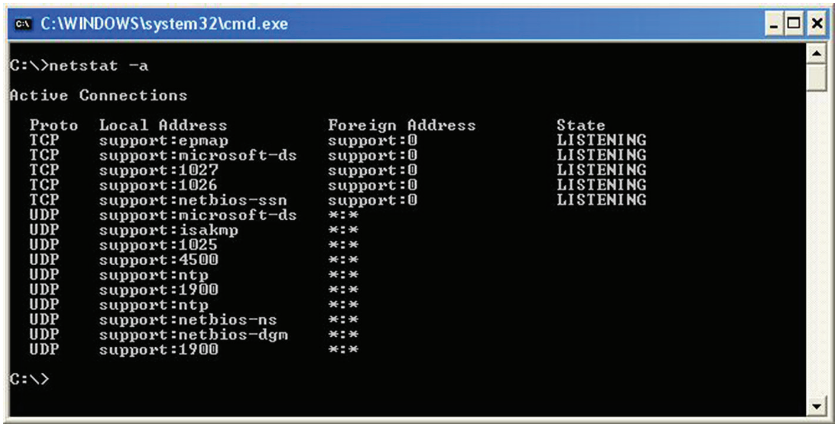
Finally, when system logs are sent to a central server such as a Syslog server, proper time synchronization is critical to understand the order of events.

Exhausted DHCP Scope When a DHCP server is implemented, it is configured with a limited number of IP addresses. When the IP addresses in a scope are exhausted, any new DHCP clients will be unable to obtain an IP address and will be unable to function on the network.

DHCP servers can be set up to provide backup to another DHCP server for a scope. When this is done, it is important to ensure that while the two DHCP servers service the same scope, they do not have any duplicate IP addresses.

Blocked TCP/UDP Ports When the ports used by common services and applications are blocked, either on the network firewall or on the personal firewall of a device, it will be impossible to make use of the service or application. One easy way to verify the open ports on a device is to execute the `netstat` command. An example of the output is shown in Figure 19.6.

FIGURE 19.6 Netstat -a



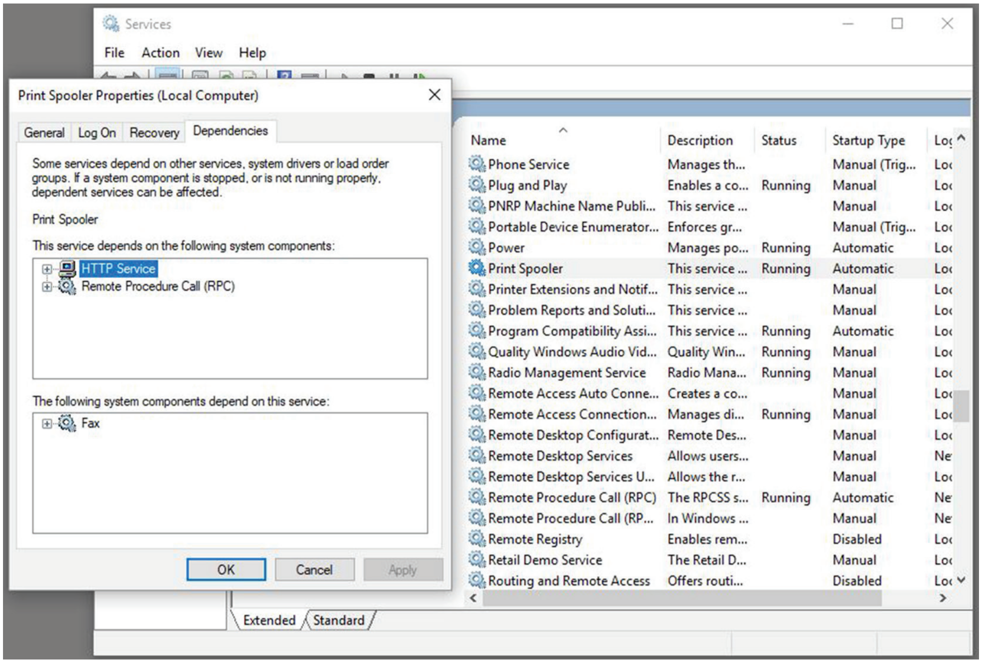
```
C:\>netstat -a

Active Connections

  Proto  Local Address          Foreign Address        State
  TCP    support:epmap          support:0              LISTENING
  TCP    support:microsoft-ds   support:0              LISTENING
  TCP    support:1027           support:0              LISTENING
  TCP    support:1026           support:0              LISTENING
  TCP    support:netbios-ssn    support:0              LISTENING
  UDP    support:microsoft-ds   *:*
  UDP    support:isakmp         *:*
  UDP    support:1025           *:*
  UDP    support:4500           *:*
  UDP    support:ntp            *:*
  UDP    support:1900           *:*
  UDP    support:ntp            *:*
  UDP    support:netbios-ns     *:*
  UDP    support:netbios-dgm    *:*
  UDP    support:1900           *:*

C:\>
```

Incorrect Host-Based Firewall Settings As you saw in the explanation of blocked TCP/UDP ports, incorrect host-based firewall settings can either prevent transmissions or allow unwanted communications. Neither of these outcomes is desirable. One of the best ways to ensure that firewall settings are consistent and correct all the time is to control these settings with a group policy. When you do this, the settings will be checked and reset at every policy refresh interval.

Incorrect ACL Settings Access control lists are used to control which traffic types can enter and exit ports on the router. When mistakes are made either in the construction of the ACLs or in their application, many devices may be affected. The creation and application of these tools should only be done by those who have been trained in their syntax and in the logic ACLs use in their operation.

Unresponsive Service Services can fail for several reasons. Many services depend on other services for their operation. Therefore, the failure of one service sometimes causes a domino effect, taking down other services that depend on it. You can use the Services applet in Control Panel to identify these dependencies as well as start and stop services. To identify the services upon which a particular service depends, use the Dependencies tab on the Services applet, as shown in Figure 19.7.

FIGURE 19.7 Service dependencies



Print Spooler Properties (Local Computer)

Some services depend on other services, system drivers or load order groups. If a system component is stopped, or is not running properly, dependent services can be affected.

Print Spooler

This service depends on the following system components:

- HTTP Service
- Remote Procedure Call (RPC)

The following system components depend on this service:

- Fax

Name	Description	Status	Startup Type	Lo
Phone Service	Manages th...		Manual (Trig...	Loc
Plug and Play	Enables a co...	Running	Manual	Loc
PNRP Machine Name Publi...	This service ...		Manual	Loc
Portable Device Enumerator...	Enforces gr...		Manual (Trig...	Loc
Power	Manages po...	Running	Automatic	Loc
Print Spooler	This service ...	Running	Automatic	Loc
Printer Extensions and Notif...	This service ...		Manual	Loc
Problem Reports and Soluti...	This service ...		Manual	Loc
Program Compatibility Assi...	This service ...	Running	Automatic	Loc
Quality Windows Audio Vid...	Quality Win...	Running	Manual	Loc
Radio Management Service	Radio Mana...	Running	Manual	Loc
Remote Access Auto Conne...	Creates a co...		Manual	Loc
Remote Access Connection...	Manages di...	Running	Manual	Loc
Remote Desktop Configurat...	Remote Des...		Manual	Loc
Remote Desktop Services	Allows users...		Manual	Ne
Remote Desktop Services U...	Allows the r...		Manual	Loc
Remote Procedure Call (RPC)	The RPCSS s...	Running	Automatic	Ne
Remote Procedure Call (RP...	In Windows ...		Manual	Ne
Remote Registry	Enables rem...		Disabled	Loc
Retail Demo Service	The Retail D...		Manual	Loc
Routing and Remote Access	Offers routi...		Disabled	Loc

In Figure 19.7, the spooler service is selected and the Dependencies tab is displayed. Here we see that the spooler service depends on the HTTP and the RPC services. Therefore, if the spooler service will not start, we may need to restart one of these two services first.

With all that in mind, let's move on with our troubleshooting steps.

Consider Multiple Approaches

There are two standard approaches that you can use to establish a theory of probable cause. Let's take a look at them next.

Top-to-Bottom/Bottom-to-Top OSI Model As its name implies, when you apply a *top-down* approach to troubleshooting a networking problem, you start with the user application and work your way down the layers of the OSI model. If a layer is *not* in good working condition, you inspect the layer below it. When you know that the current layer is not in working condition and you discover that a lower layer works, you can conclude that the problem is within the layer above the lower working layer. Once you've determined which layer is the lowest layer with problems, you can begin identifying the cause of them from within that layer.

The *bottom-up* approach to troubleshooting a networking problem starts with the physical components of the network and works its way up the layers of the OSI model. If you conclude that all the elements associated with a particular layer are in good working order, move on to inspect the elements associated with the next layer up until the cause(s) of the problem is/are identified. The downside to the bottom-up approach is that it requires you to check every device, interface, and so on. In other words, regardless of the nature of the problem, the bottom-up approach starts with an exhaustive check of all the elements of each layer, starting with the physical layer and working its way up from there.

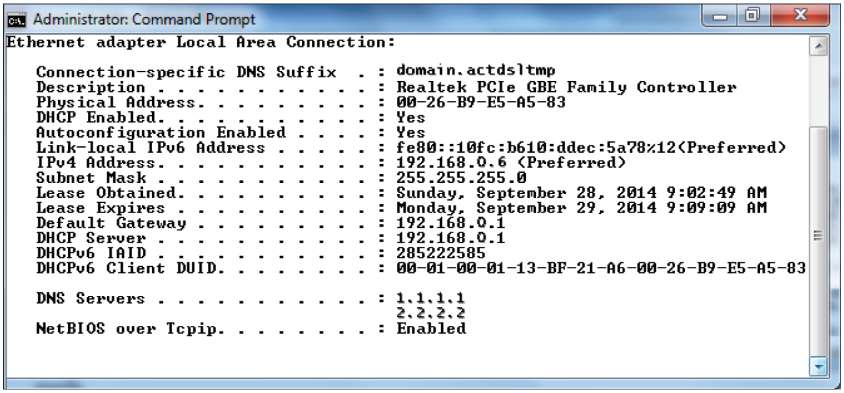
Divide and Conquer Unlike when opting for the top-down and bottom-up troubleshooting strategies, the *divide-and-conquer* approach to network troubleshooting doesn't always begin the investigation at a particular OSI layer. When using the divide-and-conquer approach, you select a layer, test its health, and based on the results, you can move up or down through the model from the layer you began scrutinizing.

Step 3: Test the Theory to Determine Cause

Once you've gathered information and established a plausible theory, you've got to determine the next steps to resolve your problem. If you can't confirm your theory during this step, you must formulate a new theory or escalate the problem.

Let's look into the matter by first checking the IP configuration of the host that just happens to include DNS information. You use the `ipconfig /all` command to show the IP configuration. The `/all` switch will give you the DNS information you need, as shown in Figure 19.8.

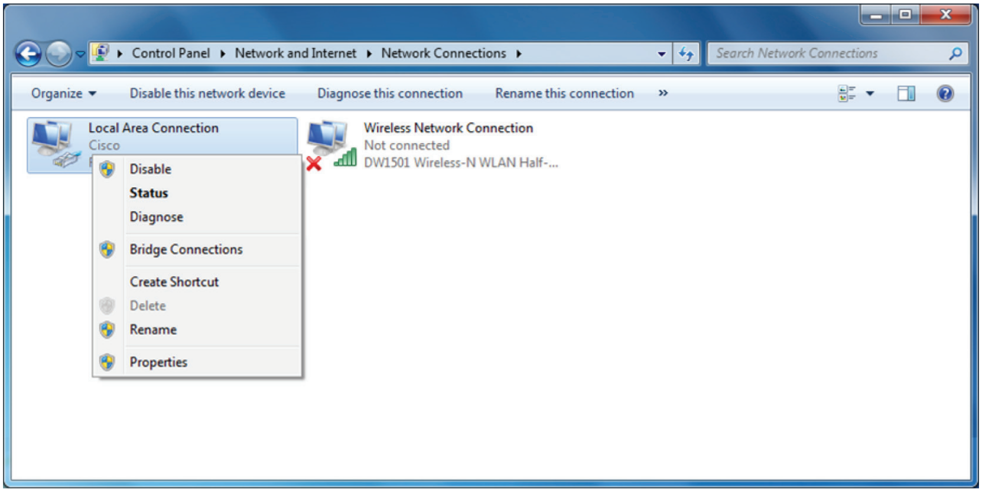
FIGURE 19.8 `ipconfig/all`



```
Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : domain.actdsltmp
   Description . . . . . . . . . . . : Realtek PCIe GBE Family Controller
   Physical Address. . . . . . . . . : 00-26-B9-E5-A5-83
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::10fc:b610:ddec:5a78%12(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.0.6 (Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Sunday, September 28, 2014 9:02:49 AM
   Lease Expires . . . . . . . . . . : Monday, September 29, 2014 9:09:09 AM
   Default Gateway . . . . . . . . . : 192.168.0.1
   DHCP Server . . . . . . . . . . . : 192.168.0.1
   DHCPv6 IAID . . . . . . . . . . . : 285222585
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-13-BF-21-A6-00-26-B9-E5-A5-83

   DNS Servers . . . . . . . . . . . : 1.1.1.1
                                       2.2.2.2
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

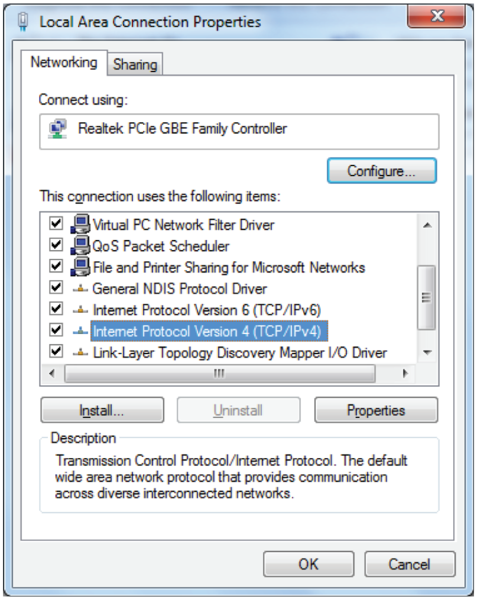
Check out the DNS entries: 1.1.1.1 and 2.2.2.2. Is this right? What are they supposed to be? You can find this out by checking the addresses on a working host, but let's check the settings on your troubled host's adapter first. Click Start, then Control Panel, then Network And Sharing Center, and then Manage Network Connections on the left side of the screen, which will take you to the screen shown in Figure 19.9.

FIGURE 19.9 Manage Network Connections



Now, click the interface in question, and click Properties. You receive this screen, shown in Figure 19.10.

FIGURE 19.10 Interface properties



Connect using:

Realtek PCIe GBE Family Controller

This connection uses the following items:

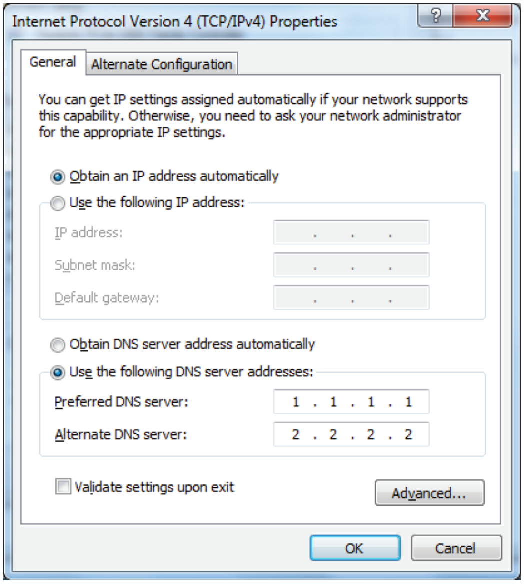
- ☑ Virtual PC Network Filter Driver
- ☑ QoS Packet Scheduler
- ☑ File and Printer Sharing for Microsoft Networks
- ☑ General NDIS Protocol Driver
- ☑ Internet Protocol Version 6 (TCP/IPv6)
- ☑ Internet Protocol Version 4 (TCP/IPv4)
- ☑ Link-Layer Topology Discovery Mapper I/O Driver

Description

Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.

From here, you highlight Internet Protocol Version 4, and click Properties (or just double-click). From Figure 19.11, do you see what may be causing the problem?

FIGURE 19.11 IP properties



You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

● Obtain an IP address automatically

○ Use the following IP address:

IP address: . . .

Subnet mask: . . .

Default gateway: . . .

○ Obtain DNS server address automatically

● Use the following DNS server addresses:

Preferred DNS server: 1 . 1 . 1 . 1

Alternate DNS server: 2 . 2 . 2 . 2

□ Validate settings upon exit

As I said, you're using DHCP, right? But DNS is statically configured on this host. Interesting enough, when you set a static DNS entry on an interface, it will override the DHCP-provided DNS entry.

Once the theory is confirmed, determine the next steps to resolve the problem When the testing of the theory is complete, you will have determined if the suggested cause is correct. If you find you are correct, the next steps (next section) is to establish a plan of action to resolve the problem and identify potential effects.

If the theory is not confirmed, reestablish a new theory or escalate If you find that the suggested theory is not the cause of the issue, then you should move on to test any other theories you may have developed. In the event you have exhausted all theories you may have developed, it is advisable to escalate the issue to a more senior technician or, when it involves a system with which you are unfamiliar, the system owner or manager.

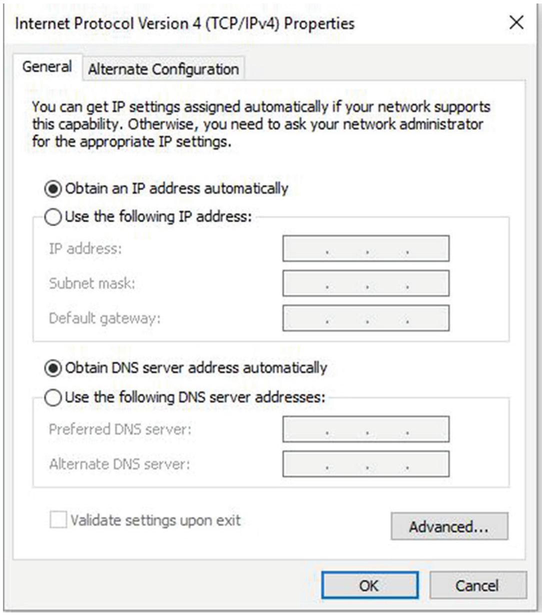
Step 4: Establish a Plan of Action to Resolve the Problem and Identify Potential Effects

Now that you've identified some possible changes, you've got to follow through and test your solution to see if you really solved the problem. In this case, you ask the user to try to access the intranet server (because that's what they called about). Basically, you just ask the user to try doing whatever it was they couldn't do when they called you in the first place. If it works—sweet—problem solved. If not, try the operation yourself.

Now you can test the proposed solution on the computer of the user who is still waiting for a solution. To do that, you need to check the DNS configuration on your host. But first, let me point out something about the neglected user's network. All hosts are using DHCP, so it's really weird that a single user is having a DNS resolution issue.

So, to fix the problem and get your user back in the game, just click Obtain DNS Server Address Automatically, and then click OK (see Figure 19.12). Voilà!

FIGURE 19.12 Obtain DNS Server Address Automatically



You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

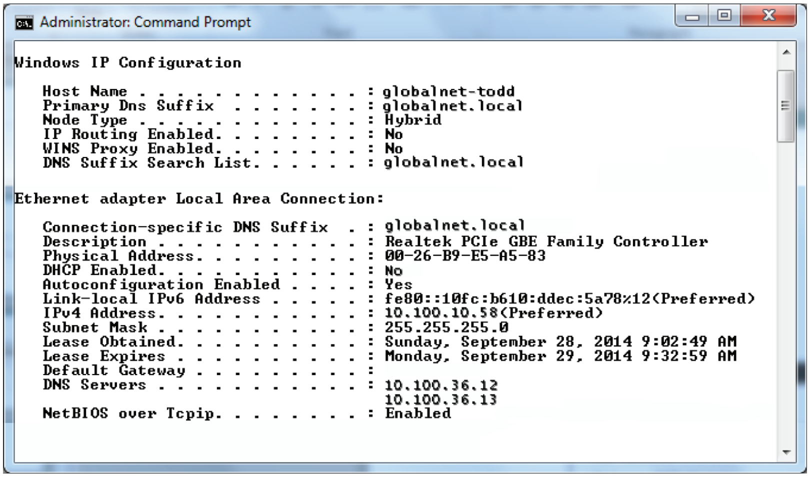
● Obtain an IP address automatically
○ Use the following IP address:
IP address: . . .
Subnet mask: . . .
Default gateway: . . .

● Obtain DNS server address automatically
○ Use the following DNS server addresses:
Preferred DNS server: . . .
Alternate DNS server: . . .

□ Validate settings upon exit

Let's take a look at the output of `ipconfig /all` in Figure 19.13 and see if you received new DNS server addresses.

FIGURE 19.13 `ipconfig /all`



```
Windows IP Configuration

   Host Name . . . . . . . . . . . . : globalnet-todd
   Primary Dns Suffix  . . . . . . . : globalnet.local
   Node Type . . . . . . . . . . . . : Hybrid
   IP Routing Enabled. . . . . . . . : No
   WINS Proxy Enabled. . . . . . . . : No
   DNS Suffix Search List. . . . . . : globalnet.local

Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : globalnet.local
   Description . . . . . . . . . . . : Realtek PCIe GBE Family Controller
   Physical Address. . . . . . . . . : 00-26-B9-E5-A5-83
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::10fc:b610:ddec:5a78%12(Preferred)
   IPv4 Address. . . . . . . . . . . : 10.100.10.58(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Sunday, September 28, 2014 9:02:49 AM
   Lease Expires . . . . . . . . . . : Monday, September 29, 2014 9:32:59 AM
   Default Gateway . . . . . . . . . :
   DNS Servers . . . . . . . . . . . : 10.100.36.12
                                       10.100.36.13
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

All good; you did. And you can test the host by trying to use HTTP to connect to a web page on the intranet server and even pinging by hostname. Congratulations on solving your first trouble ticket!

If things hadn't worked out so well, you would go back to step 2, select a new possible cause, and redo step 3. If this happens, keep track of what worked and what didn't so you don't make the same mistakes twice.

It's pretty much common sense that you should change settings like this only when you fully understand the effect your changes will have, or when you're asked to by someone who does. The incorrect configuration of these settings will disable the normal operation of your workstation, and, well, it seems that someone (the user, maybe?) did something they shouldn't have or you wouldn't have had the pleasure of solving this problem.

NOTE You have to be super careful when changing settings and always check out a troubled host's network settings. Don't just assume that because they're using DHCP, someone has screwed up the static configuration.

Step 5: Implement the Solution or Escalate as Necessary

Although it's true that CompTIA doesn't expect you to fix every single network problem that could possibly happen in the universe, they actually do expect you to get pretty close to determining exactly what the problem is. And if you can't fix it, you'll be expected to know how to escalate it and to whom. You are only as good as your resources—be they your own skill set, a book like this one, other more reference-oriented technical books, the Internet, or even a guru at a call center.

I know it seems like I talked to death physical and logical issues that cause problems in a network, but trust me, with what I've taught you, you're just getting started. There's a galaxy of networking evils that we have not even touched on because they're far beyond the objectives for Network+ certification and, therefore, the scope of this book. But out there in the real world, you'll get calls about them anyway, and because you're not yet equipped to handle them yourself, you need to escalate these nasties to a senior network engineer who has the additional experience and knowledge required to resolve the problems.

Some of the calamities that you should escalate are as follows:

- Switching loops
- Missing routes
- Routing loops
- Routing problems
- MTU black hole
- Bad modules
- Proxy Address Resolution Protocol (ARP)

- Broadcast storms
- NIC Teaming misconfiguration
- Power failures/power anomalies

NOTE

If you can't implement a solution and instead have to escalate the problem, there is no need for you to go on with steps 6 and 7 of the seven-step troubleshooting model. You now need to meet with the emergency response team to determine the next step.

And just as with other problems, you have to be able to identify these events because if you can't do that, how else will you know that you need to escalate them?

Switching Loops Today's networks often connect switches with redundant links to provide for fault tolerance and load balancing. Protocols such as Spanning Tree Protocol (STP) prevent switching loops and simultaneously maintain fault tolerance. If STP fails, it takes some expertise to reconfigure and repair the network, so you just need to be concerned with being able to identify the problem so you can escalate it. Remember, when you hear users complaining that the network works fine for a while, then unexpectedly goes down for about a minute, and then goes back to being fine, it's definitely an STP convergence issue that's pretty tough to find and fix. Escalate this problem ASAP!

Missing Routes Routers must have routes either configured or learned to function. There are a number of issues that can prevent a router from learning the routes that it needs. To determine if a router has the route to the network in question, execute the `show ip route` command and view the routing table. This can save a lot of additional troubleshooting if you can narrow the problem to a missing route.

Routing Loops Routing protocols are often used on networks to control traffic efficiently while preventing routing loops that happen when a routing protocol hasn't been configured properly or network changes didn't get the attention they deserved. Routing loops can also happen if you or the network admin blew the static configuration and created conflicting routes through the network. This evil event affects the traffic flow for all users, and because it's pretty complicated to fix, again, it's up, up, and away with this one. You can expect routing loops to occur if your network is running old routing protocols like Routing Information Protocol (RIP) and RIPv2. Just upgrading your routing protocol to Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF), or Intermediate System-to-Intermediate System (IS-IS) will usually take care of the problem once and for all. Anyway, escalate this problem to the router group—which hopefully is soon to be you.

Routing Problems Routing packets through the many subnets of a large enterprise while still maintaining security can be a tremendous challenge. A router's configuration can include all kinds of stuff like access lists, Network Address Translation (NAT), Port Address Translation (PAT), and even authentication protocols like Remote Authentication Dial In User Service (RADIUS) and Terminal Access Controller Access-Control System (TACACS).

Particularly diabolical, errant configuration changes can trigger a domino effect that can derail traffic down the wrong path or even cause it to come to a grinding halt and stop traversing the network completely. To identify routing problems, check to see if someone has simply set a wrong default route on a router. This can easily create routing loops. I see it all the time. These configurations can be highly complex and specific to a particular device, so they need to be escalated to the top dogs—get the problem to the best sys admin in the router group.

MTU Black Hole On a WAN connection, communication routes may fail if an intermediate network segment has an MTU that is smaller than the maximum packet size of the communicating hosts—and if the router does not send an appropriate Internet Control Message Protocol (ICMP) response to this condition. If ICMP traffic is allowed, the routers will take care of this problem using ICMP messages. However, as ICMP traffic is increasingly being blocked, this can create what is called a black hole. This will probably be an issue you will escalate.

Bad Modules Some multilayer switches and routers have slots available to add new features. The hardware that fits in these slots is called a module. These modules can host fiber connections, wireless connections, and other types as well. A common example is the Cisco Small Form-Factor Pluggable (SFP) Gigabit Interface Ethernet Converter (GBIC). This is an input-output device that plugs into an existing Gigabit Ethernet port or slot, providing a variety of additional capabilities to the device hosting the slot or port. Conversions can happen in all types of cables, from Ethernet to fiber, for example. Like any piece of hardware made by humans, the modules can fail. It is always worth checking if there are no other reasons a link is not functioning.

Proxy ARP Address Resolution Protocol (ARP) is a service that resolves IP addresses to MAC addresses. Proxy ARP is just wrong to use in today's networks, but hosts and routers still have it on by default. The idea of Proxy ARP was to solve the problem of a host being able to have only one configured default gateway. To allow redundancy, Proxy ARP running on a router will respond to an ARP broadcast from a host that's sending a packet to a remote network—but the host doesn't have a default gateway set. So the router responds by being the proxy for the remote host, which in turn makes the local host think the remote host is really local; as a result, the local host sends the packets to the router, which then forwards the packets to the remote host. Most of the time, in today's networks, this does not work well, if at all. Disable Proxy ARP on your routers, and make sure you have default gateways set on all your hosts. If you need router redundancy, there are much better solutions available than Proxy ARP! This is another job for the routing group.

Broadcast Storms When a switch receives a broadcast, it will normally flood the broadcast out all the ports except for the one the broadcast came in on. If STP fails between switches or is disabled by an administrator, it's possible that the traffic could continue to be flooded repeatedly throughout the switch topology. When this happens, the network can get so busy that normal traffic can't traverse it—an event referred to as a *broadcast storm*. As you can imagine, this is a particularly gruesome thing to have to troubleshoot and fix because you need to find the one bad link that is causing the mess while the network is probably still up and running—but at a heavily congested crawl. Escalate ASAP to experts!

NIC Teaming Misconfiguration NIC Teaming, also known as load balancing/failover (LBFO), allows multiple network interfaces to be placed into a team for the purposes of bandwidth aggregation and/or traffic failover to prevent connectivity loss in the event of a network component failure. The cards can be set to active-active state, where both cards are load balancing, or active-passive, where one card is on standby in case the primary card fails. Most of the time, the NIC team will use a multicast address to send and receive data, but it can also use a broadcast address so all cards receive the data at the same time. If these are not configured correctly, either they will operate at a severely diminished capacity or, worse, neither card will work at all!

Power Failure/Power Anomalies When you have power issues, whether it's a full-blown power outage or intermittent power surges, it can cause some serious issues with your network devices. Your servers and core network devices require a fully functional UPS system.

Step 6: Verify Full System Functionality, and If Applicable, Implement Preventative Measures

A trap that any network technician can fall into is solving one problem and thinking it's all fixed without stopping to consider the possible consequences of their solution. The cure can be worse than the disease, and it's possible that your solution falls into this category. So before you fully implement the solution to a problem, make sure you totally understand the ramifications of doing so—clearly, if it causes more problems than it fixes, you should toss it and find a different solution that does no harm.

NOTE

Many people update a router's operating system or firmware just because a new version of code is released from the manufacturer. Do not do this on your production routers—just say no! Always test any new code before upgrading your production routers: Like a bad solution, sometimes the new code provides new features but creates more problems, and the cons outweigh the pros.

Step 7: Document Findings, Actions, and Outcomes

I can't stress enough how vital network documentation is. Always document problems and solutions so that you have the information at hand when a similar problem arises in the future. With documented solutions to documented problems, you can assemble your own database of information that you can use to troubleshoot other problems. Be sure to include information like the following:

- A description of the conditions surrounding the problem
- The OS version, the software version, the type of computer, and the type of NIC
- Whether you were able to reproduce the problem

- The solutions you tried
- The ultimate solution

Real World Scenario

Network Documentation

I don't know how many times I've gone into a place and asked where their documentation was only to be met with a blank stare. I was recently at a small business that was experiencing network problems. The first question I asked was, "Do you have any kind of network documentation?" I got the blank stare. So, we proceeded to search through lots of receipts and other paperwork—anything we could find to help us understand the network layout and figure out exactly what was on the network. It turned out they had recently bought a WAP, and it was having trouble connecting—something that would've taken me five minutes to fix instead of searching through a mess for a couple hours!

Documentation doesn't have to look like a sleek owner's manual or anything—it can consist of a simple three-ring binder with an up-to-date network map; receipts for network equipment; a pocket for owner's manuals; and a stack of loose-leaf paper to record services, changes, network-addressing assignments, access lists, and so on. Just this little bit of documentation can save lots of time and money and prevent grief, especially in the critical first few months of a new network install.

Troubleshooting Tips

Now that you've got the basics of network troubleshooting down pat, I'm going to go over a few really handy troubleshooting tips for you to arm yourself with even further in the quest to conquer the world's networking evils.

Don't Overlook the Small Stuff

The super simple stuff (SSS) I referred to at the beginning of this chapter should never be overlooked—ever! Here's a quick review: Just remember that problems are often caused by little things like a bad power switch; a power switch in the wrong position; a card or port that's not working, indicated by a link light that's not lit; or simply operator error (OE). Even the most experienced system administrator has forgotten to turn on the power, left a cable unplugged, or mistyped a username and password—not me, of course, but others . . .

And make sure that users get solid training for the systems they use. An ounce of prevention is worth a pound of cure, and you'll experience dramatically fewer ID10T errors this way.

Prioritize Your Problems

Being a network administrator or technician of even a fairly small network can keep you hopping, and it's pretty rare that you'll get calls for help one at a time and never be interrupted by more coming in. Closer to reality is receiving yet another call when you already have three people waiting for service. So, you've got to prioritize.

You start this process by again asking some basic questions to determine the severity of the problem being reported. Clearly, if the new call is about something little and you already have a huge issue to deal with, you should put the new call on hold or get their info and get back to them later. If you establish a good set of priorities, you'll make much better use of your time. Here's an example of the rank you probably want to give to networking problems, from highest priority to lowest:

- Total network failure (affects everyone)
- Partial network failure (affects small groups of users)
- Small network failure (affects a small, single group of users)
- Total workstation failure (single user can't work at all)
- Partial workstation failure (single user can't do most tasks)
- Minor issue (single user has problems that crop up now and then)

Mitigating circumstances can, of course, change the order of this list. For example, if the president of the company can't retrieve email, you'd take the express elevator to their office as soon as you got the call, right? And even a minor issue can move up the ladder if it's persistent enough.

Don't fall prey to thinking that simple problems are easier to deal with because even though you may be able to bring up a crashed server in minutes, a user who doesn't know how to make columns line up in Microsoft Word could take a chunk out of your day. You'd want to put the latter problem toward the bottom of the list because of the time involved—it's a lot more efficient to solve problems for a big group of people than to fix this one user's problem immediately.

Some network administrators list all network-service requests on a chalkboard or a whiteboard. They then prioritize them based on the previously discussed criteria. Some larger companies have written support-call tracking software whose only function is to track and prioritize all network and computer problems. Use whatever method makes you comfortable, but prioritize your calls.

Check the Software Configuration

Often, network problems can be traced to software configuration, like our DNS configuration scenario; so when you're checking for software problems, don't forget to check types of configurations:

- DNS configuration/misconfiguration
- DHCP configuration/misconfiguration

- WINS configuration
- HOSTS file
- The Registry

Software-configuration settings love to hide in places like these and can be notoriously hard to find (especially in the Registry).

Also, look for lines that have been commented out either intentionally or accidentally in text-configuration files—another place for clues. A command such as `REM` or `REMARK`, or asterisk or semicolon characters, indicates comment lines in a file.

NOTE In the HOSTS file, a pound sign (#) is used to indicate a comment line.

Don't Overlook Physical Conditions

You want to make sure that from a network-design standpoint, the physical environment for a server is optimized for placement, temperature, and humidity. When troubleshooting an obscure network problem, don't forget to check the physical conditions under which the network device is operating. Check for problems like these:

- Excessive heat
- Excessive humidity (condensation)
- Low humidity (leads to electrostatic discharge [ESD] problems)
- EMI/RFI problems
- ESD problems
- Power problems
- Unplugged cables

Don't Overlook Cable Problems

Cables, generally speaking, work fine once they are installed properly. If the patch cable isn't the problem, use a cable tester (not a tone generator and locator) to find the source of the problem.

One of the easiest mistakes to make, especially if cables are not labeled, is to use a crossover cable where a straight-through cable should be used or vice versa. In either case, when you do this it causes TX/RX reversal. What's that? That's when the transmit wire is connected to Transmit and the receive wire to Receive. That sounds good, but it needs to be Transmit to Receive. See more about straight-through and crossover cables in Chapter 3, "Networking Topologies, Connectors, and Wiring Standards."

Wires that are moved can be prone to breaking or shorting, and a short can happen when the wire conductor comes in contact with another conductive surface, changing the path of the electrical signal. The signal will go someplace else instead of to the intended recipient. You can use cable testers to test for many types of problems:

- Broken cables
- Incorrect connections
- Interference levels
- Total cable length (for length restrictions)
- Cable shorts
- Connector problems
- Testing the cable at all possible data rates

NOTE As a matter of fact, cable testers are so sophisticated that they can even indicate the exact location of a cable break, accurate to within 6 inches or better.

Check for Viruses

People overlook scanning for viruses because they assume that the network's virus-checking software has already picked them off. But to be effective, the software must be kept up-to-date, and updates are made available pretty much daily. You've got to run the virus-definition update utility to keep the virus-definition file current.

If you are having strange, unusual, irreproducible problems with a workstation, try scanning it with an up-to-date virus-scan utility. You'd be surprised how many times people have spent hours and hours troubleshooting a strange problem only to run a virus-scan utility, find and clean out one or more viruses, and have the problem disappear like magic.

Summary

In this chapter, you learned about all things troubleshooting, and you now know how to sleuth out and solve a lot of network problems. You learned to first check all the SSS and about how to approach problem resolution by eliminating what the problem is *not*. You learned how to narrow the problem down to its basics and define it.

Next, you learned a systematic approach using a seven-step troubleshooting model to troubleshoot most of the problems you'll run into in networking. And you also learned about some resources you can use to help you during the troubleshooting process. In addition, you learned how important documentation is to the health of your network.

Finally, I gave you a bunch of cool tips to further equip you, tips about prioritizing issues, checking for configuration issues, considering environmental factors—even hunting down viruses. As you venture out into the real world, keep these tips in mind; along with your own personal experience, they'll really help make you an expert troubleshooter.

Exam Essentials

Know the seven troubleshooting steps, in order. The steps, in order, are as follows:

1. Identify the problem.
2. Establish a theory of probable cause.
3. Test the theory to determine cause.
4. Establish a plan of action to resolve the problem and identify potential effects.
5. Implement the solution or escalate as necessary.
6. Verify full system functionality, and if applicable, implement preventative measures.
7. Document findings, actions, and outcomes.

Be able to identify a link light. A link light is the small, usually green LED on the back of a network card. This LED is typically found next to the media connector on a NIC and is usually labeled Link.

Understand how proper network use procedures can affect the operation of a network. If a user is not following a network use procedure properly (for example, not logging in correctly), that user may report a problem where none exists. A good network troubleshooter should know how to differentiate between a network hardware/software problem and a "lack of user training" problem.

Know how to narrow down a problem to one specific area or cause. Most problems can be traced to one specific area or cause. You must be able to determine if a problem is specific to one user or a bunch of users, specific to one computer or a bunch of computers, and related to hardware or software. The answers to these questions will give you a very specific problem focus.

Know how to detect cabling-related problems. Generally speaking, most cabling-related problems can be traced by plugging the suspect workstation into a known, working network port. If the problem disappears (or at the very least changes significantly), it is related to the cabling for that workstation.

Written Lab

In this section, write the answers to the following questions. You can find the answers in Appendix A.

1. What is step 3 of the seven-step troubleshooting model?
2. What is step 7 of the seven-step troubleshooting model?
3. How is crosstalk minimized in twisted-pair cabling?

4. If you plug a host into a switch port and the user cannot get to the server or other services they need to access despite a working link light, what could the problem be?

5. What is it called when a cable has two wires of a twisted pair connected to two wires from a different pair?

6. When a signal moves through any medium, the medium itself will degrade the signal. What is this called?

7. What is step 4 of the seven-step troubleshooting model?

8. What is step 5 of the seven-step troubleshooting model?

9. What are some of the problems that, if determined, should be escalated?

10. What cable issues should you know and understand for network troubleshooting?

Review Questions

You can find the answers to the review questions in Appendix B.

1. Which of the following are not steps in the Network+ troubleshooting model? (Choose all that apply.)
   - **A.** Reboot the servers.
   - **B.** Identify the problem.
   - **C.** Test the theory to determine the cause.
   - **D.** Implement the solution or escalate as necessary.
   - **E.** Document findings, actions, and outcomes.
   - **F.** Reboot all the routers.

2. You have a user who cannot connect to the network. What is the first thing you could check to determine the source of the problem?
   - **A.** Workstation configuration
   - **B.** Connectivity
   - **C.** Patch cable
   - **D.** Server configuration

3. When wireless users complain that they are losing their connection to applications during a session, what is the source of the problem?
   - **A.** Incorrect SSID
   - **B.** Latency
   - **C.** Incorrect encryption
   - **D.** MAC address filter

4. Several users can't log in to the server. Which action would help you to narrow the problem down to the workstations, network, or server?
   - **A.** Run `tracert` from a workstation.
   - **B.** Check the server console for user connections.
   - **C.** Run `netstat` on all workstations.
   - **D.** Check the network diagnostics.

5. A user can't log in to the network. She can't even connect to the Internet over the LAN. Other users in the same area aren't experiencing any problems. You attempt to log in as this user from your workstation with her username and password and don't experience any problems. However, you cannot log in with either her username or yours from her workstation. What is a likely cause of the problem?
   - **A.** Insufficient rights to access the server
   - **B.** A bad patch cable
   - **C.** Server down
   - **D.** Wrong username and password

6. A user is experiencing problems logging in to a Unix server. He can connect to the Internet over the LAN. Other users in the same area aren't experiencing any problems. You attempt logging in as this user from your workstation with his username and password and don't experience any problems. However, you cannot log in with either his username or yours from his workstation. What is a likely cause of the problem?

   A. The Caps Lock key is pressed.

   B. The network hub is malfunctioning.

   C. You have a downed server.

   D. You have a jabbering NIC.

7. You receive a call from a user who is having issues connecting to a new VPN. Which is the first step you should take?

   A. Find out what has changed.

   B. Reboot the workstation.

   C. Document the solution.

   D. Identify the symptoms and potential causes.

8. A workstation presents an error message to a user. The message states that a duplicate IP address has been detected on the network. After establishing what has changed in the network, what should be the next step using the standard troubleshooting model?

   A. Test the result.

   B. Select the most probable cause.

   C. Create an action plan.

   D. Identify the results and effects of the solution.

9. You have gathered information on a network issue and determined the affected areas of the network. What is your next step in resolving this issue?

   A. You should implement the best solution for the issue.

   B. You should test the best solution for the issue.

   C. You should check to see if there have been any recent changes to this affected part of the network.

   D. You should consider any negative impact to the network that might be caused by a solution.

10. A user calls you, reporting a problem logging in to the corporate intranet. You can access the website without problems using the user's username and password. At your request, the user has tried logging in from other workstations but has been unsuccessful. What is the most likely cause of the problem?

    A. The user is logging in incorrectly.

    B. The network is down.

    C. The intranet server is locked up.

    D. The server is not routing packets correctly to that user's workstation.

11. You have just implemented a solution and you want to celebrate your success. But what should you do next before you start your celebration?

    A. Gather more information about the issue.

    B. Document the issue and the solution that was implemented.

    C. Test the solution and identify other effects it may have.

    D. Escalate the issue.

12. You can ping the local router and web server that a local user is trying to reach, but you cannot reach the web page that resides on that server. From step 2 of the troubleshooting model, what is a possible problem that would lead to this situation?

    A. Your network cable is unplugged.

    B. There is a problem with your browser.

    C. Your NIC has failed.

    D. The web server is unplugged.

13. When troubleshooting an obscure network problem, what physical conditions should be reviewed to make sure the network device is operating correctly? (Choose all that apply.)

    A. Excessive heat

    B. Low/excessive humidity

    C. ESD problems

    D. None of the above

14. Which of the following is not a basic physical issue that can occur on a network when a user is connected via cable?

    A. Crosstalk

    B. Shorts

    C. Open impedance mismatch

    D. DNS configurations

15. You are troubleshooting a LAN switch and have identified the symptoms. What is the next step you should take?

    A. Escalate the issue.

    B. Create an action plan.

    C. Implement the solution.

    D. Determine the scope of the problem.

16. A user calls you, complaining that he can't access the corporate intranet web server. You try the same address, and you receive a Host Not Found error. Several minutes later, another user reports the same problem. You can still send email and transfer files to another server. What is the most likely cause of the problem?

    A. The hub is unplugged.

    B. The server is not routing protocols to your workstation.

C. The user's workstation is not connected to the network.

D. The web server is down.

17. You have implemented and tested a solution and identified any other effects the solution may have. What is your next step?

A. Create an action plan.

B. Close the case and head home for the day.

C. Reboot the Windows server.

D. Document the solution.

18. Users are reporting that they can access the Internet but not the internal company website. Which of the following is the most likely problem?

A. The DNS entry for the server is non-authoritative.

B. The intranet server is down.

C. The DNS address handed out by DHCP is incorrect.

D. The default gateway is incorrect.

19. Several users have complained about the server's poor performance as of late. You know that the memory installed in the server is sufficient. What could you use to determine the source of the problem?

A. Server's NIC link light

B. Protocol analyzer

C. Performance-monitoring tools

D. Server's system log file

20. You lose power to your computer room and the switches in your network do not come back up when everything is brought online. After you have identified the affected areas, established the cause, and escalated this problem, what do you do next?

A. Start to implement a solution to get those users back online ASAP.

B. Create an action plan and solution.

C. Meet with the emergency response team to determine the next step.

D. Copy all the working routers' configurations to the nonworking switches.

Chapter 20

Management, Monitoring, and Optimization

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Explain the concepts and characteristics of routing and switching.**

- QoS
- Diffserv
- CoS

- Software-defined networking

✓ **1.4 Given a scenario, configure the appropriate IP addressing components**

- Virtual IP

✓ **1.7 Summarize cloud concepts and their purposes**

- Types of services
  - SaaS
  - PaaS
  - IaaS
- Cloud delivery models
  - Private
  - Public
  - Hybrid
- Connectivity methods
- Security implications/considerations
- Relationship between local and cloud resources

✓ **2.4 Explain the purposes of virtualization and network storage technologies**

- Virtual networking components
  - Virtual switch
  - Virtual firewall
  - Virtual NIC
  - Virtual router
  - Hypervisor
- Jumbo Frame
- Network storage types
  - NAS
  - SAN
- Connection type
  - FCoE
  - Fibre Channel
  - iSCSI
  - InfiniBand

✓ **3.0 Given a scenario, use appropriate documentation and diagrams to manage the network.**

- Diagram symbols
- Standard operating procedures/work instructions
- Logical vs. physical diagrams
- Rack diagrams
- Change management documentation
- Wiring and port locations
- IDF/MDF documentation
- Labeling
- Network configuration and performance baselines
- Inventory management

✓ **3.2 Compare and contrast business continuity and disaster recovery concepts.**

- Availability concepts
  - Fault tolerance
  - High availability
  - Load balancing
  - Clustering
- Backups
  - Full
  - Differential
  - Incremental

✓ **3.3 Explain common scanning, monitoring and patching processes and summarize their expected outputs**

- Processes
  - Log reviewing
  - Patch management
    - Rollback
- Reviewing baselines

✓ **3.5 Identify policies and best practices**

- Privileged user agreement
- Password policy
- On-boarding/off-boarding procedures
- Licensing restrictions
- International export controls
- Data loss prevention
- Remote access policies
- Incident response policies
- BYOD
- AUP
- NDA
- System life cycle
  - Asset disposal
- Safety procedures and policies

✓ **4.6 Explain common mitigation techniques and their purposes**

- Honeypot/honeynet

If you didn’t just skip to the end of this book, you’ve trekked through enough material to know that without a doubt, the task of designing, implementing, and maintaining a state-of-the-art network doesn’t happen magically. Ending up with a great network requires some really solid planning before you buy even one device for it. And planning includes thoroughly analyzing your design for potential flaws and optimizing configurations everywhere you can to maximize the network’s future throughput and performance. If you blow it in this phase, trust me—you’ll pay dearly later in bottom-line costs and countless hours consumed troubleshooting and putting out the fires of faulty design.

Start planning by creating an outline that precisely delimits all goals and business requirements for the network, and refer back to it often to ensure that you don’t deliver a network that falls short of your client’s present needs or fails to offer the scalability to grow with those needs. Drawing out your design and jotting down all the relevant information really helps in spotting weaknesses and faults. If you have a team, make sure everyone on it gets to examine the design and evaluate it, and keep that network plan up throughout the installation phase. Hang on to it after implementation has been completed as well because having it is like having the keys to the kingdom—it will enable you to efficiently troubleshoot any issues that could arise after everything is in place and up and running.

High-quality documentation should include a baseline for network performance because you and your client need to know what “normal” looks like in order to detect problems before they develop into disasters. Don’t forget to verify that the network conforms to all internal and external regulations and that you’ve developed and itemized solid management procedures and security policies for future network administrators to refer to and follow.

I’ll begin this chapter by going over the fundamentals of things like plans, diagrams, baselines, rules, and regulations, and then move on to cover critical hardware and software utilities you should have in your problem resolution arsenal, like packet sniffers, throughput testers, connectivity packages, and even different types of event logs on your servers. And because even the best designs usually need a little boost after they’ve been up and running for a while, I’ll wrap things up by telling you about some cool ways you can tweak things to really jack up a network’s performance, optimize its data throughput, and, well, keep it all humming along as efficiently and smoothly as possible.

NOTE

MTo find Todd Lammle CompTIA videos and practice questions, please see `www.lammle.com/network+`.

Managing Network Documentation

I'll admit it—creating network documentation is one of my least favorite tasks in network administration. It just isn't as exciting to me as learning about the coolest new technology or tackling and solving a challenging problem. Part of it may be that I figure I know my networks well enough—after all, I installed and configured them, so if something comes up, it should be easy to figure it out and fix it, right? And most of the time I can do that, but as networks get bigger and more complex, it gets harder and harder to remember it all. Plus, it's an integral part of the service I provide for my clients to have seriously solid documentation in hand to refer to after I've left the scene and turned their network over to them. So while I'll admit that creating documentation isn't something I get excited about, I know from experience that having it around is critical when problems come up—for myself and for my clients' technicians and administrators, who may not have been part of the installation process and simply aren't familiar with the system.

Using SNMP

In Chapter 6, "Introduction to the Internet Protocol," I introduced you to Simple Network Management Protocol (SNMP), which is used to gather information from and send settings to devices that are SNMP compatible. Make sure to thoroughly review the differences between versions 1, 2, and 3 that we discussed there! Remember, I told you SNMP gathers data by polling the devices on the network from a management station at fixed or random intervals, requiring them to disclose certain information. This is a big factor that really helps to simplify the process of gathering information about your entire internetwork.

SNMP uses UDP to transfer messages back and forth between the management system and the agents running on the managed devices. Inside the UDP packets (called *datagrams*) are commands from the management system to the agent. These commands can be used either to get information from the device about its state (`SNMP GetRequest`) or to make a change in the device's configuration (`SetRequest`). If a `GetRequest` command has been sent, the device will respond with an `SNMP` response. If there's a piece of information that's particularly interesting to an administrator about the device, the administrator can set something called a *trap* on the device.

So, no whining! Like it or not, we're going to create some solid documentation. But because I'm guessing that you really don't want to redo it, it's a very good idea to keep it safe in at least three forms:

- An electronic copy that you can easily modify after configuration changes
- A hard copy in a binder of some sort, stored in an easily accessible location
- A copy on an external drive to keep in a really safe place (even off site) in case something happens to the other two or the building or part of it burns to the ground

So why the hard copy? Well, what if the computer storing the electronic copy totally crashes and burns at exactly the same time a major crisis develops? Good thing you have that paper documentation on hand for reference! Plus, sometimes you'll be troubleshooting on the run—maybe literally, as in running down the hall to the disaster's origin. Having that binder containing key configuration information on board could save you a lot of time and trouble, and it's also handy for making notes to yourself as you troubleshoot. Also, depending on the size of the intranet and the amount of people staffing the IT department, it might be smart to have several hard copies. Just always make sure they're only checked out by staff who are cleared to have them and that they're all returned to a secure location at the end of each shift. You definitely don't want that information in the wrong hands!

Now that I've hopefully convinced you that you absolutely must have tight documentation, let's take a look into the different types you need on hand so you can learn how to assemble them.

I'll cover schematics and diagrams next, and discuss baselines and policies, procedures, and regulations later when I cover network monitoring.

Schematics and Diagrams

Now reading network documentation doesn't exactly compete with racing your friends on jet skis, but it's really not that bad. It's better than eating canned spinach, and sometimes it's actually interesting to check out schematics and diagrams—especially when they describe innovative, elegant designs or when you're hunting down clues needed to solve an intricate problem with an elusive solution. I can't tell you how many times, if something isn't working between point A and point B, a solid diagram of the network that precisely describes exactly what exists between point A and point B has totally saved the day. Other times these tools come in handy is when you need to extend your network and you want a clear picture of how the expanded version will look and work. Will the new addition cause one part of the network to become bogged down while another remains underutilized? You get the idea.

Diagrams can be simple sketches created while brainstorming or troubleshooting on the fly. They can also be highly detailed, refined illustrations created with some of the snappy software packages around today, like Microsoft Visio, SmartDraw, and a host of computer-aided design (CAD) programs. Some of the more complex varieties, especially CAD programs, are super pricey. But whatever tool you use to draw pictures about your networks, they basically fall into these groups:

- Wiring diagrams/schematics
- Physical network diagrams
- Logical network diagrams

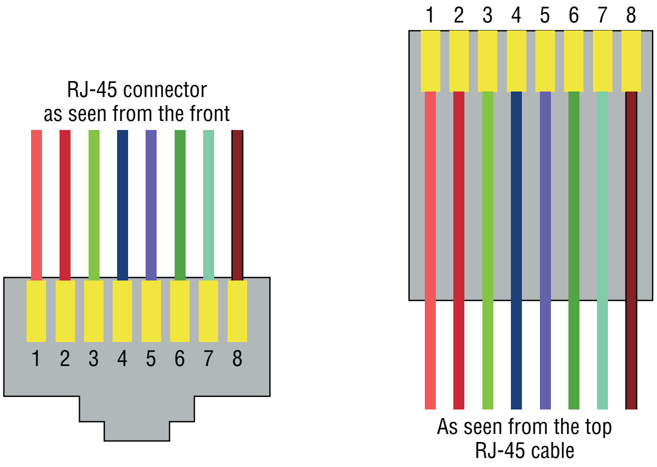
- Asset management
- IP address utilization
- Vendor documentation

Wiring Schematics

Wireless is definitely the wave of the future, but for now even the most extensive wireless networks have a wired backbone they rely on to connect them to the rest of humanity.

That skeleton is made up of cabled physical media like coax, fiber, and twisted pair. Surprisingly, it is the latter—specifically, unshielded twisted pair (UTP)—that screams to be pictured in a diagram. You'll see why in a minute. To help you follow me, let's review what we learned in Chapter 3, "Networking Topologies, Connectors, and Wiring Standards." We'll start by checking out Figure 20.1 (a diagram!) that pictures the fact that UTP cables use an RJ-45 connector (*RJ* stands for *registered jack*).

FIGURE 20.1 RJ-45 connector



What we see here is that pin 1 is on the left and pin 8 is on the right, so clearly, within your UTP cable, you need to make sure the right wires get to the right pins. No worries if you got your cables premade from the store, but making them yourself not only saves you a bunch of money, it allows you to customize cable lengths, which is really important! Table 20.1 matches the colors for the wire associated with each pin, based on the Electronic Industries Association and the Telecommunications Industry Alliance (EIA/TIA) 568B wiring standard.

TABLE 20.1 Standard EIA/TIA 568B wiring

Pin	Color
1	White/Orange
2	Orange
3	White/Green
4	Blue
5	White/Blue
6	Green
7	White/Brown
8	Brown

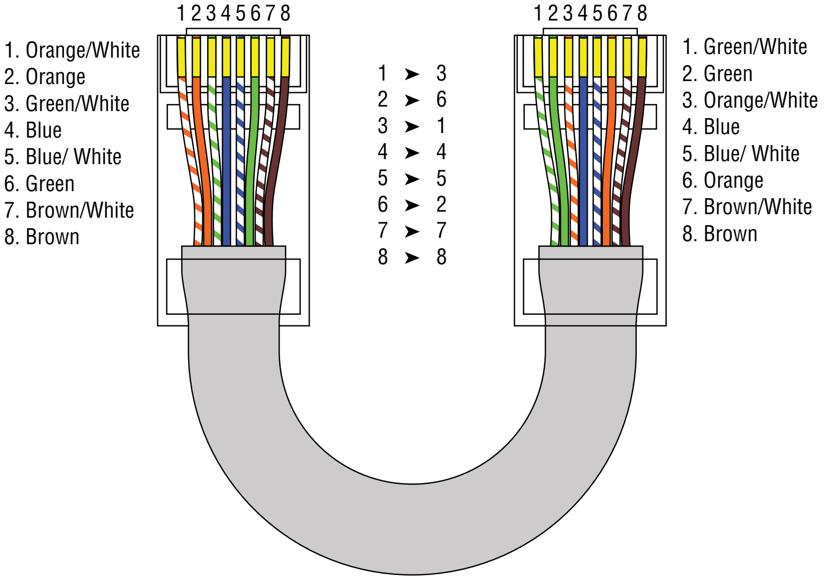
Standard drop cables, or *patch cables*, have the pins in the same order on both connectors. If you're connecting a computer to another computer directly, you should already know that you need a *crossover cable* that has one connector with flipped wires. Specifically, pins 1 and 3 and pins 2 and 6 get switched to ensure that the send port from one computer's Network Interface Card (NIC) gets attached to the receive port on the other computer's NIC. Crossover cables were also used to connect older routers, switches, and hubs through their uplink ports. Figure 20.2 shows you what this looks like.

NOTE

The crossover cable shown in Figure 20.2 is for connections up to 100BaseTX. If you are using 1000BaseT4, all four pairs of wires get crossed at the opposite end, meaning pins 4 and 7 and pins 5 and 8 get crossed as well. The Automatic MDI/MDI+ Configuration standard—an optional feature of the 1000BaseT standard—makes the need for crossover cables between gigabit-capable interfaces a thing of the past.

This is where having a diagram is golden. Let's say you're troubleshooting a network and discover connectivity problems between two hosts. Because you've got the map, you know the cable running between them is brand new and custom made. This should tell you to go directly to that new cable because it's likely it was poorly made and is therefore causing the snag.

FIGURE 20.2 Two ends of a crossover cable



Another reason it's so important to diagram all things wiring is that all wires have to plug into something somewhere, and it's really good to know what and where that is. Whether it's into a hub, a switch, a router, a workstation, or the wall, you positively need to know the who, what, where, when, and how of the way the wiring is attached.

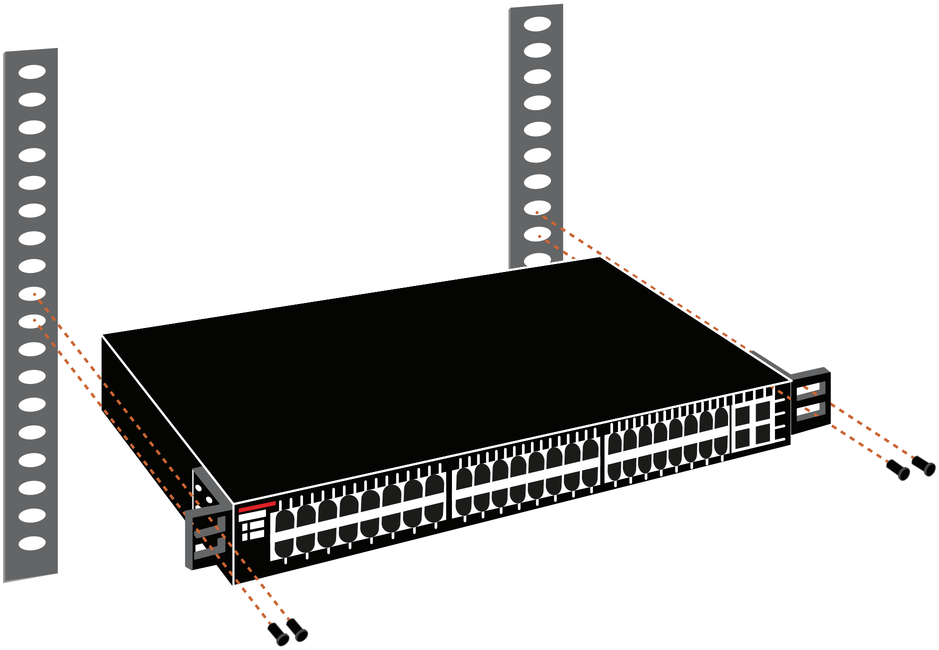
NOTE

After adding a new cable segment on your network, you need to update the wiring schematics.

For medium to large networks, devices like switches and routers are rack-mounted and would look something like the switch in Figure 20.3.

Knowing someone's or something's name is important because it helps us differentiate between people and things—especially when communicating with each other. If you want to be specific, you can't just say, "You know that router in the rack?" This is why coming up with a good naming system for all the devices living in your racks will be invaluable for ensuring that your wires don't get crossed.

FIGURE 20.3 Rack-mounted switches



Okay, I know it probably seems like we're edging over into OCD territory, but stay with me here; in addition to labeling, well, everything so far, you should actually label both ends of your cables, too. If something happens (earthquake, tsunami, temper tantrum, even repairs) and more than one cable gets unplugged at the same time, it can get really messy scrambling to reconnect them from memory—fast!

Physical Network Diagrams

A *physical network diagram* contains all the physical devices and connectivity paths on your network and should accurately picture how your network physically fits together in glorious detail. Again, I know it seems like overkill, but ideally, your network diagram should list and map everything you would need to completely rebuild your network from scratch if you had to. This is actually what this type of diagram is designed for. But there's still another physical network diagram variety that includes the firmware revision on all the switches and access points in your network. Remember, besides having your physical network accurately detailed, you must also clearly understand the connections, types of hardware, and their firmware revisions. I'm going to say it again—you will be so happy you have this documentation when troubleshooting! It will prevent much suffering and enable you to fix whatever the problem is so much faster!

Real World Scenario

Avoiding Confusion

Naming your network devices is no big deal, but for some reason, coming up with systems for naming devices and numbering connections can really stress people out.

Let me ease the pain. Let's say your network has two racks of switches, creatively named Block A and Block B. (I know this sounds like a prison, but it's just to keep things simple for this example. In the real world, you can come up with whatever naming system works for you.)

Anyway, I'm going to use the letters *FETH* for Fast Ethernet, and because each rack has six switches, I'm going to number them 1 through 6. Because we read from left to right in the West, it's intuitive to number the ports on each switch that way, too, but again, do what works best for you.

Having a solid naming system makes things so much more efficient—even if it's a bit of a hassle to create. For instance, if you were the system administrator in this example and suddenly all the computers connected to FETHB-3 couldn't access any network resources, you would have a pretty good idea of where to look first, right?

If you can't diagram everything for some reason, at least make sure all network devices are listed. As I said, physical network diagrams can run from simple, hand-drawn models to insanely complex monsters created by software packages like SmartDraw, Visio, and AutoCAD. Figure 20.4 shows a simple diagram that most of us could draw by hand.

FIGURE 20.4 Simple network physical diagram

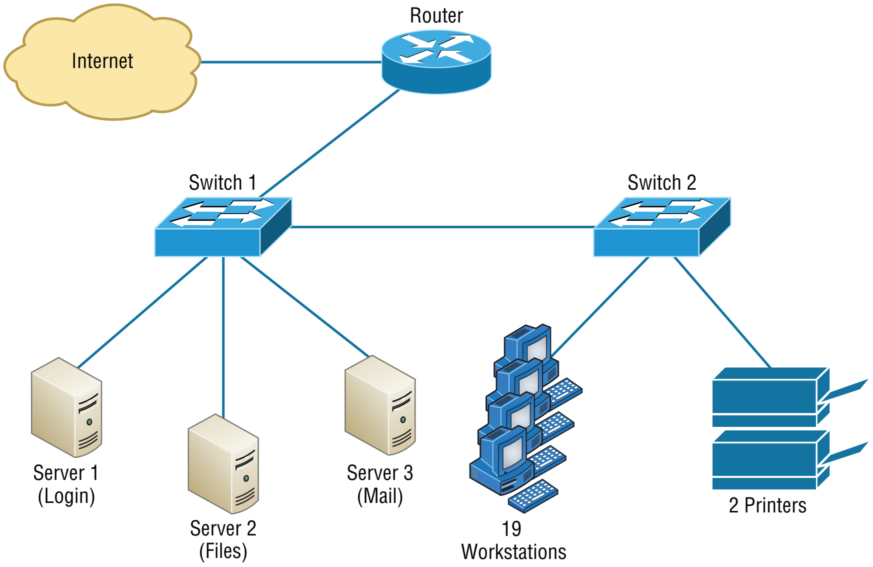
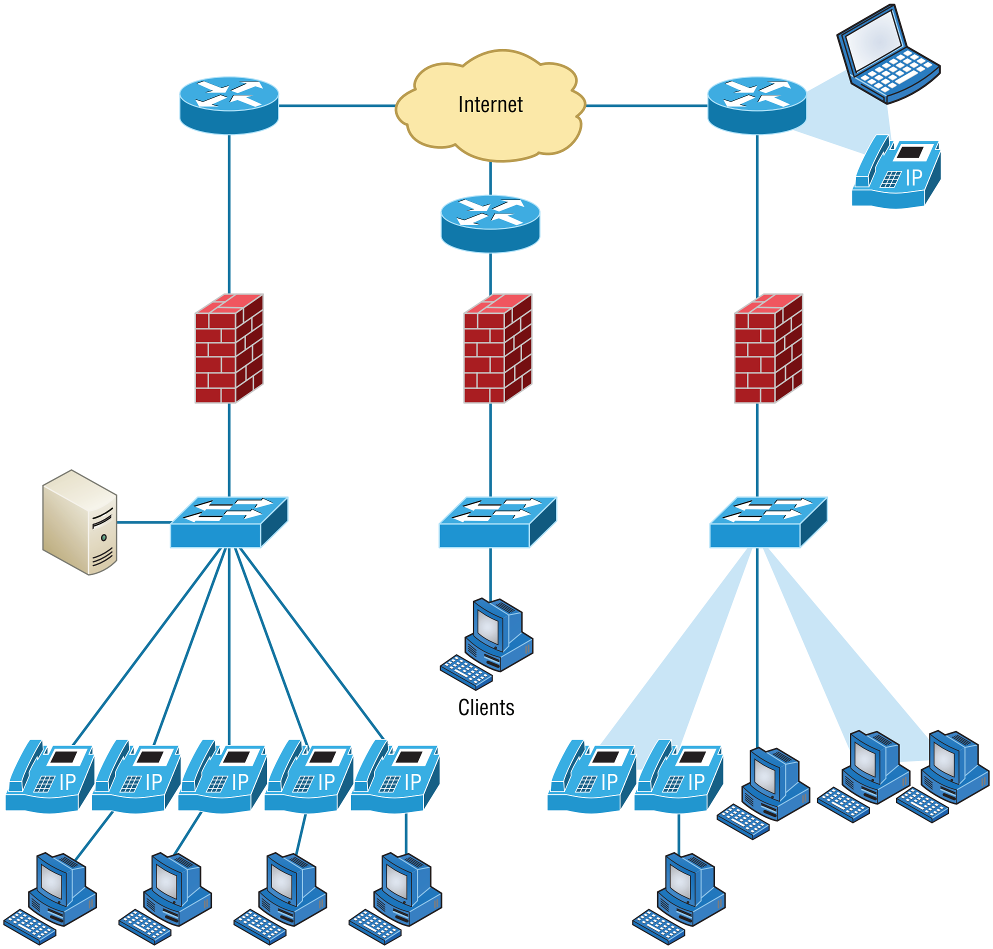


FIGURE 20.5 Network diagram with firewalls from SmartDraw

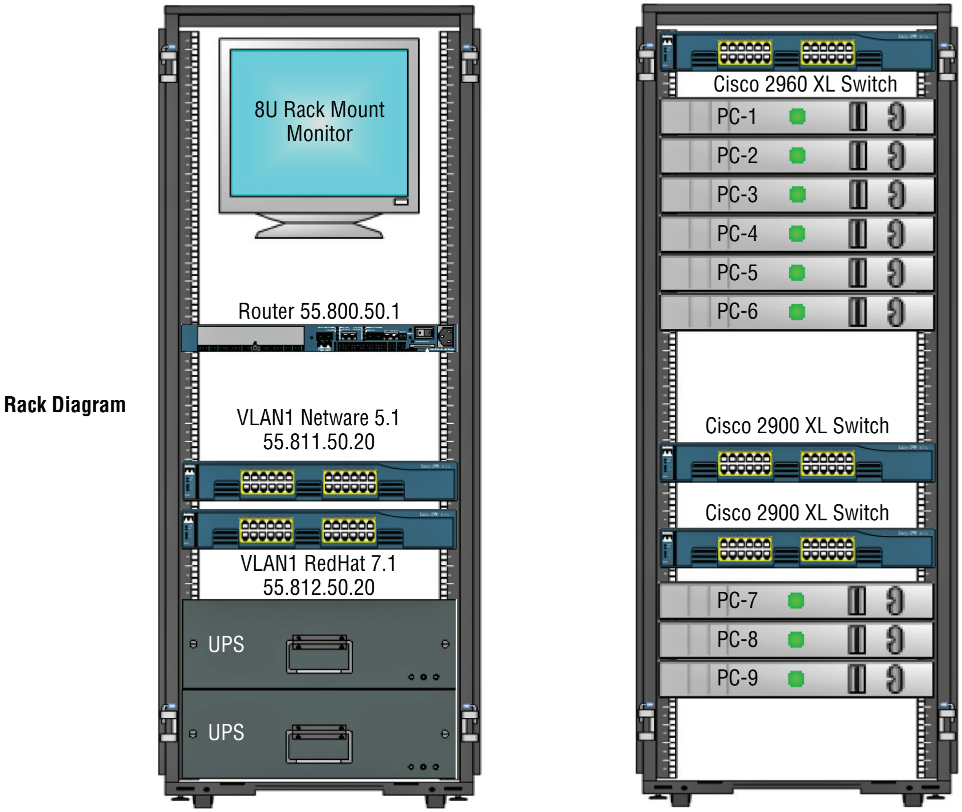


For the artistically impaired, or if you just want a flashier version, Figure 20.5 exhibits a more complex physical diagram. This is an actual sample of what SmartDraw can do for you, and you can get it at `www.smartdraw.com`. In addition, Microsoft Visio provides many, possibly more of these same functions.

My last example, also courtesy of SmartDraw, includes diagrams of hardware racks, as revealed in Figure 20.6.

Don't throw anything at me, but I need to bring up one last thing: Never forget to mirror any changes you make to your actual network in the network's diagram. Think of it like an updated snapshot. If you give the authorities your college buddy's baby picture after he goes missing, will that really help people recognize him as well as one taken just before

FIGURE 20.6 Hardware-rack diagram from SmartDraw



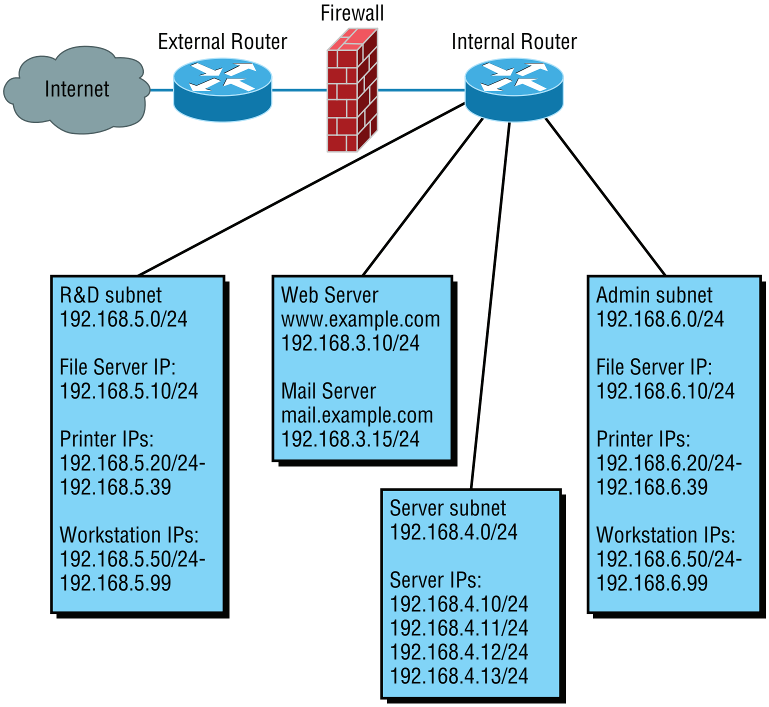
he disappeared? Because they don't make age progression software for networks, it's smart to just keep things up to date.

Logical Network Diagrams

Physical diagrams depict how data physically flows from one area of your network to the next, but a *logical network diagram* includes things like protocols, configurations, addressing schemes, access lists, firewalls, types of applications, and so on—all things that apply logically to your network. Figure 20.7 shows what a typical logical network diagram looks like.

Just as you mirror any physical changes you make to the physical network on your physical diagram, like adding devices or even just a cable, you map logical changes, such as creating a new subnet, VLAN, or security zone, on your logical network diagram. And it's equally vital that you keep this oh-so-important document up to date!

FIGURE 20.7 Logical network diagram



Asset Management

Asset management involves tracking all network assets like computers, routers, switches, and hubs through their entire life cycles. Most organizations find it beneficial to utilize asset identification numbers to facilitate this process. The ISO has established standards regarding asset management. The ISO 19770 family consists of four major parts:

- 19770-1 is a process-related standard that outlines best practices for IT asset management in an organization.
- 19770-2 is a standard for machine encapsulation (in the form of an XML file known as a SWID tag) of inventory data—allowing users to easily identify what software is deployed on a given device.
- 19770-3 is a standard that provides a schema for machine encapsulation of entitlements and rights associated with software licenses. The records (known as ENTs) will describe all entitlements and rights attendant to a piece of software and the method for measurement of license/entitlement consumption. This is still a draft.
- 19770-4 allows for standardized reporting of utilization of resources. This is crucial when considering complex data center license types and for the management of cloud-based software and hardware (software as a service, or SaaS, and infrastructure as a service, or IaaS). This is also still a draft.

IP Address Utilization

Documenting the current IP addressing scheme can also be highly beneficial, especially when changes are required. Not only is this really helpful to new technicians, it's very useful when identifying IP addressing issues that can lead to future problems. In many cases IP addresses are configured over a long period of time with no real thought or planning on the macro level.

Current and correct documentation can help administrators identify discontiguous networks (where subnets of a major network are separated by another major network) that can cause routing protocol issues. Proper IP address design can also facilitate summarization, which makes routing tables smaller, speeding the routing process. None of these wise design choices can be made without proper IP address documentation.

Vendor Documentation

Vendor agreements often have beneficial clauses that were negotiated during the purchase process. Many also contain critical details concerning SLAs and deadlines for warranties. These documents need to be organized and stored safety for future reference. Creating a spreadsheet or some other form of tracking documentation that alerts you of upcoming dates of interest can be a huge advantage!

Network Monitoring

Identifying performance issues within the network is only one of the reasons to perform structured monitoring. Security issues also require constant monitoring. In the following sections, we'll look into both types of monitoring and cover some of the best practices and guidelines for success.

Baselines

In networking, *baseline* often refers to the standard level of performance of a certain device, or to the normal operating capacity for your whole network. For instance, a specific server's baseline describes norms for factors like how busy its processors are, how much memory it uses, and how much data usually goes through the NIC at a given time.

A network baseline delimits the amount of bandwidth available and when. For networks and networked devices, baselines include information about four key components:

- Processor
- Memory
- Hard-disk (or other storage) subsystem
- Network adapter or subsystem

After everything is up and running, it's a good idea to establish performance baselines on all vital devices and for your network in general. To do this, measure things like network usage at three different strategic times to get an accurate assessment. For instance, peak usage usually happens around 8:00 a.m. Monday through Friday, or whenever most people log in to the network in the morning. After hours or on weekends is often when usage is the lowest. Knowing these values can help you troubleshoot *bottlenecks* or determine why certain system resources are more limited than they should be. Knowing what your baseline is can even tell you if someone's complaints about the network running like a slug are really valid—nice!

It's good to know that you can use network-monitoring software to establish baselines. Even some server operating systems come with software to help with network monitoring, which can help find baselines as well.

In my experience, it's wise to re-baseline network performance at least once a year. And always pinpoint new performance baselines after any major upgrade to your network's infrastructure.

Processes

When monitoring baselines there are processes that can be used to enhance the process. In this section we'll look at one particularly helpful process.

Log reviewing While regular log review is always recommended anyway, log review can have benefits when monitoring baselines. In some cases you may be able to identify a non-compliant device by the entries in its log or in the logs of infrastructure devices.

Patch Management issues In some cases, applying patches, especially device driver updates, can be problematic. Issues can include the device no longer working, loss of some key functionality or generation of odd error messages. When this occurs, you may want make use of the procedure covered in the next section.

Rollback While rollback is a general term that applies to reversing any operation about device drivers, it means to remove the newer driver and going back to using the previous driver. This is typically an available option if the last driver you used is the driver you want to which you want to roll back.

On-Boarding and Off-Boarding of Mobile Devices

Increasingly, users are doing work on their mobile devices that they once performed on laptops and desktop computers. Moreover, they are demanding that they be able to use their personal devices to work on the company network. This presents a huge security issue for the IT department because they have to secure these devices while simultaneously exercising much less control over them.

The security team must have a way to prevent these personal devices from introducing malware and other security issues to the network. Bring Your Own Device (BYOD) initiatives can be successful if implemented correctly. The key is to implement control over these personal devices that leave the safety of your network and return later after potentially being exposed to environments that are out of your control. One of the methods that has been employed successfully to accomplish this goal is network access control (NAC), covered in the next section.

NAC

Today's network access control goes beyond simply authenticating users and devices before they are allowed into the network. With the challenges presented by today's mobile workforce, it must go further. These services are called Network Admission Control in the Cisco world and Network Access Protection in the Microsoft world, but the goals of these features are the same: to examine all devices requesting network access for malware, missing security updates, and any other security issues any device could potentially introduce to the network.

In some cases network access control goes beyond simply denying access to systems that fail inspection. NAC can even redirect the failed system to a remediation server, which will then apply patches and updates before allowing the device access to the network. These systems can be especially helpful in supporting a BYOD initiative while still maintaining the security of the network.

Policies, Procedures, and Regulations

It's up to us, individually and corporately, to nail down exactly what solid guidelines there should be for *policies* and *procedures* for network installation and operation. Some organizations are bound by regulations that also affect how they conduct their business, and that kind of thing clearly needs to be involved in their choices. But let me take a minute to make sure you understand the difference between policies and procedures.

Policies govern how the network is configured and operated as well as how people are expected to behave on it. They're in place to direct things like how users access resources and which employees and groups get various types of network access and/or privileges. Basically, policies give people guidelines as to what they are expected to do. Procedures are precise descriptions of the appropriate steps to follow in a given situation, such as what to do when an employee is terminated or what to do in the event of a natural disaster. They often dictate precisely how to execute policies as well.

Of note, one of the most important aspects of any policy or procedure is that it's given high-level management support. This is because neither will be very effective if there aren't any consequences for not following the rules!

Policies

I talked extensively about security policies in Chapter 14, "Network Threats and Mitigation," so if you're drawing a blank, you can go back there for details. Here's a summary list of factors that most policies cover:

Security Policies These are policies applied to users to help maintain security in the network:

- Clean-desk policies: These policies are designed to prevent users from leaving sensitive documents on unattended desks.
- Network access (who, what, and how): These policies control which users can access which portions of the network. They should be designed around job responsibilities.
- Acceptable-use policies (AUP): These policies should be as comprehensive as possible and should outline every action that is allowed in addition to those that are *not* allowed. They should also specify which devices are allowed, which websites are allowed, and the proper use of company equipment.
- Consent to monitoring: These policies are designed to constantly remind users that their activities are subject to monitoring as they are using company equipment and as such they should have no expectation of privacy.

- Privileged user agreement: Whenever a user is given some right normally possessed by the administrator, they thus possess a privileged user account. In this agreement, they agree to use these rights responsibly.
- Password policy: This policy defines the requirements for all passwords, including length, complexity, and age.
- Licensing restrictions: These restrictions define the procedures used to ensure that all software license agreements are not violated.
- International export controls: in accordance with all agreements between countries in which the organization does business, all allowable export destinations and import sources are defined.
- Data loss prevention: This policy defines all procedures for preventing the egress of sensitive data from the network and may include references to the use of Data Loss Prevention (DLP) software.
- Remote access policies: These policies define the requirements for all remote access connections to the enterprise. This may cover VPN, dial-up and wireless access methods.
- Incident response policies: These policies define a scripted and repeatable process for responding to incidents and responsibilities of various roles in the network in this process.
- Nondisclosure agreement (NDA): All scenarios in which contractors and other third parties must execute a nondisclosure agreement are defined.
- System life cycle: The steps in the asset life cycle are defined, including acquisition, implementation, maintenance, and decommissioning. It specifies certain due diligence activities to be performed in each phase.
- Asset disposal: This is usually a subset of the system life cycle and prescribes methods of ensuring that sensitive data is removed from devices before disposal.

Change Management These policies ensure a consistent approach to managing changes to network configurations:

- Disposal of network equipment
- Use of recording equipment
- How passwords are managed (length and complexity required, and how often they need to be changed)
- Types of security hardware in place
- How often to do backups and take other fault-tolerant measures
- What to do with user accounts after an employee leaves the company

Procedures

These are the actions to be taken in specific situations:

- Disciplinary action to be taken if a policy is broken
- What to do during an audit

- How issues are reported to management
- What to do when someone has locked themselves out of their account
- How to properly install or remove software on servers
- What to do if files on the servers suddenly appear to be "missing" or altered
- How to respond when a network computer has a virus
- Actions to take if it appears that a hacker has broken into the network
- Actions to take if there is a physical emergency like a fire or flood

So you get the idea, right? For every policy on your network, there should be a credible related procedure that clearly dictates the steps to take in order to fulfill it. And you know that policies and procedures are as unique as the wide array of companies and organizations that create and employ them. But all this doesn't mean you can't borrow good ideas and plans from others and tweak them a bit to meet your requirements.

NOTE An example of a network access policy is a time-of-day restriction on logging into the network.

Standard Business Documents

In the course of supporting mergers and acquisitions, and in providing support to departments within the organization, it's always important to keep the details of agreements in writing to reduce the risk of misunderstandings. In this section, I'll discuss standard documents that are used in these situations. You should be familiar with the purpose of the following documents:

Statement of Work (SOW) This documents spells out all details concerning what work is to be performed, deliverables, and the timeline a vendor must execute in performance of specified work.

Memorandum of Understanding (MOU) This is an agreement between two or more organizations that details a common line of action. It is often used in cases where parties do not have a legal commitment or in situations where the parties cannot create a legally enforceable agreement. In some cases, it is referred to as a letter of intent.

Master License Agreement (MLA) This is an agreement whereby one party is agreeing to pay another party for the use of a piece of software for a period of time. These agreements, as you would expect, are pretty common in the IT world.

Service-Level Agreement (SLA) This is an agreement that defines the allowable time in which a party must respond to issues on behalf of the other party. Most service contracts are accompanied by an SLA, which often include security priorities, responsibilities, guarantees, and warranties.

Regulations

In contrast, *regulations* are rules imposed on your organization by an outside agency, like a certifying board or a government entity, and they're usually totally rigid and immutable. The list of possible regulations that your company could be subjected to is so exhaustively long, there's no way I can include them all in this book. Different regulations exist for different types of organizations, depending on whether they're corporate, nonprofit, scientific, educational, legal, governmental, and so on, and they also vary by where the organization is located.

For instance, US governmental regulations vary by county and state, federal regulations are piled on top of those, and many other countries have multiple regulatory bodies as well. The Sarbanes-Oxley Act of 2002 (SOX) is an example of a regulation system imposed on all publicly traded companies in the United States. Its main goal was to ensure corporate responsibility and sound accounting practices, and although that may not sound like it would have much of an effect on your IT department, it does, because a lot of the provisions in this act target the retention and protection of data. Believe me, something as innocent sounding as deleting old emails could get you in trouble—if any of them could've remotely had a material impact on the company's financial disclosures, deleting them could actually be breaking the law. All good to know, so be aware, and be careful!

I'm not going to give you a laundry list of regulations to memorize here, but I will tell you that IT regulations center around something known as the CIA triad:

- Confidentiality: Only authorized users have access to the data.
- Integrity: The data is accurate and complete.
- Availability: Authorized users have access to the data when access is needed.

One of the most commonly applied regulations is the ISO/IEC 27002 standard for information security, previously known as ISO 17799, renamed in 2007 and updated in 2013. It was developed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), and it is based on British Standard (BS) 7799-1:1999.

The official title of ISO/IEC 27002 is *Information technology - Security techniques - Code of practice for information security controls*. Although it's beyond our scope to get into the details of this standard, know that the following items are among the topics it covers:

- Risk assessment
- Security policy
- Organization of information security
- Asset management
- Human-resources security
- Physical and environmental security
- Communications and operations management
- Access control
- Information systems acquisition, development, and maintenance
- Information security incident management
- Business-continuity management
- Compliance

So, what do you take with you from this? Your mission is clear. Know the regulations your company is expected to comply with, and make sure your IT policies and procedures are totally in line with any regulations so it's easy for you to comply with them. No sense getting hauled off to jail because you didn't archive an email, right?

Safety Practices

In the course of doing business, it's the responsibility of the company to protect the safety of its workers, customers, vendors, and business partners. In the following sections, some of the issues that affect safety are considered, along with best practices and guidelines for preventing injuries and damage to equipment.

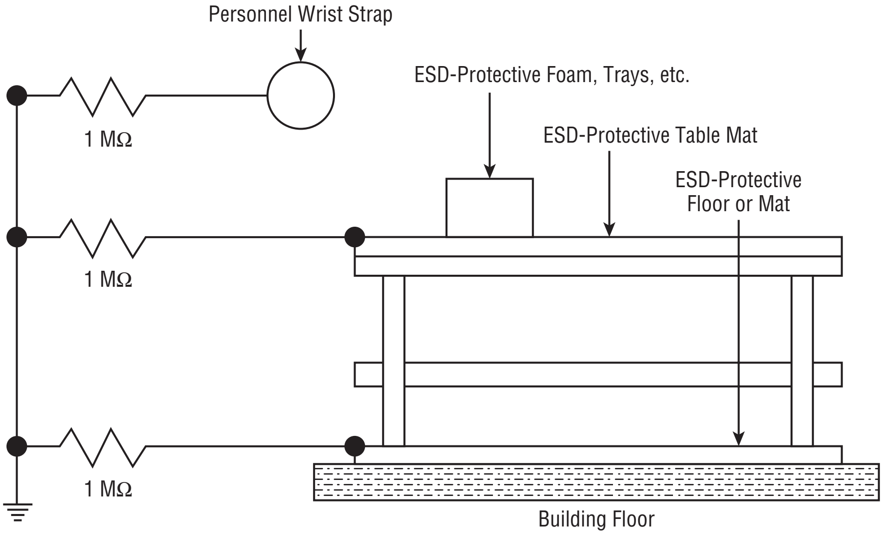
Electrical Safety

IT personnel spend a great deal of time dealing with electrical devices. Therefore, electrical safety should be stressed in all procedures. In this section, we'll look at key issues involved with electrical safety, relevant to preventing injuries and for preventing damage to computer equipment.

Grounding *Grounding* is the electrical term for providing a path for an electrical charge to follow to return to earth. To prevent injury to yourself when you are working with equipment, you should ensure that you are grounded. To avoid damaging the equipment with which you are working, it should also be grounded.

You can provide grounding to yourself or the equipment with either a grounding strap or a grounding mat. Either of these should be plugged into the ground of an electrical outlet. The way in which these devices are connected to ground is pictured in Figure 20.8.

FIGURE 20.8 Grounding methods



ESD *Electrostatic discharge (ESD)* is the technical term for what happens whenever two objects of dissimilar charge come in contact. ESD can be generated easily by walking across a carpeted floor. While the amount of ESD generated doing that may shock you if you touch a doorknob, it's really not enough to harm you. However, even that small amount is enough to seriously damage sensitive parts of computers.

This is exactly why we ground both ourselves and the equipment—to prevent ESD damage. Always use mats and straps to prevent damage when working with computing equipment.

Static When ESD is created, it's a form of static energy. Extremely dry conditions in the area where computers are utilized make the problem of static electricity worse. This is why the humidity of the area must be controlled so that it's not too humid, which causes corrosion of electrical connections, and not too dry, which causes static buildup and potential for damage.

Installation Safety

While protecting yourself from electrical injury is very important, it's not the only safety issue you've got to take into consideration. Other types of injuries can also occur, ranging from a simple pulled muscle to a more serious incident requiring a trip to the hospital. The following issues related to installing equipment should also be taken into consideration.

Lifting Equipment Oftentimes when a piece of equipment is being installed, the time pressures involved and the rush to "get 'er done" can lead to improper lifting. Always keep in mind these safe lifting techniques:

- Be careful to not twist when lifting. Keep the weight at the center of your body.
- Keep objects as close to your body as possible and at waist level.
- Lift with your legs, not your back. When you have to pick up something, bend at the knees, not at the waist. You want to maintain the natural curve of the back and spine when lifting.
- Whenever possible, push instead of pull.

Rack Installation Even for a small business, it's bad business to operate computing equipment in a poor environment such as on a shelf. There is a reason so many devices come "rack ready." Racks not only make for a neat and clean server room or closet, but when combined with proper cable management and environmental control, they provide an environment that allows the devices to breathe and stay cool.

When installing racks, always follow the manufacturer's directions and always use the correct tools! Countless screws have been ruined using the wrong tool.

Server racks are measured in terms of rack units, usually written as RU or simply U. One rack unit equals 1.75 inches (44.45 mm) in height, with compliant equipment measured in multiples of U. Network switches are generally 1U to 2U, servers can range from 1U to 4U, and blade servers can be anywhere from 5U to 10U or more.

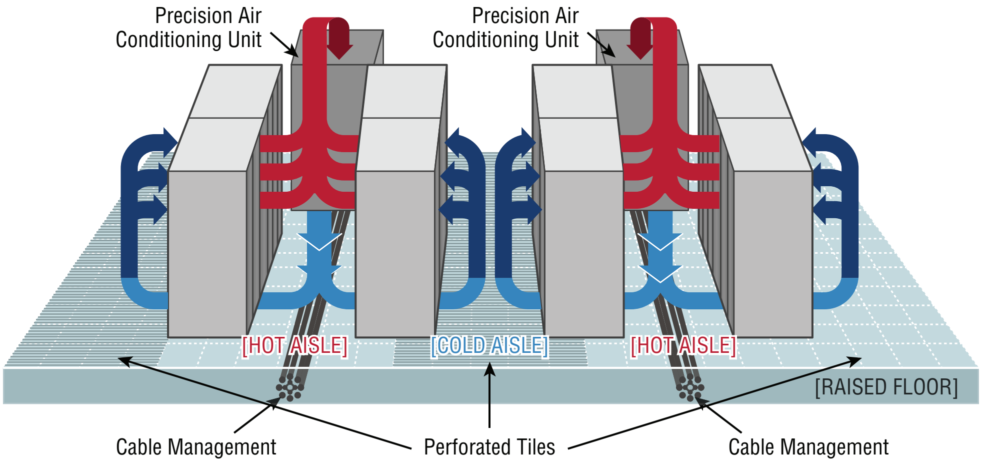
I'll cover the types of racks you're likely to encounter in more detail later in this chapter.

Placement The most important issue when placing devices is to ensure proper cooling and protection from moisture. It's a good idea to align the racks and install your equipment in hot and cold aisles. The goal of a hot aisle/cold aisle configuration is to conserve energy and lower cooling costs by managing air flow.

Hot aisle/cold aisle design involves lining up racks in alternating rows with cold air intakes facing one way and hot air exhausts facing the other. The rows composed of rack fronts are called cold aisles. Typically, cold aisles face air conditioner output ducts. The rows the heated exhausts pour into are called hot aisles and face air conditioner return ducts. Moreover, all of the racks and the equipment they hold should never be on the floor. There should be a raised floor to provide protection against water.

Figure 20.9 pictures a solid arrangement:

FIGURE 20.9 Hot and cold aisles



Tool safety It's worth mentioning again that the first step on safely using tools is to make sure you're properly grounded. Besides practicing tool safety for your own welfare, you should do so to protect the equipment. Here are some specific guidelines to follow:

- Avoid using pencils inside a computer. They can become a conductor and cause damage.
- Be sure that the tools you are using have not been magnetized. Magnetic fields can be harmful to data stored on magnetic media.
- When using compressed air to clean inside the computer, blow the air around the components with a minimum distance of 4 inches (10 centimeters) from the nozzle.
- Clean the contacts on components with isopropyl alcohol. Do not use rubbing alcohol.
- Never use a standard vacuum cleaner inside a computer case. The plastic parts of the vacuum cleaner can build up static electricity and discharge to the components. Use only vacuums that are approved for electronic components.

MSDS In the course of installing, servicing, and repairing equipment, you'll come in contact with many different types of materials. Some are safer than others. You can get all the information you need regarding the safe handling of materials by reviewing the Materials Safety Data Sheet (MSDS).

Any type of chemical, equipment, or supply that has the potential to harm the environment or people has to have an MSDS associated with it. These are traditionally created by the manufacturer and describe the boiling point, melting point, flash point, and potential health risks. You can obtain them from the manufacturer or from the Environmental Protection Agency.

Emergency Procedures

Every organization should be prepared for emergencies of all types. If possible, this planning should start with the design of the facility and its layout. In this section, I'll go over some of the components of a well-planned emergency system along with some guidelines for maintaining safety on a day-to-day basis.

Building Layout Planning for emergencies can start with the layout of the facility. Here are some key considerations:

- All walls should have a two-hour minimum fire rating.
- Doors must resist forcible entry.
- The location and type of fire suppression systems should be known.
- Flooring in server rooms and wiring closets should be raised to help mitigate flooding damage.
- Separate AC units must be dedicated to the information processing facilities.
- Backup and alternate power sources should exist.

Fire Escape Plan You should develop a plan that identifies the escape route in the event of a fire. You should create a facility map showing the escape route for each section of the building, keeping in mind that it's better to use multiple exits to move people out quickly. These diagrams should be placed in all areas.

Safety/Emergency Exits All escape routes on the map should have the following characteristics:

- Clearly marked and well lit
- Wide enough to accommodate the expected number of people
- Clear of obstructions

Fail Open/Fail Close Door systems that have electronic locks may lose power during a fire. When they do, they may lock automatically (fail close) or unlock automatically (fail open). While a fail close setting may enhance security during an electrical outage, you should consider the effect it will have during an evacuation and take steps to ensure that everyone can get out of the building when the time comes.

Emergency Alert System All facilities should be equipped with a system to alert all employees when a fire or any other type of emergency occurs. It might be advisable to connect the facility to the Emergency Alert System (EAS), which is a national warning system in the United States. One of the functions of this system is to alert the public of local weather emergencies such as tornadoes and flash floods. EAS messages are transmitted via AM and FM radio, broadcast television, cable television, and the Land Mobile Radio Service as well as VHF, UHF, and FiOS (wireline video providers).

Fire-Suppression Systems While fire extinguishers are important and should be placed throughout a facility, when large numbers of computing devices are present, it is worth the money to protect them with a fire-suppression system. The following types of systems exist:

- Wet pipe systems use water contained in pipes to extinguish the fire.
- Dry pipe systems hold the water in a holding tank instead of in the pipes.
- Preaction systems operate like a dry pipe system except that the sprinkler head holds a thermal-fusible link that must melt before the water is released.
- Deluge systems allow large amounts of water to be released into the room, which obviously makes this not a good choice where computing equipment will be located.
- Today, most companies use a fire-suppressant like Halon, which is known as a “Clean Agent, an electrically non-conducting, volatile, or gaseous fire extinguisher that does not leave a residue upon evaporation.” Leaving no residue means not rendering inoperative expensive networking equipment as water can do if released in a data center. It’s remarkably safe for human exposure, meaning that it won’t poison living things, and it will allow you to leave the area safely, returning only after the fire department gives the all-clear.

HVAC

The heating and air-conditioning systems must support the massive amounts of computing equipment deployed by most enterprises. Computing equipment and infrastructure devices like routers and switches do not like the following conditions:

- Heat. Excessive heat causes reboots and crashes.
- High humidity. It causes corrosion problems with connections.
- Low humidity. Dry conditions encourage static electricity, which can damage equipment.

Here are some important facts to know about temperature:

- At 100 degrees, damage starts occurring to magnetic media. In fact, floppy disks are the most susceptible.
- At 175 degrees, damage starts occurring to computers and peripherals.
- At 350 degrees, damage starts occurring to paper products.

Implementing Network Segmentation

Maintaining security in the network can be made easier by segmenting the network and controlling access from one segment to another. Segmentation can be done at several layers of the OSI model. The most extreme segmentation would be at Layer 1 if the networks are actually physically separated from one another. In other cases, it may be sufficient to segment a network at Layer 2 or Layer 3. Coming up next, we’ll look at some systems that require segmentation from other networks at one layer or another.

SCADA Systems/Industrial Control Systems

Industrial control system (ICS) is a general term that encompasses several types of control systems used in industrial production. The most widespread is Supervisory Control and Data Acquisition (SCADA). SCADA is a system operating with coded signals over communication channels to provide control of remote equipment. It includes the following components:

- Sensors, which typically have digital or analog I/O, and these signals are not in a form that can be easily communicated over long distances
- Remote terminal units (RTUs), which connect to the sensors and convert sensor data to digital data (includes telemetry hardware)
- Programmable logic controllers (PLCs), which connect to the sensors and convert sensor data to digital data (does not include telemetry hardware)
- Telemetry systems, which connect RTUs and PLCs to control centers and the enterprise
- Human interface, which presents data to the operator
- ICS server, also called a data acquisition server, which uses coded signals over communication channels to acquire information about the status of the remote equipment for display or for recording functions

The distributed control system (DCS) network should be a closed network, meaning it should be securely segregated from other networks. The Stuxnet virus hit the SCADA used for the control and monitoring of industrial processes.

Medianets

Medianets are networks primarily devoted to VoIP and video data that often require segmentation from the rest of the network at some layer. We implement segmentation for two reasons: first, to ensure the security of the data, and second, to ensure that the network delivers the high performance and low latency required by these applications. One such high-demand application is video teleconferencing (VTC), which I'll cover next.

Video Teleconferencing (VTC)

IP video has ushered in a new age of remote collaboration. This has saved a great deal of money on travel expenses and enabled more efficient use of time. When you're implementing IP video systems, consider and plan for the following issues:

- Expect a large increase in the need for bandwidth.
- QoS will need to be configured to ensure performance.
- Storage will need to be provisioned for the camera recordings.
- Initial cost may be high.

There are two types of VTC systems. Let's look at both:

ISDN The first VTC systems were ISDN based. These systems were based on a standard called H.320. While the bandwidth in each ISDN line is quite low by today's standard (128 Kbps per line), multiple lines could be combined or bonded.

IP/SIP VTC systems based on IP use a standard called H.323. Since these work on a packet-switched network, you don't need a direct ISDN link between the sites. Session Initiation Protocol can also be used, and it operates over IP but lacks many of the structured call control functions that H.323 provides.

Legacy Systems

Legacy systems are those that are older and incompatible with more modern systems and equipment. They may also be less secure and no longer supported by the vendor. In some cases, these legacy systems, especially with respect to industrial control systems, use propriety protocols that prevent them from communicating on the IP-based network. It's a good idea to segment these systems to protect them from security issues they aren't equipped to handle or even just to allow them to function correctly.

Separate Private/Public Networks

Public IP addressing isn't typically used in a modern network. Instead, private IP addresses are used and Network Address Translation services are employed to convert traffic to a public IP address when the traffic enters the Internet. While this is one of the strategies used to conserve the public IP address space, it also served to segment the private network from the public network (Internet). Hiding the actual IP address (private) of the hosts inside the network makes it very difficult to make an unsolicited connection to a system on the inside of the network from the outside.

Honeypot/Honeynet

Another segmentation tactic is to create honeypots and honeynets. Honeypots are systems strategically configured to be attractive to hackers and to lure them into spending enough time attacking them while information is gathered about the attack. In some cases, entire networks called honeynets are attractively configured for this purpose.

You need to make sure that either of these types of systems do not provide direct connections to any important systems. Their ultimate purpose is to divert attention from valuable resources and to gather as much information about an attack as possible. A tarpit is a type of honeypot designed to provide a very slow connection to the hacker so that the attack takes enough time to be properly analyzed.

Testing Lab

Testing labs are used for many purposes. Sometimes they're created as an environment for developers to test applications. They may also be used to test operating system patches and antivirus updates. These environments may even be virtual environments. Virtualization works well for testing labs because it makes it easier to ensure that the virtual networks have no physical connection to the rest of the network, providing necessary segmentation.

Security

One of the biggest reasons for implementing segmentation is for security purposes. At Layer 1, this means complete physical separation. However, if you don't want to go with complete segmentation, you can also segment at Layer 2 on switches by implementing VLANs and port security. This can prevent connections between systems that are connected to the same switch. They can also be used to organize users into common networks regardless of their physical location.

If segmentation at Layer 3 is required, it's achieved using access control lists on routers to control access from one subnet to another or from one VLAN to another. Firewalls can implement these types of access lists as well.

Compliance

Finally, network segmentation may be required to comply with an industry regulation. For example, while it's not strictly required, the Payment Card Industry Data Security Standard (PCI DSS) strongly recommends that the credit card network should be segmented from the regular network. If you choose not to do this, your entire network must be compliant with all sections of the standard.

Network Optimization

Regardless of how well a network is functioning, you should never stop trying to optimize its performance. This is especially true when latency-sensitive applications such as VoIP, streaming video, and web conferencing are implemented. In the next several sections, I'll discuss some techniques you can use to ensure that these applications and services deliver on their promise of increased functionality.

Reasons to Optimize Your Network's Performance

So why do we have networks, anyway? I don't mean this in a historical sense; I mean pragmatically. The reason they've become such precious resources is that as our world has become smaller and more connected, we need a way to keep in touch like never before. Networks make accessing resources easy for people who can't be in the same location as the resources they need—including other people.

In essence, networks of all types are really complex tools we use to facilitate communication from afar and to allow lots of us to access the resources we need to keep up with the demands imposed on us in today's lightning-paced world. And use them we do—a lot! And when we have many, many people trying to access one resource like a valuable file server or a shared database, our systems can get as bogged down and clogged as a freeway at rush hour. Just as road rage can result from driving on one of those not-so-expressways, frustrated people can direct some serious hostility at you if the same thing happens when they're trying to get somewhere using a network that's crawling along at snail speed.

This is why optimizing performance is in everyone's best interest—it keeps you and your network's users happily humming along. Optimization includes things like splitting up network segments, stopping unnecessary services on servers, offloading one server's work onto another, and upgrading outmoded hardware devices to newer, faster models. I'll get to exactly how to make all this happen coming up soon, but first, I'm going to talk about the theories behind performance optimization and even more about the reasons for making sure performance is at its best.

In a perfect world, there would be unlimited bandwidth, but in reality, you're more likely to find Bigfoot. So, it's helpful to have some great strategies up your sleeve.

If you look at what computers are used for today, there's a huge difference between the files we transfer now versus those transferred even three to five years ago. Now we do things like watch movies online without them stalling, and we can send huge email attachments. Video teleconferencing is almost more common than Starbucks locations. The point is that the files we transfer today are really large compared to what we sent back and forth just a few years ago. And although bandwidth has increased to allow us to do what we do, there are still limitations that cause network performance to suffer miserably. Let's start with a few reasons why you need to carefully manage whatever amount of precious bandwidth you've got.

Latency Sensitivity

Most of us have clicked to open an application or clicked a web link only to have the computer just sit there staring back at us, helplessly hanging. That sort of lag comes when the resources needed to open the program or take us to the next page are not fully available. That kind of lag on a network is called *latency*—the time between when data is requested and the moment it actually gets delivered. The more latency, the longer the delay and the longer you have to stare blankly back at your computer screen, hoping something happens soon.

Latency affects some programs more than others. If you are sending an email, it may be annoying to have to wait a few seconds for the email server to respond, but that type of delay isn't likely to cause physical harm to you or a loved one. Applications that are adversely affected by latency are said to have high *latency sensitivity*. A common example of this is online gaming. Although it may not mean actual life or death, playing certain online games with significant delays can mean the untimely demise of your character—and you won't even know it. Worse, it can affect the entire experience for those playing with you, which can get you booted from some game servers. On a much more serious level, applications like remote surgery also have high latency sensitivity.

High-Bandwidth Applications

Many of the applications we now use over the network would have been totally unserviceable in the past because of the high amount of bandwidth they consume. And even though technology is constantly improving to give us more bandwidth, developers are in hot pursuit, developing new applications that gobble up that bandwidth as soon as it becomes—even in advance of it becoming—available. A couple of good examples of high-bandwidth applications are VoIP and video streaming:

VoIP *Voice over Internet Protocol (VoIP)* describes several technologies that work to deliver voice communications over the Internet or other data networks. In many cases, VoIP includes not only voice but video transmissions as well. VoIP allows us to send voice, video, and data all over the same connection to another location. Its most common application is video teleconferencing.

Many companies are investing in VoIP systems to reduce travel costs. Ponying up for pricey plane tickets, lodging, and rental cars adds up fast, so investing in a good VoIP system that allows the company to have virtual conferences with people in another state or country pays for itself in no time.

But sadly, VoIP installations can be stressed heavily by things like really low bandwidth, latency issues, packet loss, jitter, security flaws, and reliability concerns. And in some cases, routing VoIP through firewalls and routers using address translation can prove pretty problematic as well.

Video Applications Watching real-time video on the Internet today is great if you have a decent high-speed connection. You can watch the news, sports, movies, and pretty much anything else that you watch on television. Although viewing digital media online is so common that anyone born after the year 2000 won't be able to remember a time when we had to watch videos on anything other than a computer, again, this requires lots of bandwidth. And excessive use can cause traffic problems even on the most robust networks!

Other Real-Time Services

While VoIP and video traffic certainly require the most attention with respect to performance and latency, other real-time services are probably in use in your network. We're going to briefly look at presence, another example of real-time services you may not give a lot of thought to, and then I'll compare the use of unicast and multicast in real-time services.

Presence Presence is a function provided by many collaboration solutions that indicates the availability of a user. It signals to other users whether a user is online, busy, in a meeting, and so forth. If enabled across multiple communication tools, such as IM, phone, email, and videoconferencing, it also can help determine the communication channel on which the user is currently active and therefore which channel provides the best possibility of an immediate response.

Multicast vs. Unicast Unicast transmissions represent a one-to-one conversation, that is, data sent from a single device to another single device. On the other hand, multicast is a technology that sends information for a single source to multiple recipients and is far superior to using unicast transmission when it comes to video streaming and conferencing.

While unicast transmission creates a data connection and stream for each recipient, multicast uses the same stream for all recipients. This single stream is replicated as needed by multicast routers and switches in the network. The stream is limited to branches of the network topology that actually have subscribers to the stream. This greatly reduces the use of bandwidth in the network.

Uptime

Uptime is the amount of time the system is up and accessible to your end users, so the more uptime you have the better. And depending on how critical the nature of your business is, you may need to provide four-nine or five-nine uptime on your network—that's a lot. Why is this a lot? Because you write out four-nine as 99.99 percent, or better, you write out five-nine as 99.999 percent! Now that is some serious uptime!

How to Optimize Performance

You now know that bandwidth is to networking as water is to life, and you're one of the lucky few if your network actually has an excess of it. Cursed is the downtrodden administrator who can't seem to find enough, and more fall into this category than the former. At times, your very sanity may hinge upon ensuring that your users have enough available bandwidth to get their jobs done on your network, and even if you've got a 1 Gbps connection, it doesn't mean all your users have that much bandwidth at their fingertips. What it really means is that they get a piece of it, and they share the rest with other users and network processes. Because it's your job to make sure as much of that 1 Gbps as possible is there to use when needed, I'm going to discuss some really cool ways to make that happen for you.

Quality of Service

Quality of Service (QoS) refers to the way the resources are controlled so that the quality of services is maintained. It's basically the ability to provide a different priority to one or more types of traffic over other levels for different applications, data flows, or users so that they can be guaranteed a certain performance level.

QoS methods focus on one of five problems that can affect data as it traverses network cable:

Delay Data can run into congested lines or take a less-than-ideal route to the destination, and delays like these can make some applications, such as VoIP, fail. This is the best reason to implement QoS when real-time applications are in use in the network—to prioritize delay-sensitive traffic.

Dropped Packets Some routers will drop packets if they receive them while their buffers are full. If the receiving application is waiting for the packets but doesn't get them, it will usually request that the packets be retransmitted—another common cause of a service(s) delay.

Error Packets can be corrupted in transit and arrive at the destination in an unacceptable format, again requiring retransmission and resulting in delays.

Jitter Not every packet takes the same route to the destination, so some will be more delayed than others if they travel through a slower or busier network connection. The variation in packet delay is called *jitter*, and this can have a nastily negative impact on programs that communicate in real time.

Out-of-Order Delivery Out-of-order delivery is also a result of packets taking different paths through the network to their destinations. The application at the receiving end needs to put them back together in the right order for the message to be completed, so if there are significant delays or the packets are reassembled out of order, users will probably notice degradation of an application's quality.

QoS can ensure that applications with a required bit rate receive the necessary bandwidth to work properly. Clearly, on networks with excess bandwidth, this is not a factor, but the more limited your bandwidth is, the more important a concept like this becomes.

DSCP

One of the methods that can be used for classifying and managing network traffic and providing Quality of Service (QoS) on modern IP networks is Differentiated Services Code Point (DSCP), or DiffServ. DiffServ uses a 6-bit differentiated services code point (DSCP) in the 8-bit Differentiated Services field (DS field) in the IP header for packet classification. This allows for the creation of traffic classes that can be used to assign priorities to various traffic classes.

In theory, a network could have up to 64 different traffic classes using different DSCPs, but most networks use the following traffic classifications:

- Default, which is typically best-effort traffic
- Expedited Forwarding (EF), which is dedicated to low-loss, low-latency traffic
- Assured Forwarding (AF), which gives assurance of delivery under prescribed conditions
- Class Selector, which maintains backward compatibility with the IP Precedence field (a field formerly used by the Type of Service, or TOS, function)

Class of Service (COS)

The second method of providing traffic classification and thus the ability to treat the classes differently is a 3-bit field called the Priority Code Point (PCP) within an Ethernet frame header when VLAN tagged frames as defined by IEEE 802.1Q are used.

This method is defined in the IEEE 802.1p standard. It describes eight different classes of service as expressed through the 3-bit PCP field in an IEEE 802.1Q header added to the frame. These classes are shown in Table 20.2.

TABLE 20.2 Eight levels of QoS

Level	Description
0	Best effort
1	Background
2	Standard (spare)

Level	Description
3	Excellent load (business-critical applications)
4	Controlled load (streaming media)
5	Voice and video (interactive voice and video, less than 100 ms latency and jitter)
6	Layer 3 Network Control Reserved Traffic (less than 10 ms latency and jitter)
7	Layer 2 Network Control Reserved Traffic (lowest latency and jitter)

QoS levels are established per call, per session, or in advance of the session by an agreement known as a service-level agreement (SLA).

Unified Communications

Increasingly, workers and the organizations for which they work are relying on new methods of communicating and working together. Unified communications (UC) is the integration of real-time communication services such as instant messaging with non-real-time communication services such as unified messaging (integrated voicemail, email, SMS, and fax). UC allows an individual to send a message on one medium and receive the same communication on another medium.

UC systems are made of several components that make sending a message on one medium and receiving the same communication on another medium possible. The following may be part of a UC system:

UC Servers The UC server is the heart of the system. It provides call control mobility services and administrative functions. It may be a stand-alone device or in some cases a module that is added to a router.

UC Devices UC devices are the endpoints that may participate in unified communications. This includes computers, laptops, tablets, and smartphones.

UC Gateways UC gateways are used to tie together geographically dispersed locations that may want to make use of UC facilities. They are used to connect the IP-based network with the Public Switched Telephone Network (PSTN).

Traffic Shaping

Traffic shaping, or packet shaping, is another form of bandwidth optimization. It works by delaying packets that meet a certain criteria to guarantee usable bandwidth for other applications. Traffic shaping is basically traffic triage—you're really just delaying attention to some traffic so other traffic gets A-listed through. Traffic shaping uses *bandwidth throttling* to ensure that certain data streams don't send too much data in a specified period of time as well as *rate limiting* to control the rate at which traffic is sent.

Most often, traffic shaping is applied to devices at the edge of the network to control the traffic entering the network, but it can also be deployed on devices within an internal network. The devices that control it have what's called a *traffic contract* that determines which packets are allowed on the network and when. You can think of this kind of like the stoplights on busy freeway on-ramps, where only so much traffic is allowed onto the road at one time, based on predefined rules. Even so, some traffic (like carpools and emergency vehicles) is allowed on the road immediately. Delayed packets are stored in the managing device's first-in, first-out (FIFO) buffer until they're allowed to proceed per the conditions in the contract. If you're the first car at the light, this could happen immediately. If not, you get to go after waiting briefly until the traffic in front of you is released.

Load Balancing

Load balancing refers to a technique used to spread work out to multiple computers, network links, or other devices.

Using load balancing, you can provide an active/passive server cluster in which only one server is active and handling requests. For example, your favorite Internet site might actually consist of 20 servers that all appear to be the same exact site because that site's owner wants to ensure that its users always experience quick access. You can accomplish this on a network by installing multiple, redundant links to ensure that network traffic is spread across several paths and to maximize the bandwidth on each link.

Think of this as like having two or more different freeways that will both get you to your destination equally well—if one is really busy, just take the other one.

High Availability

High availability is a system-design protocol that guarantees a certain amount of operational uptime during a given period. The design attempts to minimize unplanned downtime—the time users are unable to access resources. In almost all cases, high availability is provided through the implementation of duplicate equipment (multiple servers, multiple NICs, etc.). Organizations that serve critical functions obviously need this; after all, you really don't want to blaze your way to a hospital ER only to find that they can't treat you because their network is down!

NOTE

There's a difference between planned downtime and unplanned downtime. Planned downtime is good—it's occasionally scheduled for system maintenance and routine upgrades. Unplanned downtime is bad: It's a lack of access due to system failure, which is exactly the issue high availability resolves.

One of the highest standards in uptime is the ability to provide the five-nine availability I mentioned earlier. This actually means the network is accessible 99.999 percent of the time—way impressive! Think about this. In one non-leap year, there are 31,536,000 seconds. If you are available 99.999 percent of the time, it means you can be down only 0.001 percent of the time, or a total of 315.36 seconds, or 5 minutes and 15.36 seconds per year—wow!

NOTE There's a difference between uptime and availability. Your servers may be up but not accessible if a cable gets cut or something, and that outage would definitely count against your availability time.

Caching Engines

A *cache* is a collection of data that duplicates key pieces of original data. Computers use caches all the time to temporarily store information for faster access, and processors have both internal and external caches available to them, which speeds up their response times.

A *caching engine* is basically a database on a server that stores information people need to access fast. The most popular implementation of this is with web servers and proxy servers, but caching engines are also used on internal networks to speed up access to things like database services.

Fault Tolerance

Fault tolerance means that even if one component fails, you won't lose access to the resource it provides. To implement fault tolerance, you need to employ multiple devices or connections that all provide a way to access the same resource(s).

A familiar form of fault tolerance is configuring an additional hard drive to be a mirror image of another so that if either one fails, there's still a copy of the data available to you. In networking, fault tolerance means that you have multiple paths from one point to another. What's really cool is that fault-tolerant connections can be configured to be available either on a standby basis only or all the time if you intend to use them used as part of a load-balancing system.

Archives/Backups

While providing redundancy to hardware components is important, the data that resides on the components must also be archived in case a device where the data is stored has to be replaced. It could be a matter of replacing a hard drive on which the data cannot be saved and restoring the data from tape backup. Or suppose RAID has been enabled in a system; in that case, the loss of a single hard drive will not present an immediate loss of access to the data (although a replacement of the bad drive will be required to recover from another drive failure). RAID systems are covered in more detail in Chapter 15, "Physical Security and Risk."

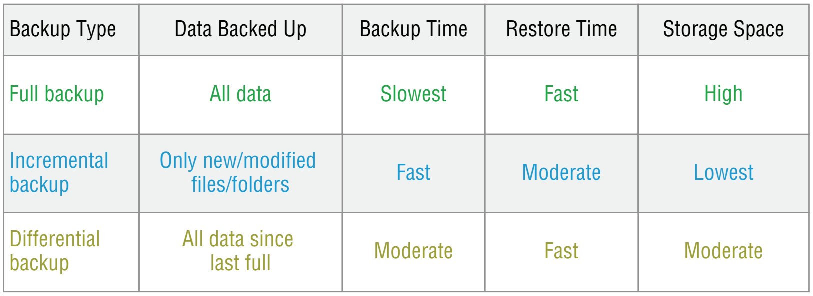
With regard to the data backups, they must be created on a schedule and tested regularly to ensure that a data restoration is successful. The three main data backup types are full backups, differential backups, and incremental backups. But to understand them, you must grasp the concept of archive bits. When a file is created or updated, the archive bit for the file is enabled. If the archive bit is cleared, the file will not be archived during the next backup. If the archive bit is enabled, the file will be archived during the next backup.

The end result is that each type of backup differs in the amount of time taken, the amount of data backed up, whether unchanged data is backed up repeatedly, and the number of tapes required to restore the data. Keep these key facts in mind:

- If you use a full back up once a week and differential backups the other days of the week, to restore you will only need the last full backup tape and the last differential tape. This is the fastest restore.
- If you use a full back up once a week and incremental backups the other days of the week, to restore you will need the last full backup tape and all of the incremental tapes. This is the slowest restore.

A comparison of the three main backup types is shown in Figure 20.10.

FIGURE 20.10 Backup types



Backup Type	Data Backed Up	Backup Time	Restore Time	Storage Space
Full backup	All data	Slowest	Fast	High
Incremental backup	Only new/modified files/folders	Fast	Moderate	Lowest
Differential backup	All data since last full	Moderate	Fast	Moderate

Common Address Redundancy Protocol

Common Address Redundancy Protocol (CARP) provides IP-based redundancy, allowing a group of hosts on the same network segment (referred to as a *redundancy group*) to share an IP address. One host is designated the *master* and the rest are *backups*. The master host responds to any traffic or ARP requests directed toward it. Each host may belong to more than one redundancy group at a time.

One of its most common uses is to provide redundancy for devices such as firewalls or routers. The virtual IP address (this is another name for the shared group IP address) will be shared by a group of routers or firewalls.

The client machines use the virtual IP address as their default gateway. In the event that the master router suffers a failure or is taken offline, the IP will move to one of the backup routers and service will continue. Other protocols that use similar principles are Virtual Router Redundancy Protocol and the Hot Standby Router Protocol.

Virtual Networking

Over the last few years, one of the most significant developments helping to increase the efficient use of computing resources—leading to an increase in network performance without an increase in spending on hardware—has been the widespread adoption of virtualization technology. You can't read an industry publication without coming across the term *cloud computing* within 45 seconds!

The concept of virtualization is quite simple. Instead of dedicating a physical piece of hardware to every server, run multiple instances of the server operating system, each in its own "virtual environment" on the same physical piece of equipment. This saves power, maximizes the use of memory and CPU resources, and can even help to "hide" the physical location of each virtual server.

Virtual computing solutions come from a number of vendors. The following are some of the more popular currently:

- VMware vSphere
- Microsoft Hyper-V
- Citrix XenServer

All of these solutions work on the same basic concept but each has its own unique features, and of course all claim to be the best solution. In the following sections, I will discuss the building blocks of virtualization rather than the specific implementation from any single vendor.

On Site vs. Off Site

Often you hear the terms *public cloud* and *private cloud*. *Clouds* can be thought of as virtual computing environments where virtual servers and desktops live and can be accessed by users. A private cloud is one in which this environment is provided to the enterprise by a third party for a fee. This is a good solution for a company that has neither the expertise nor the resources to manage their own cloud yet would like to take advantage of the benefits that cloud computing offers:

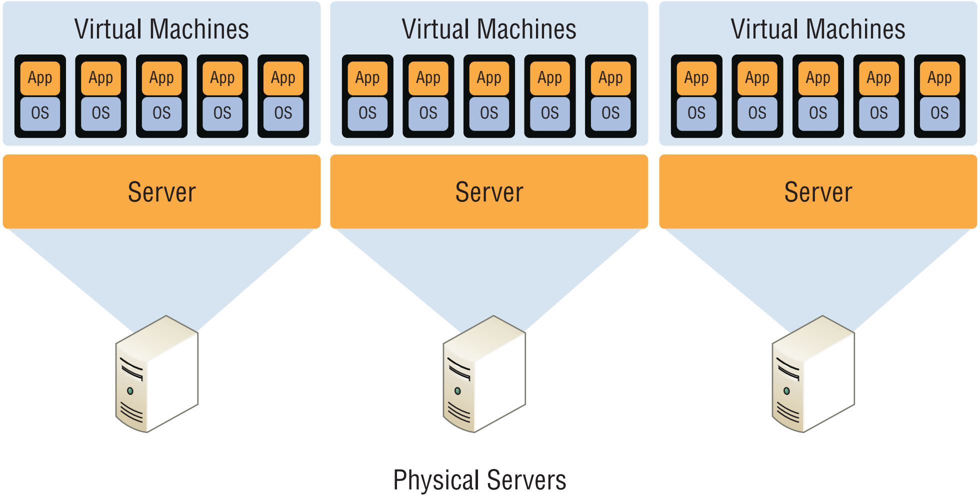
- Increased performance
- Increased fault tolerance
- Constant availability
- Access from anywhere

These types of clouds might be considered off site or public. On the other hand, for the organization that has the expertise and resources, a private or onsite solution might be better and might be more secure. This approach will enjoy the same benefits as a public cloud and may offer more precise control and more options to the organization.

Virtual Networking Components

The foundation of virtualization is the host device, which may be a workstation or a server. This device is the physical machine that contains the software that makes virtualization possible and the containers or virtual machines for the guest operating systems. The host provides the underlying hardware and computing resources, such as processing power, memory, and disk and network I/O to the VMs. Each guest is a separate and independent instance of an operating system and application software. From a high level, the relationship is shown in Figure 20.11.

FIGURE 20.11 Guests and hosts



Virtualization can be deployed in several different ways to deliver cost-effective solutions to different problems. Each of the following components can have its place in the solution:

Hypervisor The host is responsible for allocating compute resources to each of the VMs as specified by the configuration. The software that manages all of this is called the *hypervisor*. Based on parameters set by the administrator, the hypervisor may take various actions to maintain the performance of each guest as specified by the administrator. This may include the following actions:

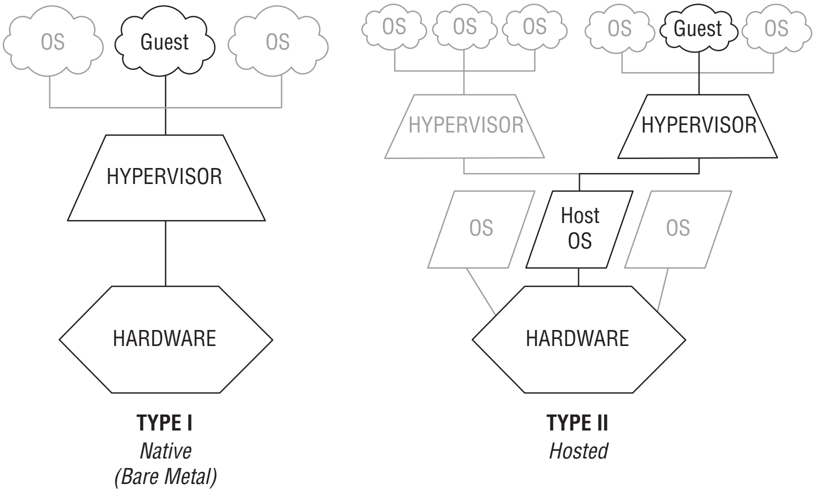
- Turning off a VM not in use
- Taking CPU resources away from one VM and allocating them to another
- Turning on additional VMs when required to provide fault tolerance

The exact nature of the relationship between the hypervisor, the host operating system, and the guest operating systems depends on the type of hypervisor in use. There are two types of hypervisors in use today. Let's review both of these.

Type I A Type I hypervisor (or native, bare metal) runs directly on the host's hardware to control the hardware and to manage guest operating systems. A guest operating system runs on another level above the hypervisor. Examples of these are VMware vSphere and Microsoft Hyper-V.

Type II A Type II hypervisor runs within a conventional operating system environment. With the hypervisor layer as a distinct second software level, guest operating systems run at the third level above the hardware. VMware Workstation and Virtual Box exemplify Type II hypervisors. A comparison of the two approaches is shown in Figure 20.12.

FIGURE 20.12 Hypervisors



Virtual Servers Virtual servers can perform all the same functions as physical servers but can enjoy some significant advantages. By clustering a virtual server with other virtual servers located on different hosts, you can achieve fault tolerance in the case of a host failure. Increased performance can also be derived from this approach.

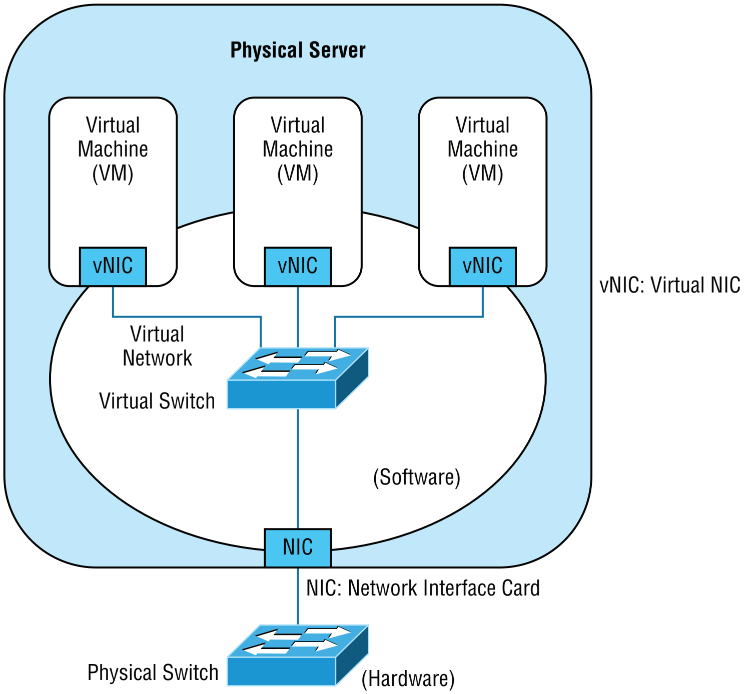
The virtualization software can allow you to allocate CPU and memory resources to the virtual machines (VMs) dynamically as needed to ensure that the maximum amount of computing power is available to any single VM at any moment while not wasting any of that power on an idle VM. In fact, in situations where VMs have been clustered, they may even be suspended or powered down in times of low demand in the cluster.

Virtual Switches Virtual switches are software versions of a Layer 2 switch that can be used to create virtual networks. They can be used for the same purposes as physical switches. VLANs can be created, virtual servers can be connected to the switches, and the virtual network can be managed, all while residing on the same physical box. These switches can also span multiple hosts (the physical machines that house multiple virtual servers, desktops, and switches are called hosts).

Distributed virtual switches are those switches that span multiple hosts, and they are what link together the VMs that are located on different hosts yet are members of the same cluster.

Virtual vs. Physical NICs Figure 20.13 shows the relationship between a physical server and the virtual servers and virtual switches that it hosts. The virtual servers, called virtual machines (VMs), have virtual network cards (vNICs) that connect to the virtual switch. Keep in mind that all three of these components are software running on the same physical server. Then the virtual switch makes a software connection to the physical NIC on the physical host, which makes a physical connection to the physical switch in the network.

FIGURE 20.13 Virtualization



It is interesting to note and important to be aware of the fact that the IP address of the physical NIC in Figure 20.13 will actually be transmitting packets from multiple MAC addresses since each of the virtual servers will have a unique virtual MAC address.

Virtual Routers In virtualized environments, virtual routers are typically implemented as specialized software. They consist of individual routing and forwarding tables, each of which could be considered a virtual router.

Virtual Firewall Virtual firewalls are also implemented as software in the virtualized environment. Like their physical counterparts, they can be used to restrict traffic between virtual subnets created by virtual routers.

Software-Defined Networking Software-defined networking (SDN) is an approach to computer networking that allows network administrators to manage network services through abstraction of lower-level functionality. SDN architectures decouple network control and forwarding functions, enabling network control to become directly programmable and the underlying infrastructure to be abstracted from applications and network services.

Virtual Desktops Using operating system images for desktop computers is not a new concept. Delivering these desktop images to users from a virtual environment when they start their computer is. This allows for the user desktop to require less computing power, especially if the applications are also delivered virtually and those applications are running in a VM in the cloud rather than in the local desktop eating up local resources. Another benefit of using virtual desktops is the ability to maintain a consistent user environment (same desktop, applications, etc.), which can enhance user support.

Thin computing takes this a step further. In this case, all of the computing is taking place on the server. A *thin client* is simply displaying the output from the operating system running in the cloud, and the keyboard is used to interact with that operating system in the cloud. Does this sound like dumb terminals with a GUI to anyone yet? Back to the future indeed! The thin client needs very little processing power for this job.

Virtual PBX Virtual PBX is an example of what is called *software as a service* (SaaS). A hosting company manages the entire phone system for the company, freeing the organization from the need to purchase and manage the physical equipment that would be required otherwise to provide the same level of service. To the outside world, the company appears to have a professional phone system while everything is actually being routed through the hosting company's system.

Network as a Service (NaaS) Now that you know what SaaS is you can probably guess what NaaS is. You guessed it: a network hosted and managed by a third party on behalf of the company. For many enterprises, it makes more sense to outsource the management of the network to a third party when it is not cost effective to maintain a networking staff.

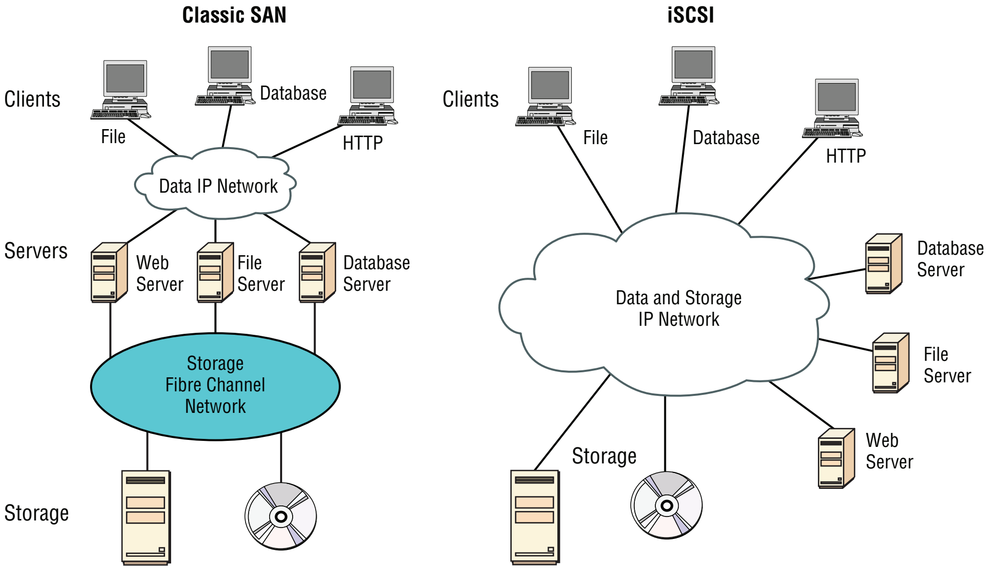
An example of this is the Cisco OpenStack cloud operating system, which is an open-source platform that provides computers and storage.

Storage Area Network

Storage area networks (SANs) comprise high-capacity storage devices that are connected by a high-speed private network (separate from the LAN) using a storage-specific switch. This storage information architecture addresses the collection of data, management of data, and use of data. In this section, we'll take a look at the protocols that can be used to access the data and the client systems that can use those various protocols. We'll also look at an alternative to a SAN, network-attached storage (NAS).

iSCSI Internet Small Computer System Interface (iSCSI) is an IP-based networking storage standard method of encapsulating SCSI commands (which are used with storage area networks) within IP packets. This allows the use of the same network for storage as is used for the balance of the network. A comparison of a regular SAN that uses the Fibre-Channel protocol, and one using iSCSI is shown in Figure 20.14. I'll talk more about Fiber Channel in a bit.

FIGURE 20.14 Classic SAN vs. iSCSI



InfiniBand InfiniBand is a communications standard that provides high performance and low latency. It is utilized as a direct, or switched, interconnect between servers and storage systems as well as an interconnect between storage systems. It uses a switched fabric topology. The adaptors can exchange information on QoS.

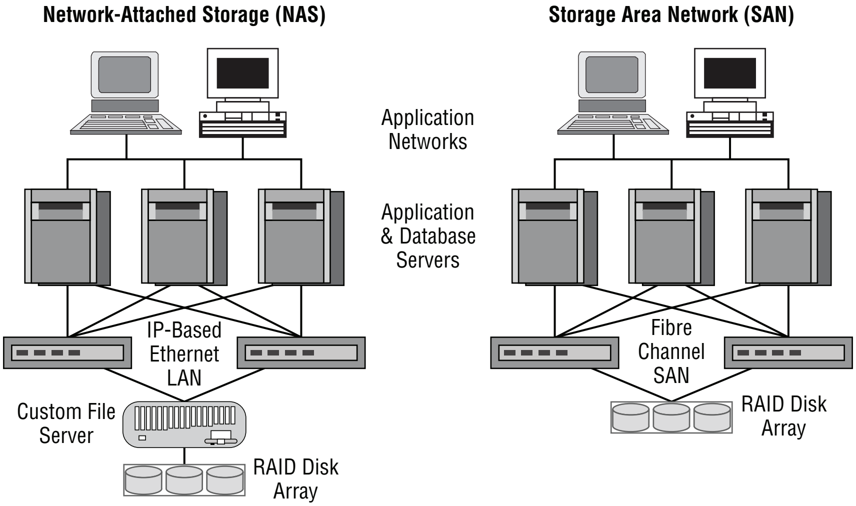
Fiber Channel Fiber Channel, or FC, is a high-speed network technology (commonly running at 2, 4, 8, and 16 gigabit per second rates) primarily used to connect computer data storage. It operates on an optical network that is not compatible with the regular IP-based data network. As you can see in Figure 20.14, this protocol runs on a private network that connects the servers to the storage network.

Fibre-Channel over Ethernet (FCoE), on the other hand, encapsulates Fiber Channel traffic within Ethernet frames much like iSCSI encapsulates SCSI commands in IP packets. However, unlike iSCSI, it does not use IP at all. It does allow this traffic on the IP network.

Jumbo Frames Jumbo frames are Ethernet frames with more than 1,500 bytes of payload. Jumbo frames with more than 9,000-byte payloads have the potential to reduce overhead and CPU cycles. In high-speed networks such as those typically used in a SAN, it may be advisable to enable jumbo frames to improve performance.

Network-Attached Storage Network-attached storage (NAS) serves the same function as SAN, but clients access the storage in a different way. In a NAS configuration, almost any machine that can connect to the LAN (or is interconnected to the LAN through a WAN) can use protocols such as NFS, CIFS, and HTTP to connect to the NAS and share files. In a SAN configuration, only devices that can use the Fiber Channel SCSI network can access the data, so it's typically done though a server with this capability. A comparison of the two systems is shown in Figure 20.15.

FIGURE 20.15 NAS and SAN



Cloud Concepts

Cloud storage locates the data on a central server, but unlike with an internal data center in the LAN, the data is accessible from anywhere and in many cases from a variety of device types. Moreover, cloud solutions typically provide fault tolerance and dynamic computer resource (CPU, memory, network) provisioning.

Cloud deployments can differ in two ways:

- The entity that manages the solution
- The percentage of the total solution provided by the vendor

First, let's look at the options relative to the entity that manages the solution:

- **Private cloud**: This is a solution owned and managed by one company solely for that company's use.
- **Public cloud**: This is a solution provided by a third party. It offloads the details to the third party but gives up some control and can introduce security issues.

- **Hybrid cloud**: This is some combination of private and public. For example, perhaps you only use the facilities of the provider but still manage the data yourself.
- **Community cloud**: This is a solution owned and managed by a group of organizations that create the cloud for a common purpose.

There are several levels of service that can be made available through a cloud deployment:

- **Infrastructure as a service (IaaS)**. The vendor provides the hardware platform or data center, and the company installs and manages its own operating systems and application systems.
- **Platform as a service (PaaS)**. The vendor provides the hardware platform or data center and the software running on the platform.
- **Software as a service (SaaS)**. The vendor provides the entire solution. This includes the operating system, infrastructure software, and the application.

Connectivity Methods

When connecting to a virtual server that is in a cloud environment, there are several ways to make this connection:

- Virtual Private Network (VPN) connections: This is the most direct way to connect. An example is the Amazon Web Services (AWS) Virtual Private Cloud (VPC) that will set up a VPN connection between your entire enterprise network and its cloud.
- Remote Desktop: While the VPN connection connects you to the virtual network, an RDP connection can be directly to a server. If the server is Windows, then you will use the Remote Desktop client. If the server is Linux, then the connection will most likely be an SSH connection to the command line.
- File Transfer Protocol (FTP): The FTP server will need to be enabled on the server and then you can use the FTP client or work at the command line. This is best when performing bulk data downloads.
- VMware remote console: This allows you to mount a local DVD drive to the virtual server. This is handy for uploading ISO or installation disks to the cloud server.

Security Implications/Considerations

While an entire book could be written on the security implications of the cloud, there are some concerns that stand above the others. Among them are these:

- While clouds increasingly contain valuable data, they are just as susceptible to attacks as on-premises environments. Cases such as the Salesforce.com incident in which a technician fell for a phishing attack that compromised customer passwords remind us of this.

- Customers are failing to ensure that the provider keeps their data safe in multitenant environments. They are failing to ensure that passwords are assigned, protected, and changed with the same attention to detail the customer might desire.
- No specific standard has been developed to guide providers with respect to data privacy.
- Data security varies greatly from country to country and customers have no idea where their data is located at any point in time.

Relationship Between Local and Cloud Resources

When comparing the advantages of local and cloud environments and the resources that reside in each, several things stand out:

- A cloud environment requires very little infrastructure investment on the part of the customer, while a local environment requires an investment in both the equipment and the personnel to set it up and manage it.
- A cloud environment can be extremely scalable and at a moment's notice, while scaling a local environment either up or out requires an investment in both equipment and personnel.
- Investments in cloud environments involve monthly fees rather that capital expenditures as would be required in a local environment.
- While a local environment provides total control for the organization, a cloud takes some of that control away.
- While you always know where your data is in a local environment, that may not be the case in a cloud, and the location may change rapidly.

Locating and Installing Equipment

When infrastructure equipment is purchased and deployed, the ultimate success of the deployment can depend on selecting the proper equipment, determining its proper location in the facility, and installing it correctly. Let's look at some common data center or server room equipment and a few best practices for managing these facilities.

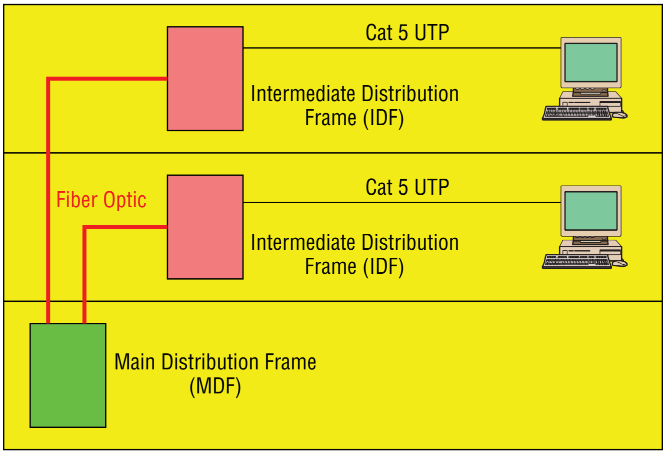
Main Distribution Frame

The main distribution frame connects equipment (inside plant) to cables and subscriber carrier equipment (outside plant). It also terminates cables that run to intermediate distribution frames distributed throughout the facility.

Intermediate Distribution Frame

An intermediate distribution frame (IDF) serves as a distribution point for cables from the main distribution frame (MDF) to individual cables connected to equipment in areas remote from these frames. The relationship between the IDFs and the MDF is shown in Figure 20.16.

FIGURE 20.16 MDF and IDFs


Cat 5 UTP
Intermediate Distribution Frame (IDF)
Fiber Optic
Cat 5 UTP
Intermediate Distribution Frame (IDF)
Main Distribution Frame (MDF)

Cable Management

While some parts of our network may be wireless, the lion's share of the network will be connected with cables. The cables come together in large numbers at distribution points where managing them becomes important both to protect the integrity of the cables and to prevent overheating of the infrastructure devices caused by masses of unruly cabling. The points of congestion typically occur at the patch panels.

Patch panels terminate cables from wall or data outlets. These masses of wires that emerge from the wall in a room will probably feed to the patch panel in a cable tray, which I'll talk more about soon. The critical maintenance issues at the patch panel are to ensure that cabling from the patch panel to the switch is neat, that the patch cables are as short as possible without causing stress on the cables, and that the positioning of the cabling does not impede air flow to the devices, which can cause overheating.

Power Management

Computing equipment of all types needs clean and constant power. Power fluctuations of any sort, especially complete outages and powerful surges, are a serious matter. In this section, we'll look at power issues and devices that can be implemented to avoid or mitigate them.

Power Converters Power conversion is the process of converting electric energy from one form to another. This conversion could take several forms:

- AC to DC
- From one voltage level to another
- From one frequency to another

Power converters are devices that make these conversions, and they typically are placed inline, where the energy flowing into one end is converted to another form when it exits the converter.

Circuits In situations where high availability is required, it may be advisable to provision multiple power circuits to the facility. This is sometimes called A+B or A/B power. To provision for A+B power, you should utilize a pair of identically sized circuits (e.g., 2 × 20 amperes). In the final analysis, even these systems can fail you in some natural disasters and so you should always also have power generators as well as a final backup.

UPS All infrastructure systems and servers should be connected to an uninterruptible power supply (UPS). As described in Chapter 15, a UPS can immediately supply power from a battery backup when a loss of power is detected. They provide power long enough for you to either shut the system down gracefully or turn on a power generator.

Inverters A power inverter is type of power converter that specifically converts DC to AC. It produces no power and must be connected to a DC source.

Power Redundancy While the facility itself needs redundant power circuits and backup generators, a system can still fail if the power supply in the device fails. Mission-critical devices should be equipped with redundant power supplies, which can mitigate this issue.

Device Placement

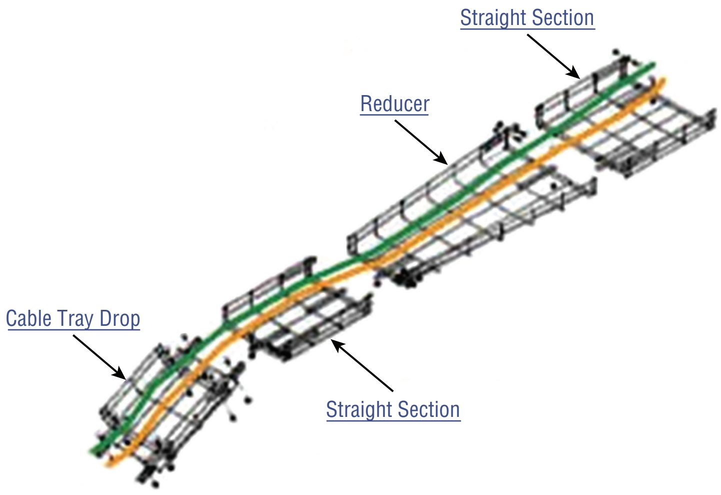
When locating equipment in a data center, server room, or wiring closet, the placement of the equipment should take several issues into consideration.

Air Flow Air flow around the equipment is crucially important to keep devices running. When hot air is not removed from the area and replaced with cooler air, the devices overheat and start doing things like rebooting unexpectedly. Even if the situation doesn't reach that point, the high heat will shorten the life of costly equipment.

One of the approaches that has been really successful is called hot/cold aisles. As explained earlier in this chapter, hot aisle/cold aisle design involves lining up racks in alternating rows with cold air intakes facing one way and hot air exhausts facing the other. The rows composed of rack fronts are called cold aisles. Typically, cold aisles face air conditioner output ducts. The rows the heated exhausts pour into are called hot aisles. They face air conditioner return ducts. Moreover, all of the racks and the equipment they hold should never be on the floor. There should be a raised floor to provide some protection against water.

Cable Trays Masses of unruly cables can block air flow and act as a heat blanket on the equipment if the situation is bad enough. Cable trays are metal trays used to organize the cabling neatly and keep it away from the areas where it can cause heat buildup. In Figure 20.17, some examples of cable tray components are shown. These are used to organize the cables and route them as needed.

FIGURE 20.17 Cable trays



Rack Systems Rack systems are used to hold and arrange the servers, routers, switches, firewalls, and other rack-ready equipment. Rack devices are advertised in terms of Us. U is the standard unit of measure for designating the vertical usable space, or the height of racks. 1U is equal to 1.75 inches. For example, a rack designated as 20U has 20 rack spaces for equipment and has 35 (20 × 1.75) inches of vertical usable space. You should be familiar with the following types of rack systems and components:

Server Rail Racks Server rail racks are used to hold servers in one of the types of racks described next. They are designed to hold the server while allowing the server to be slid out from the rack for maintenance.

Two-Post Racks A two-post rack is one in which only two posts run from the floor. These posts may reach to the ceiling or they may not (freestanding). Several sizes of two-post racks are shown in Figure 20.18.

Four-Post Racks As you would expect, these racks have four rails and can be either floor to ceiling or freestanding. One is shown in Figure 20.19.

FIGURE 20.18 Two-post racks

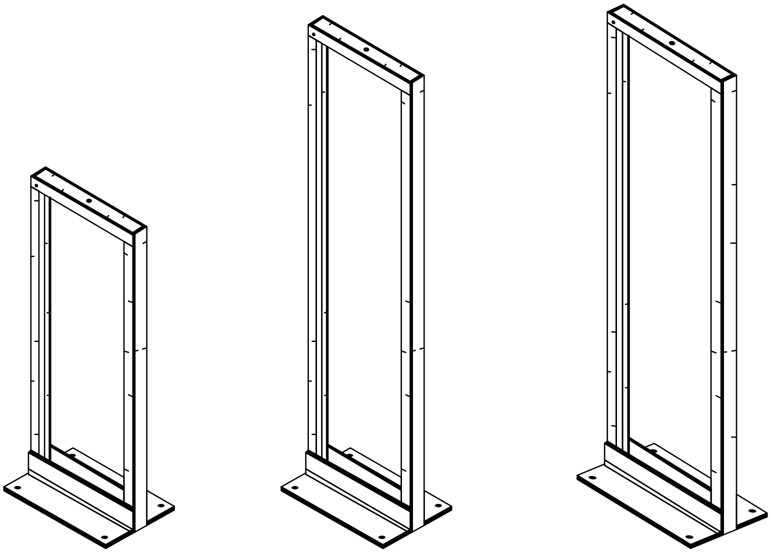
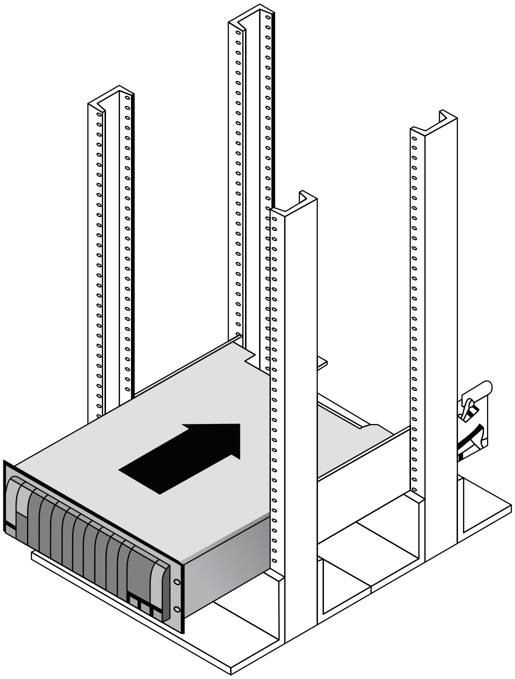
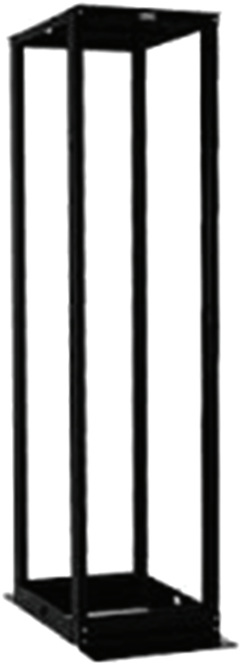


FIGURE 20.19 Four-post rack



Freestanding racks A freestanding rack is one that does not reach the ceiling and stands on its own. A four-post freestanding rack is shown in Figure 20.20.

FIGURE 20.20 Freestanding rack



Real World Scenario

Applying Your Knowledge

You have been assigned the job of positioning the following pieces of equipment in the network for maximum performance and security:

Firewall

Patch server

Main distribution frame (MDF)

Intermediate distribution frame (IDF)

Public web server

Using the following table, match the five pieces of equipment in the left column with the correct position in the right column. The answer follows.

Device	Position
Firewall	In the DMZ
Patch server	Just after the Internet router
MDF	In the server room or closet on each floor
IDF	Inside the LAN
Public web server	In the server room or closet that is connected to the service provider

Firewall	Just after the Internet router
Patch server	Inside the LAN
MDF	In the server room or closet that is connected to the service provider
IDF	In the server room or closet on each floor
Public web server	In the DMZ

Labeling

In a data center, server room, or wiring closet, correct and updated labeling of ports, systems, circuits, and patch panels can prevent a lot of confusion and mistakes when configuration changes are made. Working with incorrect or incomplete (in some cases nonexistent) labeling is somewhat like trying to locate a place with an incorrect or incomplete map. In this section, we'll touch on some of the items that should be correctly labeled.

Port Labeling Ports on switches, patch panels, and other systems should be properly labeled, and the wall outlets to which they lead should match! You should arrive at an agreement as to the naming convention to use so that all technicians are operating from the same point of reference. They also should be updated in any case where changes are made that dictate an update.

System Labeling Other systems that are installed in racks, such as servers, firewall appliances, and redundant power supplies, should also be labeled with IP addresses and DNS names that the devices possess.

Circuit Labeling Circuits entering the facility should also be labeled. Label electrical receptacles, circuit breaker panels, and power distribution units. Include circuit information, voltage and amperage, the type of electrical receptacle, and where in the data center the conduit terminates.

Naming Conventions A naming system or convention guides and organizes labeling and ensures consistency. No matter what name or numbering system you use, be consistent.

Patch Panel Labeling The key issue when labeling patch panels is to ensure that they're correct. Also, you need to make sure that the wall outlet they're connected to is the same. The American National Standards Institute/Telecommunications Industry Association (ANSI/TIA) 606-B.1 Administration Standard for Telecommunications Infrastructure for identification and labeling approved in April 2012 provides clear specifications for labeling and administration best practices across all electrical and network systems premise classes, including large data centers.

Rack Monitoring

Racks should contain monitoring devices that can be operated remotely. These devices can be used to monitor the following issues:

- Temperature
- Humidity
- Physical security (open doors)
- Smoke
- Water leaks
- Vibration

Rack Security

Rack devices should be secured from theft. There are several locking systems that can be used to facilitate this. These locks are typically implemented in the doors on the front of a rack cabinet:

- Swing handle/wing knob locks with common key
- Swing handle/wing knob locks with unique key
- Swing handle with number and key lock
- Electronic locks
- Radio-frequency identification (RFID) card locks

Change Management Procedures

Throughout this chapter I've stressed that network operations need to occur in a controlled and managed fashion. For this to occur, an organization must have a formal change management process in place. The purpose of this process is to ensure that all changes are approved by the proper personnel and are implemented in a safe and logical manner. Let's look at some of the key items that should be included in these procedures.

Document Reason for a Change

Clearly, every change should be made for a reason, and before the change is even discussed, that reason should be documented. During all stages of the approval process (discussed later), this information should be clearly communicated and attached to the change under consideration.

Change Request

A change should start its life as a change request. This request will move through various stages of the approval process and should include certain pieces of information that will guide those tasked with approving or denying it.

Configuration Procedures

The exact steps required to implement the change and the exact devices involved should be clearly detailed. Complete documentation should be produced and submitted with a formal report to the change management board.

Rollback Process

Changes always carry a risk. Before any changes are implemented, plans for reversing the changes and recovering from any adverse effects from the change should be identified. Those making the changes should be completely briefed in these rollback procedures, and they should exhibit a clear understanding of them prior to implementing the changes.

Potential Impact

While unexpected adverse effects of a change can't always be anticipated, a good-faith effort should be made to identity all possible systems that could be impacted by the change. One of the benefits of performing this exercise is that it can identify systems that may need to be more closely monitored for their reaction to the change as the change is being implemented.

Notification

When all systems and departments that may be impacted by the change are identified, system owners and department heads should be notified of all changes that could potentially affect them. One of the associated benefits of this is that it creates additional monitors for problems during the change process.

Approval Process

Requests for changes should be fully vetted by a cross section of users, IT personnel, management, and security experts. In many cases, it's wise to form a change control board to complete the following tasks:

- Assure that changes made are approved, tested, documented, and implemented correctly.
- Meet periodically to discuss change status accounting reports.
- Maintain responsibility for assuring that changes made do not jeopardize the soundness of the verification system.

Maintenance Window

A maintenance window is an amount of time a system will be down or unavailable during the implementation of changes. Before this window of time is specified, all affected systems should be examined with respect to their criticality in supporting mission-critical operations. It may be that the time required to make the change may exceed the allowable downtime a system can suffer during normal business hours, and the change may need to be implemented during a weekend or in the evening.

Authorized Downtime

Once the time required to make the change has been compared to the maximum allowable downtime a system can suffer and the optimum time for the change is identified, the authorized downtime can be specified. This amounts to a final decision on when the change will be made.

Notification of Change

When the change has been successfully completed and a sufficient amount of time has elapsed for issues to manifest themselves, all stakeholders should be notified that the change is complete. At that time, these stakeholders (those possibly affected by the change) can continue to monitor the situation for any residual problems.

Documentation

The job isn't complete until the paperwork is complete. In this case, the following should be updated to reflect the changed state of the network:

- Network configurations
- Additions to network
- Physical location changes

Summary

In this chapter, I talked a lot about the documentation aspects of network administration. I started off discussing physical diagrams and schematics and moved on to the logical form as well as configuration-management documentation. You learned about the importance of these diagrams as well as the simple to complex forms they can take and the tools used to create them—from pencil and paper to high-tech AutoCAD schematics. You also found out a great deal about creating performance baselines. After that, I delved deep into a discussion of network policies and procedures and how regulations can affect how you manage your network.

Next, you learned about network monitoring and optimization and how monitoring your network can help you find issues before they develop into major problems.

You learned that server operating systems and intelligent network devices have built-in graphical monitoring tools to help you troubleshoot your network.

We got into performance optimization and the many theories and strategies you can apply to optimize performance on your network. All of them deal with controlling the traffic in some way and include methods like QoS, traffic shaping, load balancing, high availability, and the use of caching servers. We discussed how Common Address Redundancy Protocol (CARP) can be used to increase availability of gateways and firewalls. You also learned how important it is to ensure that you have plenty of bandwidth available for any applications that vitally need it, like critical service operations, VoIP, and real-time multimedia streaming.

Finally, we discussed cloud computing, or virtualization. We looked at its benefits, including increased performance and fault tolerance, increased availability, and the ability to access cloud services from anywhere. You also learned about some of its major components, such as virtual servers, virtual switches, virtual desktops, and an example of software as a service (SaaS), virtual PBX.

Exam Essentials

Understand the difference between a physical network diagram and a logical network diagram. A physical diagram shows all of the physical connections and devices, and in many cases the cables or connections between the devices. It's a very detail-oriented view of the hardware on your network. A logical network diagram takes a higher-level view, such as your subnets and which protocols those subnets use to communicate with each other.

Identify the elements of unified communications technology. This includes the proper treatment of traffic types such as VoIP and video. You should also understand what UC servers, devices, and gateways are. Finally, describe the methods used to provide QoS to latency-sensitive traffic.

Understand the difference between policies, procedures, and regulations. A policy is created to give users guidance as to what is acceptable behavior on the network. Policies also help resolve problems before they begin by specifying who has access to what resources and how configurations should be managed. Procedures are steps to be taken when an event occurs on the network, such as what to do when a user is fired or how to respond to a natural disaster. Regulations are imposed on your organization; you are required to follow them, and if you don't, you may be subject to punitive actions.

Know how your servers and network devices can help you monitor your network. Most servers and network devices have monitoring tools built in that are capable of tracking data and events on your network. These include graphical tools as well as log files.

Compare and contrast cloud technologies. Understand the differences between public IaaS, SaaS, PaaS; private IaaS, SaaS, PaaS; hybrid IaaS, SaaS, PaaS; and community IaaS, SaaS, PaaS. Also know the difference between a NAS and a SAN.

Understand several theories of performance optimization. There are several ways to manage traffic on your network to speed up access and in some cases guarantee available bandwidth to applications. These include QoS, traffic shaping, load balancing, high availability, and using caching servers.

Know some examples of bandwidth-intensive applications. Two examples of high-bandwidth applications are Voice over IP (VoIP) and real-time video streaming.

Describe the major building blocks of virtualization. Understand how virtual servers, virtual switches, and virtual desktops are used to supply the infrastructure to deliver cloud services. Differentiate onsite or private clouds from offsite or public cloud services. Identify services that can be provided, such as network as a service (NaaS) and software as a service (SaaS).

Summarize safety and environmental issues in the data center. Understand electrical safety as it relates to both devices and humans. Understand the use of fire suppression systems. Describe proper emergency procedures.

Written Lab

You can find the answers to the written labs in Appendix A. In this section, write the answers to the following management questions:

1. ____________ are systems that are configured to be attractive to hackers and to lure them into spending time attacking them while information is gathered about the attack.
2. Which network-performance optimization technique uses a contract to determine which data can get on to the network?
3. The lowest level of QoS is called ____________.
4. ____________ is a type of power converter that specifically converts DC to AC.
5. Spreading network traffic across multiple connections is called ____________.
6. A standard of normal network performance is called ____________.
7. If you need to connect two PCs directly together using their network adapters, what type of cable do you need?
8. What is another name for using virtualization to provide services?
9. List at least three major components of virtualization.
10. The steps you should take when, for example, a network user is fired are called ____________.

Review Questions

You can find the answers to the review questions in Appendix B.

1. UTP cables use which type of connector?

   A. RJ-11

   B. RJ-25

   C. RJ-45

   D. BNC

2. Which type of cable will have the pins in the same order on both connectors?

   A. Crossover cable

   B. Straight-through cable

   C. Console cable

   D. Telephone cable

3. Which pins are switched in a crossover cable?

   A. 1 and 2, 3 and 4

   B. 1 and 3, 2 and 6

   C. 2 and 4, 5 and 7

   D. 1 and 4, 5 and 8

4. UTP cable has specific colors for the wire associated with each pin. Based on the TIA/EIA 568B wiring standard, what is the correct color order, starting with pin 1?

   A. White/Orange, Orange, Blue, White/Green, White/Blue, Green, White/Brown, Brown

   B. Orange, White/Orange, White/Green, Blue, White/Blue, White/Brown, Brown, Green

   C. White/Orange, Orange, White/Green, Blue, White/Blue, Green, White/Brown, Brown

   D. White/Green, Green, White/Orange, Blue, White/Blue, Orange, White/Brown, Brown

5. What is the technical term for what happens when two objects of dissimilar charge come in contact?

   A. RFI

   B. EMI

   C. ESD

   D. Crosstalk

6. Which of the following govern how the network is configured and operated as well as how people are expected to behave on the network?

   A. Baselines

   B. Laws

   C. Policies

   D. Procedures

7. You have upgraded the firmware on your switches and access points. What documentation do you need to update?

   A. Baselines and configuration documentation

   B. Physical network diagram

   C. Logical network diagram

   D. Wiring schematics

8. In an ICS, which of the following uses coded signals over communication channels to acquire information about the status of the remote equipment?

   A. ICS server

   B. Telemetry system

   C. Human interface

   D. PLC

9. Load testing, connectivity testing, and throughput testing are all examples of what?

   A. Load balancing

   B. Network monitoring

   C. Packet sniffing

   D. Traffic shaping

10. What can provide different priority levels to different applications, data flows, or users to help guarantee performance levels?

    A. 1 Gbps connection

    B. Bandwidth

    C. Uptime

    D. Quality of Service

11. Which of the following identifies steps to recover from adverse effects caused by a change?

    A. Rollback process

    B. Approvable process

    C. Notification process

    D. Impact assessment

12. After a change has been made, which of the following is *not* a document that needs to be updated?

    A. Network configurations

    B. Additions to the network

    C. Physical location changes

    D. All of the above

13. Which of the following provides increased availability to firewalls and gateways?

A. DHCP

B. CARP

C. SaaS

D. NaaS

14. You have added a new cable segment to your network. You need to make sure you document this for troubleshooting purposes. What should you update?

A. The disaster recovery plan

B. The wiring schematics

C. The router connections document

D. The baseline document

15. What is the basic purpose of QoS? (Choose two.)

A. Block access to certain websites

B. Make your entire network run faster

C. Provide priority to one or more types of traffic over others

D. Block access to web resources for just certain users or groups

E. Prioritize delay-sensitive traffic

16. Which network-performance optimization technique can delay packets that meet certain criteria to guarantee usable bandwidth for other applications?

A. Traffic shaping

B. Jitter

C. Logical

D. Load balancing

17. Which of the following is neither a virtualization component nor a service made available through virtualization?

A. Virtual servers

B. SaaS

C. CARP

D. Virtual switches

18. Which of the following are reasons to optimize network performance? (Choose all that apply.)

A. Maximizing uptime

B. Minimizing latency

C. Using VoIP

D. Using video applications

E. None of the above

19. What term describes technologies that can deliver voice communications over the Internet?

A. Jitter

B. Uptime

C. Voice over Internet Protocol

D. None of the above

20. To optimize performance on your network, which of the following control traffic in some way? (Choose all that apply.)

A. QoS

B. Traffic shaping

C. Load balancing

D. Caching services

E. None of the above

Appendix A

Answers to Written Labs

Chapter 1: Introduction to Networks

1. Bus, ring, and star
2. Multiprotocol Label Switching (MPLS)
3. Server
4. Client-server
5. Point-to-point
6. Hub or switch
7. Multiprotocol Label Switching
8. Wide area network
9. A segment
10. Bus

Chapter 2: The Open Systems Interconnection Specifications

1. The Application layer is responsible for finding the network resources broadcast from a server and adding flow control and error control (if the application developer chooses).
2. The Physical layer takes frames from the Data Link layer and encodes the 1s and 0s into a digital signal for transmission on the network medium.
3. The Network layer provides routing through an internetwork and logical addressing.
4. The Presentation layer makes sure that data is in a readable format for the Application layer.
5. The Session layer sets up, maintains, and terminates sessions between applications.
6. Protocol Data Units (PDUs) at the Data Link layer are called frames. As soon as you see the word *frame* in a question, you know the answer.
7. The Transport layer uses virtual circuits to create a reliable connection between two hosts.
8. The Network layer provides logical addressing, typically IP addressing, and routing.
9. The Physical layer is responsible for the electrical and mechanical connections between devices.
10. The Data Link layer is responsible for the framing of data packets.

Chapter 3: Networking Topologies, Connectors, and Wiring Standards

1. Category 6
2. Demarcation point, or demarc
3. Crossover
4. RG-6
5. Category 5e
6. Straight-through
7. To connect two CSU/DSUs
8. 1, 2, 3, and 6
9. 1 to 3 and 2 to 6
10. It is completely immune to EMI and RFI and can transmit up to 40 kilometers (about 25 miles).

Chapter 4: The Current Ethernet Specifications

1.

Decimal	128	64	32	16	8	4	2	1	Binary
192	1	1	0	0	0	0	0	0	11000000
168	1	0	1	0	1	0	0	0	10101000
10	0	0	0	0	1	0	1	0	00001010
15	0	0	0	0	1	1	1	1	00001111

2.

Decimal	128	64	32	16	8	4	2	1	Binary
172	1	0	1	0	1	1	0	0	10101100
16	0	0	0	1	0	0	0	0	00010000
20	0	0	0	1	0	1	0	0	00010100
55	0	0	1	1	0	1	1	1	00110111

3.

Decimal	128	64	32	16	8	4	2	1	Binary
10	0	0	0	0	1	0	1	0	00001010
11	0	0	0	0	1	0	1	1	00001011
12	0	0	0	0	1	1	0	0	00001100
99	0	1	1	0	0	0	1	1	01100011

4.

Binary	128	64	32	16	8	4	2	1	Decimal
11001100	1	1	0	0	1	1	0	0	204
00110011	0	0	1	1	0	0	1	1	51
10101010	1	0	1	0	1	0	1	0	170
01010101	0	1	0	1	0	1	0	1	85

5.

Binary	128	64	32	16	8	4	2	1	Decimal
11000110	1	1	0	0	0	1	1	0	198
11010011	1	1	0	1	0	0	1	1	211
00111001	0	0	1	1	1	0	0	1	57
11010001	1	1	0	1	0	0	0	1	209

6.

Binary	128	64	32	16	8	4	2	1	Decimal
10000100	1	0	0	0	0	1	0	0	132
11010010	1	1	0	1	0	0	1	0	210
10111000	1	0	1	1	1	0	0	0	184
10100110	1	0	1	0	0	1	1	0	166

7.

Binary	128	64	32	16	8	4	2	1	Hexadecimal
11011000	1	1	0	1	1	0	0	0	D8
00011011	0	0	0	1	1	0	1	1	1B
00111101	0	0	1	1	1	1	0	1	3D
01110110	0	1	1	1	0	1	1	0	76

8.

Binary	128	64	32	16	8	4	2	1	Hexadecimal
11001010	1	1	0	0	1	0	1	0	CA
11110101	1	1	1	1	0	1	0	1	F5
10000011	1	0	0	0	0	0	1	1	83
11101011	1	1	1	0	1	0	1	1	EB

9.

Binary	128	64	32	16	8	4	2	1	Hexadecimal
10000100	1	0	0	0	0	1	0	0	84
11010010	1	1	0	1	0	0	1	0	D2
01000011	0	1	0	0	0	0	1	1	43
10110011	1	0	1	1	0	0	1	1	B3

Chapter 5: Networking Devices

Description	Device or OSI layer
This device sends and receives information about the Network layer.	Router
This layer creates a virtual circuit before transmitting between two end stations.	Transport

Description	Device or OSI layer
A Layer 3 switch or multilayer switch.	Router
This device uses hardware addresses to filter a network.	Bridge or switch
Ethernet is defined at these layers.	Data Link and Physical
This layer supports flow control and sequencing.	Transport
This device can measure the distance to a remote network.	Router
Logical addressing is used at this layer.	Network
Hardware addresses are defined at this layer.	Data Link (MAC sublayer)
This device creates one big collision domain and one large broadcast domain.	Hub
This device creates many smaller collision domains, but the network is still one large broadcast domain.	Switch or bridge
This device can never run full duplex.	Hub
This device breaks up collision domains and broadcast domains.	Router

Chapter 6: Introduction to the Internet Protocol

1. This would be a Layer 2 broadcast, or FF:FF:FF:FF:FF:FF.
2. FTP uses both TCP ports 20 and 21 for the data channel and the control channel, respectively.
3. Both TCP and UDP! A DNS server uses TCP port 53 for zone transfers and UDP port 53 for name resolutions. Notice that DNS uses both TCP and UDP. Whether it opts for one or the other depends on what it’s trying to do.
4. ICMP uses IP directly to build error-reporting packets that are transmitted back to the originating source host when issues arise during the delivery of data packets. ICMP is also used during Ping and some Traceroute operations.
5. Quite simply, the service might not be running currently on that server. Another possibility might be that a firewall between the client and the server has blocked the protocol in question from passing.

6. RDP uses port 3389.
7. MGCP uses ports 2427 and 2727.
8. ICMP is the protocol that the `ping` and `tracert` commands rely on. If you're having trouble getting pings and traceroutes through a router, you might need to check if ICMP is being allowed through.
9. TFTP servers respond to UDP messages sent to port 69.
10. SMTP uses TCP port 25, POP3 uses TCP port 110, RDP uses TCP port 3389, and IMAP4 uses TCP port 143.

Chapter 7: IP Addressing

Written Lab 7.1

1. The class C private range is 192.168.0.0 through 192.168.255.255.
2. IPv6 has the following characteristics, among others, that make it preferable to IPv4: more available addresses, simpler header, options for authentication, and other security.
3. Automatic Private IP Addressing (APIPA) is the technology that results in hosts automatically configuring themselves with addresses that begin with 169.254.
4. An IP address assigned to an interface
5. One-to-many address
6. A MAC address, sometimes called a hardware address or even a burned-in address
7. The fact that it has 128-bit (16-octet) addresses, compared to IPv4's 32-bit (4-octet) addresses
8. 172.16.0.0 through 172.31.255.255
9. 192–223, 110*xxxxx*
10. Loopback or diagnostics

Written Lab 7.2

1. Unicast
2. Global unicast
3. Link-local
4. Unique local (used to be called site-local)
5. Multicast
6. Anycast

7. Anycast
8. ::1
9. FE80::/10
10. FC00:: /7

Written Lab 7.3

1. 2001:db8:1:1:090c:abff:fecd:1234
2. 2001:db8:1:1: 040c:32ff:fef1:a4d2
3. 2001:db8:1:1:12bc:abff:fecd:1234
4. 2001:db8:1:1:0f01:3aff:fe2f:1234
5. 2001:db8:1:1:080c:abff:feac:caba

Chapter 8: IP Subnetting, Troubleshooting IP, and Introduction to NAT

1. 192.168.100.25/30. A /30 is 255.255.255.252. The valid subnet is 192.168.100.24, broadcast is 192.168.100.27, and valid hosts are 192.168.100.25 and 26.
2. 192.168.100.37/28. A /28 is 255.255.255.240. The fourth octet is a block size of 16. Just count by 16s until you pass 37. 0, 16, 32, 48. The host is in the 32 subnet, with a broadcast address of 47. Valid hosts are 33–46.
3. 192.168.100.66/27. A /27 is 255.255.255.224. The fourth octet is a block size of 32. Count by 32s until you pass the host address of 66. 0, 32, 64. The host is in the 64 subnet, broadcast address of 95. The valid host range is 65–94.
4. 192.168.100.17/29. A /29 is 255.255.255.248. The fourth octet is a block size of 8. 0, 8, 16, 24. The host is in the 16 subnet, broadcast of 23. Valid hosts are 17–22.
5. 192.168.100.99/26. A /26 is 255.255.255.192. The fourth octet has a block size of 64. 0, 64, 128. The host is in the 64 subnet, broadcast of 127. Valid hosts are 65–126.
6. 192.168.100.99/25. A /25 is 255.255.255.128. The fourth octet is a block size of 128. 0, 128. The host is in the 0 subnet, broadcast of 127. Valid hosts are 1–126.
7. A default Class B is 255.255.0.0. A Class B 255.255.255.0 mask is 256 subnets, each with 254 hosts. We need fewer subnets. If we use 255.255.240.0, this provides 16 subnets. Let's add one more subnet bit. 255.255.248.0. This is 5 bits of subnetting, which provides 32 subnets. This is our best answer, a /21.

8. A /29 is 255.255.255.248. This is a block size of 8 in the fourth octet. 0, 8, 16. The host is in the 8 subnet, and broadcast is 15.
9. A /29 is 255.255.255.248, which is 5 subnet bits and 3 host bits. This is only 6 hosts per subnet.
10. A /23 is 255.255.254.0. The third octet is a block size of 2. 0, 2, 4. The host is in the 16.2.0 subnet; the broadcast address is 16.3.255.

Chapter 9: Introduction to IP Routing

1. False. RIP and RIPv2 are both distance vector protocols.
2. False. RIP and RIPv2 are both distance vector protocols.
3. False. EIGRP is a Cisco-proprietary routing protocol.
4. Autonomous system
5. RIP does not work well in large networks, so OSPF would be the best answer, and both RIP and OSPF are nonproprietary.
6. Static routing
7. The MAC address of your default gateway (router)
8. The IP address of the server
9. The MAC address of the router sending the frame to the server
10. The IP address of the server

Chapter 10: Routing Protocols

1. 120
2. 90
3. 120
4. 1
5. RIPng (Next Generation). I wonder how many of you answered RIPv3.
6. OSPFv3
7. EIGRPv6
8. When you need to connect two autonomous systems (ASs) together
9. When all your routers are Cisco routers
10. Distance vector

Chapter 11: Switching and Virtual LANs

1. Broadcast
2. Collision
3. Trunking allows you to send information about many or all VLANs through the same link. Access ports allow information about only one VLAN transmitted.
4. Power over Ethernet (PoE)
5. The VLAN port membership is set wrong.
6. Flood the frame out all ports except the port on which it was received.
7. Address learning, filtering, and loop avoidance
8. It will add the source MAC address to the forward/filter table.
9. Spanning Tree Protocol (STP)
10. Create a VLAN for contractors and another VLAN for guests.

Chapter 12: Wireless Networking

1. 11 Mbps
2. 54 Mbps
3. 54 Mbps
4. 2.4 GHz
5. 2.4 GHz
6. 5GHz
7. 1 Gbps
8. The values of WPA keys can change dynamically while the system is being used.
9. The IEEE 802.11i standard has been sanctioned by WPA and is called WPA version 2.
10. Three

Chapter 13: Authentication and Access Control

1. Anti-malware updates, operating system updates, or Windows Registry settings
2. Persistent

3. SSL VPN
4. PKI
5. Only the owner of the key
6. Kerberos
7. Authentication, authorization, and accounting
8. 802.1X
9. MS-CHAP
10. TACACS+

Chapter 14: Network Threats and Mitigation

1. Botnet
2. Once per week
3. Buffer overflow
4. Amplified or reflective
5. Packet sniffer
6. A macro virus
7. Man-in-the-middle attack
8. A rogue access point
9. Windows Update
10. On-demand and on-access virus scans

Chapter 15: Physical Security and Risk

1. Virtual wire firewall interfaces
2. Stateful
3. Content filtering
4. Single point of failure
5. A VPN concentrator
6. Security zones
7. Mantrap

8. Deny
9. Honeynet
10. Passive reactions from an IDS

Chapter 16: Wide Area Networks

1. It is readily available.
2. Cable. In a modern network, *hybrid fiber coaxial (HFC)* is a telecommunications industry term for a network that incorporates both optical fiber and coaxial cable to create a broadband network.
3. Frame Relay. Although Frame Relay is not available in many markets today, it is a possible solution for the problem presented.
4. 1.544 Mbps
5. Digital Subscriber Line
6. Frame Relay and X.25
7. LTE and WiMAX
8. ATM
9. HDSL, SDSL, VDSL, ADSL
10. Fiber to the premises

Chapter 17: Troubleshooting Tools

1. `traceroute` or `tracert`
2. Throughput tester
3. `ipconfig /all`
4. Telnet
5. `route`
6. FTP
7. `nslookup`
8. `netstat-n`
9. `ifconfig`
10. `route print`

Chapter 18: Software and Hardware Tools

1. False
2. False
3. True
4. True
5. False. A typical network analyzer can see only one segment at a time.
6. Cable certifier
7. False. Unless you don't mind prison.
8. A temperature monitor
9. A voltage event recorder
10. A cable stripper/crimper

Chapter 19: Network Troubleshooting

1. Test the theory to determine cause.
2. Document findings, actions, and outcomes.
3. Network designers minimize crosstalk inside network cables by twisting the wire pairs together, putting them at a 90-degree angle to each other.
4. The port has the wrong VLAN assignment.
5. Split pairs
6. Attenuation
7. Establish a plan of action to resolve the problem and identify potential effects.
8. Implement the solution or escalate as necessary.
9. Switching loops, routing loops, routing problems, Proxy ARP, broadcast storms
10. Crosstalk, attenuation, collisions, shorts, open impedance mismatch, interference

Chapter 20: Management, Monitoring, and Optimization

1. Honeypots
2. Traffic shaping
3. Best effort
4. An inverter
5. Load balancing
6. A baseline
7. Crossover
8. Cloud computing
9. Virtual servers, virtual switches, virtual desktops, software as a service (SaaS), and network as a service (NaaS)
10. Procedures

Appendix B

Answers to Review Questions

Chapter 1: Introduction to Networks

1. C. A client-server logical topology allows you to have a centralized database of users so that authentication is provided in one place.

2. C. To install a physical topology that provides ease of scalability, use a star network. This is a hub or switch device, and this is the most common LAN network today.

3. D. Only a mesh physical topology has point-to-point connections to every device, so it has more connections and is not a popular LAN technology.

4. B. In a star topology, each workstation connects to a hub, switch, or similar central device but not to other workstations. The benefit is that when connectivity to the central device is lost, the rest of the network lives on.

5. C. Multiprotocol Label Switching has as many advantages as a LAN protocol. When labels are used, voice can have priority over basic data, for example.

6. B. A logical grouping of hosts is called a LAN, and you typically group them by connecting them to a hub or switch.

7. C. It is easy to relax about security in a peer-to-peer environment. Because of the trouble it takes to standardize authentication, a piecemeal approach involving users' personal preferences develops. There are no dedicated servers in a peer-to-peer network, and such a network can be created with as few as two computers.

8. A. When a central office, such as headquarters, needs to communicate directly with its branch offices but the branches do not require direct communication with one another, the point-to-multipoint model is applicable. The other scenarios tend to indicate the use of a point-to-point link between sites.

9. D. LANs generally have a geographic scope of a single building or smaller. They can range from simple (two hosts) to complex (with thousands of hosts).

10. B. The only disadvantage mentioned is the fact that there is a single point of failure in the network. However, this topology makes troubleshooting easier; if the entire network fails, you know where to look first. The central device also ensures that the loss of a single port and the addition of a new device to an available port do not disrupt the network for other stations attached to such a device.

11. D. A typical WAN connects two or more remote LANs together using someone else's network (your ISP's) and a router. Your local host and router see these networks as remote networks and not as local networks or local resources. Routers use proprietary serial connections for WANs.

12. D. Multiprotocol Label Switching provides logical links between sites, so branch offices can be easily and quickly added.

13. A. In a peer-to-peer network, all computers are considered equal. It is up to the computer that has the resource being requested to perform a security check for access rights to its resources.

14. D. In client-server networks, requests for resources go to a main server that responds by handling security and directing the client to the resource it wants instead of the request going directly to the machine with the desired resource (as in peer-to-peer).

15. A. The best answer to this question is an Ethernet switch, which uses a star physical topology with a logical bus technology.

16. D. Routers are used to connect different networks together.

17. D. In the mesh topology, there is a path from every connection to every other one in the network. A mesh topology is used mainly because of the robust fault tolerance it offers—if one connection goes on the blink, computers and other network devices can simply switch to one of the many redundant connections that are up and running.

18. A. As its name implies, in a point-to-point topology you have a direct connection between two routers, giving you one communication path. The routers in a point-to-point topology can either be linked by a serial cable, making it a physical network, or be far away and only connected by a circuit within a Frame Relay network, making it a logical network.

19. B. A hybrid topology is a combination of two or more types of physical or logical network topologies working together within the same network.

20. A, B, C, D. Each topology has its own set of pros and cons regarding implementation, so it’s important to ask the right questions and consider cost, ease of installation, maintenance, and fault tolerance.

Chapter 2: The Open Systems Interconnection Specifications

1. C. A connection-oriented session is set up using what is called a three-way handshake. The transmitting host sends a SYN packet, the receiving host sends a SYN/ACK, and the transmitting host replies with the last ACK packet. The session is now set up.

2. D. TCP and UDP are Transport layer protocols. The Transport layer is Layer 4 of the OSI model.

3. A. The top layer of the OSI model gives applications access to the services that allow network access.

4. A. If the remote server is busy or does not respond to your web browser request, this is an Application layer problem.

5. B. The Presentation layer makes data “presentable” for the Application layer.

6. C. Bridges, like switches, are Data Link layer devices. Hubs, like repeaters, are Physical layer devices. Routers are Network layer devices.

7. D. The Physical layer's job is to convert data into impulses that are designed for the wired or wireless medium being used on the attached segment.

8. D. A receiving host can control the transmitter by using flow control (TCP uses windowing by default). By decreasing the window size, the receiving host can slow down the transmitting host so the receiving host does not overflow its buffers.

9. C, D. Not that you really want to enlarge a single collision domain, but a hub (multiport repeater) will provide this functionality for you.

10. D. The Transport layer receives large data streams from the upper layers and breaks these up into smaller pieces called segments.

11. C. The encapsulation order is data, segment, packet, frame, bits.

12. B, C. Bridges and switches break up collision domains, which allows more bandwidth for users.

13. C. A reliable Transport layer connection uses acknowledgments to make sure all data is received reliably. A reliable connection is defined by the use of acknowledgments, sequencing, and flow control, which is characteristic of the Transport layer (Layer 4).

14. A, C, D. When sequencing and acknowledgments are used, the segments delivered are acknowledged back to the sender upon their reception. At this point, any segments not acknowledged are retransmitted, and segments are sequenced back into their proper order upon arrival at their destination.

15. C. Flow control allows the receiving device to control the pace of the transmitting device so the receiving device's buffer does not overflow.

16. B. IP is a Network layer protocol. TCP is an example of a Transport layer protocol, Ethernet is an example of a Data Link layer protocol, and T1 can be considered a Physical layer protocol.

17. D. The Presentation layer is the sixth layer of the model. Only the Application layer is higher, but it is not listed. Session is Layer 5, Transport is Layer 4, and Network is Layer 3.

18. C. A router is specified at the Network layer and a router routes packets. Routers can also be called Layer 3 switches.

19. C. The phrase "Please Do Not Throw Sausage Pizza Away" contains the first letters of the layers in order, from Layer 1 through Layer 7. "All People Seem To Need Data Processing" works from the top down. The other options have all the right letters, just not in the right order.

20. B. The 802.3 standard, commonly associated with Ethernet, specifies the media-access method used by Ethernet, which is known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

Chapter 3: Networking Topologies, Connectors, and Wiring Standards

1. B, C. Plenum-rated means that the cable's coating doesn't begin burning until a much higher temperature of heat, doesn't release as many toxic fumes as PVC when it does burn, and is rated for use in air plenums that carry breathable air, usually as nonenclosed fresh-air return pathways that share space with cabling.

2. D. UTP is commonly used in twisted-pair Ethernet like 10BaseT, 100BaseTX, 1000BaseTX, and so on.

3. D. Unshielded twisted-pair has standards from Category 2 through 8 for use on Ethernet networks. There is no Category 9 defined.

4. C. UTP usually connects with RJ-45. You use a crimper to attach an RJ connector to a cable.

5. A. Single-mode fiber allows for the maximum cable run distances.

6. B. You would use a straight-through cable to connect a host to a switch, and the typical pin-out is called T568A.

7. C. Fiber-optic cable transmits digital signals using light impulses rather than electricity; therefore, it is immune to EMI and RFI.

8. B. Remember that fiber-optic cable transmits a digital signal using light impulses. Light is carried on either a glass or a plastic core.

9. B. The difference between single-mode fibers and multimode fibers is in the number of light rays (and thus the number of signals) they can carry. Generally speaking, multimode fiber is used for shorter-distance applications and single-mode fiber for longer distances.

10. C. Standards limit UTP to a mere 100 meters. Different fiber-optic types have different maximum lengths, but fiber-optic is the only cable type that can extend well beyond 100 meters.

11. B, D, E. There are many different types of fiber-optic connectors. SC, ST, LC, and MT-RJ are some of the more typical connectors in use today.

12. B. To connect two devices for voice on a vertical connect, the minimum cable you can use is Category 5.

13. B. In half-duplex communication, a device can either send communication or receive communication, but it cannot do both at the same time.

14. B. Fiber-optic cable transmits only light (not electricity like UTP), so EMI has zero effect on it.

15. C. Full-duplex communication requires a point-to-point configuration because the collision-avoidance circuit is disabled.

16. B. 100BaseTX utilizes only pins 1, 2, 3, and 6.

17. D. All devices that are pinned the same for transmit and receive require a crossover cable to communicate directly.

18. A. A T1 cable uses pairs 1 and 2, so connecting two T1 CSU/DSU devices back-to-back requires a crossover cable that swaps these pairs. Specifically, pins 1, 2, 4, and 5 are connected to 4, 5, 1, and 2, respectively.

19. D. The demarcation point, or demarc, is the point at which the operational control or ownership changes from your company to a service provider. This is often at the MDF in relation to telephone connections and the CSU/DSU in regard to WAN connections.

20. B. Fast Ethernet is 100BaseTX and this type of cable uses two pairs of wires.

Chapter 4: The Current Ethernet Specifications

1. B. On an Ethernet network, the MAC address (hardware address) is used for one host to communicate with another.

2. B. 100BaseTX uses CAT 5e and can run 200 Mbps when using full duplex.

3. D. When one device sends a packet out on a network segment, all other devices on the same physical network segment must wait and let it be transmitted.

4. E. 10Base2 was one of the very first Ethernet network physical mediums and is a thinnet coax.

5. B. Carrier Sense Multiple Access with Collision Detection (CSMA/CD) helps packets that are transmitted simultaneously from different hosts share bandwidth evenly.

6. B. A 10GBaseSR cable can have a maximum distance of 990 feet (302 meters).

7. B. With half duplex, you are using only one wire pair at a time, with a digital signal either transmitting or receiving.

8. A. Full-duplex Ethernet uses two pairs of wires at the same time.

9. C. A 10GBaseLR implementation can go a distance of up to 6 miles.

10. B. Double up! You can get 20 Mbps with a 10 Mbps Ethernet running full duplex or 200 Mbps for Fast Ethernet.

11. B. Full-duplex communication cannot be used with a hub because a hub is a half-duplex single communication device. A host, switch, and router have the ability to process traffic (frames), whereas a hub is a multiport repeater.

12. B. 11000000 is 192, 10101000 is 168, 00110000 is 48, and 11110000 is 240.

13. B. In February 2011, the IEEE finally published a standard for Broadband over Power Line (BPL) called IEEE 1901; this is also referred to as Power Line Communication (PLC) or even Power Line Digital Subscriber Line (PDSL).

14. C. Nibble values are 8 + 4 + 2 + 1, giving us a maximum value of 15. If we have a decimal value of 10, that means the 8 bit and the 2 bit are turned on.

15. D. The 128, 64, 32, and 8 bits are on, so just add the values: 128 + 64 + 32 + 8 = 232.

16. B. The first 10 hexadecimal digits (0–9) are the same values as the decimal values. We already know the binary value for the number 10 is 1010—in hex, the number 10 needs to be displayed as a single character. To display double-digit numbers as a single character, we substitute letters. In our example, 10 is A.

17. C. A MAC, or hardware, address is a 48-bit (6-byte) address written in hexadecimal format.

18. A. 100BaseT and 1000BaseT both have a maximum distance of 100 meters, or 328 feet.

19. B. The FCS can detect frames in the sequence by calculating the cyclic redundancy check (CRC), which verifies that all the bits in the frame are unchanged.

20. C. The 100 means 100 Mbps. The *Base* means *baseband*, which refers to baseband technology—a signaling method for communication on the network.

Chapter 5: Networking Devices

1. C. NICs are the physical network connections for a computer but are not one of the devices or mediums used to provide Internet access in a SOHO setting.

2. C. Like a hub, a switch connects multiple segments of a network together, with one important difference. Whereas a hub sends out anything it receives on one port to all the others, a switch recognizes frame boundaries and pays attention to the destination MAC address of the incoming frame as well as the port on which it was received.

3. B. When we say segment, we mean to create multiple collision or broadcast domains. Hubs don't segment a network; they just connect network segments together. Repeaters don't segment the network; they repeat a signal and allow the distance covered to be increased. So the only correct option is B, a switch.

4. A. The primary function of a bridge is to keep traffic separated on both sides of it, breaking up collision domains.

5. A. Hubs create one collision domain and one broadcast domain.

6. B. By allowing full-duplex operation on each port, a switch provides extra bandwidth to each port.

7. B. A switch is typically just a Layer 2 device segmenting the network by using MAC addresses. However, some higher-end switches can provide Layer 3 services.

8. D. Remember that DHCP servers assign IP addresses to hosts. Thus, DHCP allows easier administration than providing IP information to each host by hand (called static IP addressing).

9. B. Multilayer switches (also called Layer 3 switches) don't have fewer features, less bandwidth, or fewer ports than a normal switch; they just allow routing functions between subnets.

10. B. A load balancer uses a little trickery and sends incoming packets to one or more machines that are hidden behind a single IP address. Modern load-balancing routers can use different rules to make decisions about where to route traffic, which can be based on least load, fastest response times, or simply balancing requests.

11. A. DNS translates human names to IP addresses for routing your packet through the Internet. Hosts can receive the IP address of this DNS server and then resolve hostnames to IP addresses.

12. C. Routers, switches, and bridges are all devices that help break up big networks into a number of smaller ones—also known as network segmentation. Hubs don't segment networks—they just connect network segments together.

13. A. Web cache, of course! Most proxy programs provide a means to deny access to certain URLs in a blacklist, thus providing content filtering, usually in corporate environments.

14. D. Options A, B, and C all aid in boosting network performance, so the only option left is broadcast storms. Increased traffic will increase LAN congestion.

15. B. If the DHCP server has stopped functioning, it will not hand out IP addresses to hosts that are restarted. However, the hosts that were not shut down still have IP addresses because the lease time has not expired.

16. D. A proxy server can be used to prevent external traffic from reaching your internal network directly and can also be used to filter the sites to which your users are allowed to connect.

17. C. Switches create separate collision domains but a single broadcast domain. Remember that routers provide a separate broadcast domain for each interface.

18. A. Using appliances to offload functions such as encryption, content filtering, and VPN concentration can decrease the workload of other systems and add functionality that may be present in these dedicated devices.

19. C. A DNS server uses many types of records. An A record is a hostname to IP address record, and a pointer record is an IP address to hostname record.

20. D. A proxy server can provide many functions. A proxy server can use a caching engine so repeated access requests for web information would accelerate repeated access for users, and they can also limit the availability of websites.

Chapter 6: Introduction to the Internet Protocol

1. D. SMTP resides at the Application layer of the OSI and DoD models.

2. D. HTTPS, or Secure HTTP, uses port 443 by default.

3. C. Dynamic Host Configuration Protocol (DHCP) is used to provide IP information to hosts on your network. DHCP can provide a lot of information, but the most common is IP address, subnet mask, default gateway, and DNS information.

4. B. Address Resolution Protocol (ARP) is used to find the hardware address from a known IP address.

5. B. Secure Shell (SSH) allows you to remotely administer router, switches, and even servers securely.

6. C. The problem is with DNS, which uses both TCP and UDP port 53.

7. A, B. A client that sends out a DHCP Discover message in order to receive an IP address sends out a broadcast at both Layer 2 and Layer 3. The Layer 2 broadcast is all *F*s in hex, or FF:FF:FF:FF:FF:FF. The Layer 3 broadcast is 255.255.255.255, which means all networks and all hosts. DHCP is connectionless, which means it uses User Datagram Protocol (UDP) at the Transport layer, also called the Host-to-Host layer.

8. E. Telnet uses TCP at the Transport layer with a default port number of 23.

9. C, D. Internet Control Message Protocol (ICMP) is used to send error messages through the network, but ICMP does not work alone. Every segment or ICMP payload must be encapsulated within an IP datagram (or packet).

10. B, C, D, E. SMTP, SNMP, FTP and HTTP are connection oriented and use TCP.

11. A, C, F. DHCP, SNMP, and TFTP use UDP. SMTP, FTP, and HTTP use TCP.

12. C, D, E. Telnet, File Transfer Protocol (FTP), and Trivial FTP (TFTP) are all Application layer protocols. IP is a Network layer protocol. Transmission Control Protocol (TCP) is a Transport layer protocol.

13. C. SMTP is used by a client to send mail to its server and by that server to send mail to another server. POP3 and IMAP are used by clients to retrieve their mail from the server that stores it until it is retrieved. HTTP is only used with web-based mail services.

14. C. Remote Desktop Protocol (RDP) allows you to connect to a remote computer and run programs, as Telnet does. However, the large advantage that RDP has over Telnet is that RDP allows you to have a GUI interface connection.

15. B. Simple Network Management Protocol is typically implemented using version 3, which allows for a connection-oriented service, authentication and secure polling of network devices, and alerts and reports on network devices.

16. D. File Transfer Protocol (FTP) can be used to transfer files between two systems.

17. B. The four layers of the IP stack (also called the DoD model) are Application/Process, Host-to-Host, Internet, and Network Access. The Host-to-Host layer is equivalent to the Transport layer of the OSI model.

18. C. Network Time Protocol will ensure a consistent time across network devices on the network.

19. A. Through the use of port numbers, TCP and UDP can establish multiple sessions between the same two hosts without creating any confusion. The sessions can be between the same or different applications, such as multiple web-browsing sessions or a web-browsing session and an FTP session.

20. D. DNS uses TCP for zone exchanges between servers and UDP when a client is trying to resolve a hostname to an IP address.

Chapter 7: IP Addressing

1. D. The addresses in the range 172.16.0.0 through 172.31.255.255 are all considered private, based on RFC 1918. Use of these addresses on the Internet is prohibited so that they can be used simultaneously in different administrative domains without concern for conflict. Some experts in the industry believe these addresses are not routable, which is not true.

2. B. APIPA uses the link-local private address range of 169.254.0.0 through 169.254.255.255 and a subnet mask of 255.255.0.0.

   APIPA addresses are used by DHCP clients that cannot contact a DHCP server and have no static alternate configuration. These addresses are not Internet routable and cannot, by default, be used across routers on an internetwork.

3. C. Private IP addresses are not routable over the Internet, as either source or destination addresses. Because of that fact, any entity that wishes to use such addresses internally can do so without causing conflicts with other entities and without asking permission of any registrar or service provider. Despite not being allowed on the Internet, private IP addresses are fully routable on private intranets.

4. D. The Class A range is 1 through 126 in the first octet/byte, so only option D is a valid Class A address.

5. C. The Class B range is 128 through 191 in the first octet/byte. Only option C is a valid Class B address.

6. B. If you turned on all host bits (all of the host bits are 1s), this would be a broadcast address for that network.

7. B. A Layer 2 broadcast is also referred to as a MAC address broadcast, which is in hexadecimal and is FF.FF.FF.FF.FF.FF.

8. C. A default Class C subnet mask is 255.255.255.0, which means that the first three octets, or first 24 bits, are the network number.

9. A. Packets addressed to a unicast address are delivered to a single interface. For load balancing, multiple interfaces can use the same address.

10. C. I wonder how many of you picked APIPA address as your answer? An APIPA address is 169.254.*x*.*x*. The host address in this question is a public address. Somewhat of a tricky question if you did not read carefully.

11. B. An IPv6 address is 128 bits in size.

12. B. Packets addressed to a multicast address are delivered to all interfaces identified by the multicast address, the same as in IPv4. A multicast address is also called a one-to-many address. You can tell multicast addresses in IPv6 because they always start with *FF*.

13. C. Anycast addresses identify multiple interfaces, which is the same as multicast; however, the big difference is that the anycast packet is delivered to only one address: the first one it finds defined in terms of routing distance. This address can also be called one-to-one-of-many or one-to-nearest.

14. A, C. The loopback address with IPv4 is 127.0.0.1. With IPv6, that address is ::1.

15. B, D. In order to shorten the written length of an IPv6 address, successive fields of zeros may be replaced by double colons. In trying to shorten the address further, leading zeros may also be removed. Just as with IPv4, a single device's interface can have more than one address; with IPv6 there are more types of addresses and the same rule applies. There can be link-local, global unicast, and multicast addresses all assigned to the same interface.

16. C, D. IPv4 addresses are 32 bits long and are represented in decimal format. IPv6 addresses are 128 bits long and represented in hexadecimal format.

17. D. Only option D is in the Class C range of 192 through 224. It might look wrong because there is a 255 in the address, but this is not wrong—you can have a 255 in a network address, just not in the first octet.

18. C, E. The Class A private address range is 10.0.0.0 through 10.255.255.255. The Class B private address range is 172.16.0.0 through 172.31.255.255, and the Class C private address range is 192.168.0.0 through 192.168.255.255.

19. B. This can be a hard question if you don't remember to invert the 7th bit! Always look for the 7th bit when studying for the exam. The EUI-64 autoconfiguration inserts an FF:FE in the middle of the 48-bit MAC address to create a unique IPv6 address.

20. C. Option C is a multicast address and cannot be used to address hosts.

Chapter 8: IP Subnetting, Troubleshooting IP, and Introduction to NAT

1. D. A /27 (255.255.255.224) is 3 bits on and 5 bits off. This provides 8 subnets, each with 30 hosts. Does it matter if this mask is used with a Class A, B, or C network address? Not at all. The number of host bits would never change.

2. B. Don't freak because this is a Class A. What is your subnet mask? 255.255.255.128. Regardless of the class of address, this is a block size of 128 in the fourth octet. The subnets are 0 and 128. The 0 subnet host range is 1–126, with a broadcast address of 127. The 128 subnet host range is 129–254, with a broadcast address of 255. You need a router for these two hosts to communicate because they are in different subnets.

3. C. This is a pretty simple question. A /28 is 255.255.255.240, which means that our block size is 16 in the fourth octet (0, 16, 32, 48, 64, 80, and so on). The host is in the 64 subnet.

4. F. A CIDR address of /19 is 255.255.224.0. This is a Class B address, so that is only 3 subnet bits, but it provides 13 host bits, or 8 subnets, each with 8,190 hosts.

5. C. The host ID of 10.0.37.144 with a 255.255.254.0 mask is in the 10.0.36.0 subnet (yes, you need to be able to subnet in this exam!). Do not stress that this is a Class A; what we care about is that the third octet has a block size of 2, so the next subnet is 10.0.38.0, which makes the broadcast address 10.0.37.255. The default gateway address of 10.0.38.1 is not in the same subnet as the host. Even though this is a Class A address, you still should easily be able to subnet this because you look more at the subnet mask and find your interesting octet, which is the third octet in this question. 256 – 254 = 2. Your block size is 2.

6. D. A /30, regardless of the class of address, has a 252 in the fourth octet. This means we have a block size of 4 and our subnets are 0, 4, 8, 12, 16, and so on. Address 14 is obviously in the 12 subnet.

7. D. A point-to-point link uses only two hosts. A /30, or 255.255.255.252, mask provides two hosts per subnet.

8. C. Devices with Layer 3 awareness, such as routers and firewalls, are the only ones that can manipulate the IP header in support of NAT.

9. A. A /29 (255.255.255.248), regardless of the class of address, has only 3 host bits. Six hosts is the maximum number of hosts on this LAN, including the router interface.

10. C. A computer should be configured with an IP address that is unique throughout the reachable internetwork. It should be configured with a subnet mask that matches those of all other devices on its local subnet, but not necessarily one that matches the mask used on any other subnet. It should also be configured with a default gateway that matches its local router's interface IP address.

11. A. A /29 (255.255.255.248) has a block size of 8 in the fourth octet. This means the subnets are 0, 8, 16, 24, and so on. 10 is in the 8 subnet. The next subnet is 16, so 15 is the broadcast address.

12. B. A 24-bit mask, or prefix length, indicates that the entire fourth octet is used for host identification. In a special case, such as this, it is simpler to visualize the all-zeros value (172.16.1.0) and the all-ones value (172.16.1.255). The highest usable address, the last one before the all-ones value, is 172.16.1.254.

13. A, E. First, if you have two hosts directly connected, as shown in the graphic, then you need a crossover cable. A straight-through cable won't work. Second, the hosts have different masks, which puts them in different subnets. The easy solution is just to set both masks to 255.255.255.0 (/24).

14. A. A /25 mask is 255.255.255.128. Used with a Class B network, the third and fourth octets are used for subnetting with a total of 9 subnet bits: 8 bits in the third octet and 1 bit in the fourth octet. Because there is only 1 bit in the fourth octet, the bit is either off or on—which is a value of 0 or 128. The host in the question is in the 0 subnet, which has a broadcast address of 127 because 128 is the next subnet.

15. A. A /28 is a 255.255.255.240 mask. Let's count to the ninth subnet (we need to find the broadcast address of the eighth subnet, so we need to count to the ninth subnet). We start at 16 (remember, the question stated that we will not use subnet 0, so we start at 16, not 0): 16, 32, 48, 64, 80, 96, 112, 128, 144. The eighth subnet is 128, and the next subnet is 144, so our broadcast address of the 128 subnet is 143. This makes the host range 129–142. 142 is the last valid host.

16. C. A /28 is a 255.255.255.240 mask. The first subnet is 16 (remember that the question stated not to use subnet 0), and the next subnet is 32, so our broadcast address is 31. This makes our host range 17–30. 30 is the last valid host.

17. A. The best method here is to check the configuration of devices that were using the old router as a gateway to the rest of the internetwork. Routers do not periodically cache their configurations to servers of any sort. You might have copied the old router's configuration to a TFTP server or the like, but failing that, you will have to rebuild the configuration from scratch, which might well be much more than interface addresses. Therefore, keeping a copy of the router's current configuration somewhere other than on the router is a wise choice. Routers don't auto-configure themselves; we wouldn't want them to.

18. E. A Class B network ID with a /22 mask is 255.255.252.0, with a block size of 4 in the third octet. The network address in the question is in subnet 172.16.16.0 with a broadcast address of 172.16.19.255. Only option E has the correct subnet mask listed, and 172.16.18.255 is a valid host.

19. D, E. The router's IP address on the E0 interface is 172.16.2.1/23, which is a 255.255.254.0. This makes the third octet a block size of 2. The router's interface is in the 2.0 subnet, and the broadcast address is 3.255 because the next subnet is 4.0. The valid host range is 2.1 through 3.254. The router is using the first valid host address in the range.

20. A. Network Address Translation can allow up to 65,000 hosts to get onto the Internet with one IP address by using Port Address Translation (PAT).

Chapter 9: Introduction to IP Routing

1. C. Yep, you got it. RIP, RIPv2, and EIGRP are all examples of routing protocols.

2. C. In dynamic routing, routers update each other about all the networks they know about and place this information into the routing table. This is possible because a protocol on one router communicates with the same protocol running on neighbor routers. If changes occur in the network, a dynamic routing protocol automatically informs all routers about the event.

3. D. Dynamic routing scales well in large networks and routes are automatically added into the routing table. Static routing is done by hand, one route at a time into each router.

4. B. Media Access Control (MAC) addresses are always local on the LAN and never go through and past a router.

5. C. Routing convergence is the time required by the routing protocols to update the routing tables (forwarding tables) on all routers in the network.

6. D. The `arp -a` command will show the ARP cache on your host.

7. D. Hope you answered D! A router will not send a broadcast looking for the remote network—the router will discard the packet.

8. C. RIPv1 and 2 and IGRP are all distance vector (DV) protocols. Routers using a DV protocol send all or parts of their routing table in a routing-update message at a regular interval to each of their neighbor routers.

9. C, D. Open Shortest Path First (OSPF) and Intermediate System-to-Intermediate System (IS-IS) are link state (LS) routing protocols.

10. B. The only protocol you could select is Enhanced Interior Gateway Routing Protocol (EIGRP).

11. A. Interior Gateway Routing Protocol is a distance vector (DV) interior gateway protocol.

12. C. Border Gateway Protocol (BGP) is the most popular choice for ISPs or really large corporations.

13. A, C. Distance vector (DV) and link state (LS) are the two routing protocols to remember.

14. A, D. A frame uses MAC addresses to send a packet on the LAN. The frame will take the packet to either a host on the LAN or a router's interface if the packet is destined for a remote network.

15. A. I hope you said A! Packets specifically have to be carried to a router in order to be routed through a network.

16. C. Remember that the frame changes at each hop but that the packet is never changed in any way until it reaches the destination device.

17. D. When the routing tables are complete because they include information about all networks in the internetwork, they are considered converged.

18. A. This is step 6 in the IP routing process. If the hardware address isn't in the ARP cache of the host, an ARP broadcast is sent out onto the local network to search for the hardware address.

19. C. The best answer would be to reroute traffic using a temporary static route until the maintenance is complete on the router.

20. A. You are most likely to see a Request Timed Out message when (if) a packet is lost on the way back to the originating host for an unknown error. Remember, if the error occurs because of a known issue, you are likely to see a Destination Unreachable message.

Chapter 10: Routing Protocols

1. C, D, F. RIPv1 and IGRP are true distance vector routing protocols and can't do much, really—except build and maintain routing tables and use a lot of bandwidth! RIPv2, EIGRP, and OSPF build and maintain routing tables, but they also provide classless routing, which allows for VLSM, summarization, and discontiguous networking.

2. B, C. RIP and RIPv2 are distance vector routing protocols. OSPF and IS-IS are link state.

3. A, D. RIP and RIPv2 are distance vector routing protocols. OSPF and IS-IS are link state.

4. B, E. RIP and RIPv2 are distance vector routing protocols. OSPF and IS-IS are link state. EIGRP uses qualities from both distance vector and link state to create a hybrid routing protocol. BGP can be used as an EGP and IGP, and the objectives consider BGP a hybrid routing protocol.

5. C. Dynamic routing is typically used in today's networks because it scales to larger networks and takes less administrative work.

6. F. Hot Standby Router Protocol (HSRP) is Cisco's FHRP.

7. C. Static routes may be a good solution, but remember that they are not dynamic, and if a piece of equipment goes down, new routes to remote networks will not automatically update, so OSPF is the best answer. It dynamically will update the routing tables with faster convergence than RIP.

8. C. The administrative distance (AD) is a very important parameter in a routing protocol. The lower the AD, the more trusted the route. If you have IGRP and OSPF running, by default IGRP routes would be placed in the routing table because IGRP has a lower AD of 100. OSPF has an AD of 110. RIPv1 and RIPv2 both have an AD of 120, and EIGRP is the lowest at 90.

9. B. The routing protocols that have been upgraded to advertise IPv6 routes are RIPng, OSPFv3, and EIGRPv6. IS-IS can advertise IPv6 routes as well, but no upgrade was needed for IS-IS.

10. C. Dynamic routing protocols, like RIP, EIGRP and OSPF, automatically add route updates to the routing table. Static routes must be added by hand.

11. A. The distance vector protocols RIPv1 and RIPv2 both have a maximum hop count of 15 (remember, 16 is unreachable). IGRP and EIGRP have a hop count of 255, and OSPF doesn't have a maximum hop count.

12. B. Routing convergence time is the time for all routers to update their routing tables (forwarding tables).

13. C. BGP is used to connect autonomous systems together on the Internet because of its ability to make classless routing and summarization possible. This helps to keep routing tables smaller and more efficient at the ISP core.

14. B. RIPv1 sends broadcasts every 30 seconds and has an AD of 120. RIPv2 sends multicasts (224.0.0.9) every 30 seconds and also has an AD of 120. RIPv2 sends subnet-mask information with the route updates, which allows it to support classless networks and noncontiguous networks. RIPv2 also supports authentication between routers; RIPv1 does not.

15. A, B. Both RIPv1 and RIPv2 have an AD of 120. EIGRP has an AD of 90 and OSPF is 110.

16. C. Border Gateway Protocol (BGP) attributes include the IP address to get to the next AS (the next-hop attribute) as well as an indication of how the networks at the end of the path were introduced into BGP (the origin code attribute). The AS path information is useful to construct a graph of loop-free autonomous systems and is used to identify routing policies so that restrictions on routing behavior can be enforced based on the AS path.

17. A. RIPng, which uses port 521, has many of the same features as RIPv2: It's a distance vector protocol; it has a max hop count of 15; and it uses split horizon, poison reverse, and other loop-avoidance mechanisms. And it still uses multicast to send its updates, too, but in IPv6, it uses FF02::9 for the transport address. For RIPv2, the multicast address was 224.0.0.9, so the address still has a 9 at the end in the new IPv6 multicast range.

18. B, C. EIGRP holds three tables in RAM: neighbor, topology, and routing. The neighbor and topology tables are built and also maintained with the use of hello packets.

19. D. A successor route (think "successful" rather than standby or backup) is used by EIGRP to forward traffic to a destination and is stored in the routing table. It is backed up by a feasible successor route that is stored in the topology table—if one is available. Remember that all routes are in the topology table.

20. A. RIP and RIPv2 use only hop count as a metric, with a maximum of 15 hops, to find the best path to a remote network.

Chapter 11: Switching and Virtual LANs

1. D. By creating and implementing VLANs in your switched network, you can break up broadcast domains at Layer 2. For hosts on different VLANs to communicate, you must have a router or Layer 3 switch.

2. B, D. Hosts are connected to a switch and are members of one VLAN. This is called an access port. Trunk links connect between switches and pass information about all VLANs.

3. C. Virtual LANs break up broadcast domains in Layer 2 switched internetworks.

4. C, E. Both 802.1D and 802.1w are IEEE STP versions, with 802.1w being the latest and greatest version.

5. D, E. The best answers are that the VLAN membership for the port is configured incorrectly and that STP shut down the port.

6. B, C, F. VLANs break up broadcast domains in a switched Layer 2 network, which means smaller broadcast domains. They allow configuration by logical function instead of physical location and can create some security if configured correctly.

7. B. The Spanning Tree Protocol is used to stop switching loops in a switched network with redundant paths.

8. A, E. Bridges break up collision domains, which would increase the number of collision domains in a network and also make smaller collision domains.

9. C. In order to see all frames that pass through the switch and read the packets with a network analyzer, you need to enable port mirroring on the port your diagnostic host is plugged into.

10. C. Trunking allows switches to pass information about many or all VLANs configured on the switches.

11. A, C, E. Layer 2 features include address learning, forwarding and filtering of the network, and loop avoidance.

12. B. Switches break up collision domains, and routers break up broadcast domains.

13. C. With the exception of the source port, switches flood all frames that have an unknown destination address. If a device answers the frame, the switch will update the MAC address table to reflect the location of the device.

14. C. Because the source MAC address is not in the MAC address table, the switch will add the source address and the port it is connected to into the MAC address table and then forward the frame to the outgoing port.

15. D. Virtual Trunk Protocol (VTP) is a Cisco proprietary method of having a single VLAN database advertised to all other switches in your network. This allows for ease of VLAN management in a larger network. Option C is not a possible configuration, by the way; I made that up.

16. A, B. The sequence of steps for STP convergence is, by default, blocking, listening, learning, forwarding, disabled. When all ports are in either the blocking or forwarding state, STP is converged.

17. C, D. In the blocking and listening states, the MAC address table is not learning. Only in the learning and forwarding states is the MAC address table learning MAC addresses and populating the MAC address table.

18. B. Switches break up collision domains by default, but the network is still one large broadcast domain. In order to break up broadcast domains in a Layer 2 switched network, you need to create virtual LANs.

19. C. If you are configuring voice VLANs, you'll want to configure Quality of Service (QoS) on the switch ports to provide a higher precedence to voice traffic over data traffic to improve quality of the line.

20. B. Be careful when using port mirroring/spanning on a switch because it can cause a lot of overhead on the switch and possibly crash your network. It's therefore a good idea to use this feature at strategic times and only for short periods, if possible.

Chapter 12: Wireless Networking

1. C. It is imperative that a good site survey is completed before you install your wireless network. Trying various types of antennas and their placements is the key to covering the whole wireless area.

2. C. TLS provides really good wireless security, but it's hard to implement because you need to install a certificate on your server and also on all your clients. TTLS only uses a server-side certificate.

3. C. The IEEE 802.11b and IEEE 802.11g both run in the 2.4 GHz RF range.

4. B, D. If you are running 802.11b/g frequency, which most networks are, then you can receive interference from microwave ovens and cordless phones.

5. D. 802.11n uses channel bonding of both the 2.4 GHz range and the 5 GHz range to get increased bandwidth of over 100 Mbps.

6. D. Bluetooth works wirelessly to connect our phones, keyboards, and so on in small areas, also known as personal area networks (PANs).

7. B. The IEEE 802.11a standard provides up to 12 non-overlapping channels, or up to 23 if you add the 802.11h standard.

8. D. The IEEE 802.11a standard provides a maximum data rate of up to 54 Mbps.

9. C. If you have a large area to cover with wireless, you need to be concerned with channel overlap.

10. B. The IEEE 802.11b standard provides a maximum data rate of up to 11 Mbps.

11. B. If everything is correctly configured on the host, then MAC filtering would stop the host from connecting to the AP. If you try to connect and can't, check the AP's settings.

12. A. The IEEE 802.11i standard replaced Wired Equivalent Privacy (WEP) with a specific mode of the Advanced Encryption Standard (AES) known as the Counter Mode Cipher Block Chaining-Message Authentication Code (CBC-MAC) protocol. This allows AES-Counter Mode CBC-MAC Protocol (AES-CCMP) to provide both data confidentiality (encryption) and data integrity.

13. C. If you disable SSID broadcasting, which you should, then you must configure the SSID name on the clients that need to connect to the AP.

14. B. The IEEE 802.11b standard uses Direct Sequence Spread Spectrum (DSSS). If you are running 802.11g, it uses Orthogonal Frequency Division Multiplexing (OFDM).

15. B. If you are running an extended service set (meaning more than one AP with the same SSID), you need to overlap the cell coverage by 10 percent or more so clients will not drop out while roaming.

16. B. You need to use directional antennas, like a Yagi, to get the best signal between antennas.

17. A. Extended service set ID means that you have more than one access point, they all are set to the same SSID, and they are all connected together in the same VLAN or distribution system so users can roam.

18. D. WPA is cool because it is easy to configure and works great. Type in a passphrase (assuming you're using a pre-shared key) and you're done. Plus, you have great security because the keys change dynamically.

19. C. 802.11n uses two 20 MHz wide channels to create a 40 MHz wide channel, which provides over 100 Mbps wireless.

20. B. 802.11n MIMO sends multiple frames by several antennas over several paths. The frames are then recombined by another set of antennas to optimize throughput and multipath resistance. This is called spatial multiplexing.

Chapter 13: Authentication and Access Control

1. A. A nonpersistent agent is one that is used to assess the device only during the onetime check-in at login. It can be used to support the assessment of endpoints not owned by the organization and as such can help to make a Bring Your Own Device (BYOD) policy possible.

2. C. On a private network, only authorized users have access to the data, whereas in a public network, everyone connected has access to the data.

3. B. After determining that the user has Internet access, your next step would be to verify the VPN address and password.

4. D. To have good security on your network, deny any addresses from your internal networks, deny any local host addresses (127.0.0.0/8), deny any reserved private addresses, and deny any addresses in the IP multicast address range (224.0.0.0/4).

5. D. Tunneling is encapsulating one protocol within another protocol to complete a secure transmission. Options A, B, and C are all tunneling protocols you should be aware of, as well as Secure Sockets Layer Virtual Private Network (SSL VPN) and Point-to-Point Tunneling Protocol (PPTP).

6. A. SSL is based on RSA public-key encryption and is used to provide secure Session layer connections over the Internet between a web browser and a web server.

7. C. The minimum length should be 8 characters, and the maximum length should be 15 characters. A strong password is a combination of alphanumeric and special characters that is easy for you to remember but difficult for someone else to guess.

8. B. IPSec works at the Network layer of the OSI model (Layer 3) and secures all applications that operate above it (Layer 4 and above). Additionally, because it was designed by the IETF and designed to work with IPv4 and IPv6, it has broad industry support and is quickly becoming the standard for VPNs on the Internet.

9. D. IPSec works in both transport mode and tunneling mode. In transport mode, a secure IP connection between two hosts is created. Data is protected by authentication or encryption (or both). Tunnel mode is used between network endpoints to protect all data going through the tunnel.

10. B. Companies that want to ensure that their data is secure during transit should encrypt their data before transmission. Encryption is the process that encodes and decodes data.

11. A, C. Some older network utilities such as FTP and Telnet don't have the ability to encrypt passwords.

12. C. To encode a message and decode an encrypted message, you need the proper encryption key or keys. The encryption key is the table or formula that defines which character in the data translates to which encoded character.

13. C. TLS was available for use with VPNs in earlier versions prior to 2.0.

14. D. The Data Encryption Standard (DES) is not a type of public-key encryption.

15. D. PPTP is a VPN protocol that was created by Microsoft and uses TCP port 1723 for authetication and Generic Routing Encapsulation (GRE) to encrpyt data at the Application level.

16. B. PPPoE has only two stages: discovery and session. In the discovery phase, the MAC addresses of the endpoints are exchanged so that a secure PPP connection can be made.

17. C. A fingerprint is an example of something you are. Other examples are retina scans and facial recognition.

18. A. RADIUS servers provide both authentication and encryption services and can combine these into one service. RADIUS can be used for allowing or denying both wired and wireless access at the domain level.

19. A. RADIUS combines user authentication and authorization into one centralized database and maintains user profiles.

20. D. Independent Computing Architecture (ICA) is a protocol designed by Citrix Systems to provide communication between servers and clients. ICA is a remote-access method.

Chapter 14: Network Threats and Mitigation

1. D. A denial of service (DoS) attack prevents users from accessing the system. All of the options are possible denial-of-service attacks.

2. A. Session fixation is an attack in which the attacker sets the session ID ahead of time by sending a link to the victim with the ID preset. Then when the user connects, the attacker waits for the authentication to complete and takes over the session by disconnecting the user and using the ID to reconnect.

3. A. Options B, C, and D are all DoS attacks, so the only real answer is a file virus. A file virus attacks executable application and system program files scanning for networks.

4. A. In war driving, the attacker simply drives around with a high-powered antenna connected to a wireless laptop.

5. D. These are all examples of boot-sector viruses that get into the master boot record. A boot-sector virus will overwrite the boot sector, thereby making it look as if there is no pointer to your operating system. When you power up the computer, you will see a Missing Operating System or Hard Disk Not Found error message.

6. A. A multipartite virus is one that affects both the boot sector and files on your computer.

7. C. A worm can actively replicate itself without user intervention, whereas a virus can be activated and spread only if a user opens an application.

8. B. A brute force attack is a software-related attack that employs a program that is running on a targeted network to log in to some type of shared network resource like a server.

9. A. Social engineering, or phishing, refers to the act of attempting to illegally obtain sensitive information by pretending to be a credible source. Phishing usually takes one of two forms: an email or a phone call.

10. B. A clean-desk policy means that all important documents, such as books, schematics, confidential letters, and the like, are removed from the desk (and locked away) when employees leave their workstations.

11. D. It is important to train all employees by informing them that people may try to call and email them to gather information to attack the company. This is called phishing or social engineering.

12. B. When you set the AP to not broadcast the SSID, it will remove the SSID from packets called beacons (these are the packets that populate the display when you scan for networks) but the SSID will still be present in many other packet types.

13. A. A security procedure defines the appropriate response to a security event on your network.

14. A. Soon after WEP's adoption as a security measure, it was discovered that due to a weakness in the way the algorithm was employed, programs that became widely available on the Internet could be used to crack the WEP key.

15. B. Windows Update is a utility that is typically automatically installed when you install Windows. The update engine will periodically scan your system for the version of Windows components you have installed and compare them to the most current versions available from Microsoft. If your software is out-of-date, a Windows Update dialog box will appear, asking if you want to install the software updates.

16. C. With so much code written for applications and operating systems, developers go back after the initial release to fix any problems that are uncovered. These fixes are released as hotfixes or patches.

17. A. The first responder is responsible for securing the crime scene and protecting the evidence from corruption.

18. D. Heuristic scanning allows for this type of scanning. The engine looks for suspicious activity that might indicate a virus.

19. A. Every week, you need to update your list of known viruses—called the virus definition files. You can do this manually or automatically through the manufacturer's website. You can use a staging server within your company to download and then distribute the updates, or you can set up each computer to download updates.

20. D. An antivirus program examines the computer suspected of being infected and eradicates any viruses it finds using any of these methods.

Chapter 15: Physical Security and Risk

1. C. Firewalls work by allowing only packets that pass security restrictions to be forwarded through the firewall. A firewall can also permit, deny, encrypt, decrypt, and proxy all computer traffic that flows through it; this can be between a public and private network or between different security domains (or zones) on a private network. You, as the administrator, set up the rules by which a firewall decides to forward or reject packets of data.

2. B. Proximity readers are door controls that read a card from a short distance and are used to control access to sensitive rooms.

3. B. A network-based firewall is what companies use to protect their private network from attacks sourced in the public network. The defining characteristic of this type of firewall is that it's designed to protect an entire network of computers as opposed to just one system. This is usually a combination of hardware and software. A host-based firewall is implemented on one machine and is designed to protect that machine only. Most often, this is implemented as software; no additional hardware is required on your personal computer to run a host-based firewall.

4. C. A properly designed disaster recovery plan (DRP) minimizes the effect of a disaster and includes the steps necessary to resume normal operation. The DRP is implemented when the emergency occurs and includes the steps to restore functions and systems.

5. B. Nessus cannot identify incorrect IP addresses.

6. C. One of the benefits of using a firewall is that it helps protect LAN resources from unwanted attacks.

7. B. An intrusion detection system (IDS) monitors network traffic, looking for signs of an intrusion. Intrusions are detected by an attack signature.

8. A. RAID-0, also called disk striping, writes the data across multiple drives. While it improves performance, it does not provide fault tolerance.

9. C. Standard, extended, and outbound are all types of ACLs. Referred is not.

10. B. You can sometimes just ignore the attack because it's possible it won't affect your network. This is called shunning.

11. C. A DMZ can be set up many different ways, but the best explanation is that the DMZ is used to separate and secure your inside network from the Internet while still allowing hosts on the Internet to access your servers.

12. E. Most firewalls provide content filtering, signature identification, and the ability to segregate network segments into separate security zones. Most firewalls are also capable of performing scanning services, which means that they scan different types of incoming traffic in an effort to detect problems.

13. A. In a blind test, the testing team is provided with limited knowledge of the network systems and devices, using publicly available information. The organization's security team knows that an attack is coming. This type of test requires more effort by the testing team.

14. B. Nessus is a proprietary vulnerability scanning program that requires a license for commercial use yet is the single most popular scanning program in use.

15. C. Nmap does not collect passwords.

16. D. Changing network configurations, terminating sessions, and deceiving the attacker are all actions that can be taken by an IPS device.

17. D. Proxies act on behalf of the whole network to completely separate packets from internal hosts and external hosts.

18. B. Nessus operates by performing a port scan and then follows up with more specific tests, but it cannot identify IP address conflicts.

19. C. A stateful firewall keeps track of the established connections passing through it. When another packet is received that's part of an existing connection (part of a current state), the packet is passed without checking the ACLs.

20. C. An intrusion prevention system (IPS) is like an IDS but with two key differences. First, it learns what is "normal" on the network and can react to abnormalities even if they're not part of the signature database. Second, it can issue an active response such as shutting down a port, resetting connections, or attempting to lull an attacker into a trap.

Chapter 16: Wide Area Networks

1. D. Routing Information Protocol (RIP) is not a WAN protocol but a routing protocol used in internetworks.

2. C. These different protocols and technologies all occupy the lower three layers of the OSI model: the Physical layer, the Data Link layer, and sometimes the Network layer. Most WAN protocols work only at the Physical layer and Data Link layer.

3. B. The demarcation point is the precise spot where the service provider's responsibility ends and the CPE begins.

4. D. The European version of the T1 is the E1, which operates at 2.048 Mbps and uses 30 64 Kbps channels (30 DS0s), and two channels are used for D channels, which makes 32 total DS0s.

5. C. The demarc is the precise spot where the service provider's (local exchange carrier's) responsibility ends and the CPE begins. It's generally a device in a telecommunications closet owned and installed by the telecommunications company (telco).

6. D. Cable is a great cost-effective connection for a small office or home office (SOHO).

7. C. A T1 has a line speed of 1.544 Mbps. This 1.544 Mbps connection uses Digital Signal 1 (DS1) and aggregates 24 discrete 64 Kbps channels that use Digital Signal 0 (DS0). Other T-series connections have greater maximum connection speeds.

8. C. LTE is true 4G and has the best data rates.

9. B. OC-1, OC-3, OC-12, OC-48, and OC-192 are the normal service offerings. OC-1 has the lowest data rate at 51.84 Mbps, and OC-192 is the highest at 9.953 Gbps.

10. A. Bluetooth uses a radio technology called Frequency Hopping Spread Spectrum. It chops up the data being sent and transmits chunks of it through the air on up to 75 different frequencies.

11. C. The *x* in *x*DSL represents the different letters that refer to the DSL flavors. *x*DSLs use high-frequency signals, whereas regular phone calls use low-frequency signals over the same lines.

12. C. ADSL, HDSL, SDSL, VDSL or VHDSL, and VDSL2 are all common *x*DSL types. Synchronous Optical Network (SONET) is the standard for synchronous data transmission on optical fiber.

13. D. DOCSIS stands for data over cable service Interface Specifications. All cable modems and like devices have to measure up to this standard.

14. C. Optical carrier 12 has speeds up to 622 Mbps.

15. C. ATM uses a high-speed cell-switching technology that can handle data as well as real-time voice and video. The ATM protocol breaks up transmitted data into 53-byte cells.

16. A. Frame Relay is the frame WAN technology in which variable-length packets are transmitted by switching.

17. C. The committed information rate (CIR) is the rate, in bits per second, at which the Frame Relay switch guarantees to transfer data.

18. C. We're thinking in terms of a DSL, so a CSU/DSU is not used, nor is a demarc. If clocking was down, your Internet would be completely down. Input errors could be indicative of a duplex issue.

19. C. The public domain (responsibility of the provider) is the part of the network that allows access into the PSTN (Public Switched Telephone Network) or PLMN (Public Land Mobile Network).

20. A. Benefits of Dynamic Multipoint VPN include elimination of traffic between remote sites traversing the hub, elimination of additional bandwidth requirements at the hub, elimination of additional network delays, conservation of WAN bandwidth, lower costs for VPN circuits, and increased resiliency and redundancy.

Chapter 17: Troubleshooting Tools

1. C. The program Packet Internet Groper (`ping`) is used to find out if a host has the IP stack initialized.

2. A. The `arp` utility is used to display the contents of the ARP cache, which tracks the resolution of IP addresses to physical (MAC) addresses and will produce the displayed output.

3. A. Microsoft has made what it calls Remote Desktop software available for free with Windows products since Windows NT. When this software is installed (installed by default in later versions) on both source and destination computers, a remote desktop connection can be made.

4. B. The purpose of the `ping` utility is to test the communications channel between two IP hosts as well as how long it takes the packets to get from one host to another.

5. C. The `ipconfig /all` utility will display the current configuration of TCP/IP on a given workstation—including the current IP address, DNS configuration, WINS configuration, and default gateway.

6. B, D. The address 127.0.0.1 is the special IP address designated for the local TCP/IP interface. The hostname localhost is the hostname given to the local interface. Therefore, pinging either the IP address or the hostname for the local interface will tell you whether the local interface is working.

7. A. The command `nbtstat -r` displays all the name resolutions performed by the local client as well as their associated IP addresses. The `-R` switch will reload the cache.

8. C. The `arp` utility will show you the resolved MAC to IP address of all hosts on your network segment. Remember, this will work for only local hosts, not remote hosts.

9. B. To purge and reload the remote NetBIOS name cache, you must use `nbtstat -R`. Remember that the `R` must be uppercase and that it will not work correctly without the hyphen before it.

10. B. Commercial sniffers like Wireshark and Omnipeek can capture any packets because they set the NIC to operate in promiscuous mode, which means the NIC processes all packets that it sees.

11. B. The `tracert` utility will give you that output. The `tracert` command (or trace for short) traces the route from the source IP host to the destination host.

12. C. The `tracert` utility will tell you which router is having the performance problem and how long it takes to move between each host. `Tracert` can be used to locate problem areas in a network.

13. A. The `ipconfig /all` switch will display the most complete listing of TCP/IP configuration information, also displaying the MAC address, DHCP lease times, and the DNS addresses.

14. C. The `tracert` utility returns the names and addresses of all routers through which a packet passes on its way to a destination host.

15. E. The `telnet` utility can be used to test if a particular IP host is responding on a particular TCP port.

16. C. The `arp -a` command will display the current contents of the ARP cache on the local workstation.

17. C. `dig` is an old UNIX command that will show you DNS server information.

18. A, D. The `arp` utility's `–a` and `–g` switches perform the same function. They both show the current ARP cache.

19. B. There are three different chain types:

    Input: Controls behavior for incoming connections.

    Forward: Used for incoming connections that aren't being delivered locally (like a router would receive)

    Output: Used for outgoing connections

20. A. To capture traffic on all interfaces, use the `any` keyword with the `-i` (interface) switch.

Chapter 18: Software and Hardware Tools

1. A, B, C. Yep, all of the above. The CompTIA Network+ objectives cover all three in regard to tools used to analyze today's networks.

2. C. The basic purpose of packet sniffers or network analyzers is to collect and analyze each individual packet that is captured on a specific network segment to determine whether problems are happening. You can also use them to see if there is too much traffic on a segment.

3. A. A toner probe sends a signal down a pair of wires so that the wires can be traced. Typically, a butt set is used to find this signal, but toner probe is the best answer to this question.

4. B. An optical time-domain reflectometer (OTDR) is an optoelectronic instrument used to give you the skinny on optical fibers. It works by putting out a series of optical pulses into the specific fiber you want to test and can tell you if a break in the fiber has occurred and where.

5. B. To create a patch cable (568A) to connect your host to a jack in the wall, you need to use a snip.

6. A. Remember that firewalls are the first line of defense for an Internet-connected network. If a network was directly connected to the Internet without a firewall, an attacker could theoretically gain direct access to the computers and servers on that network with little effort. The IDS/IPS software is usually positioned between your internal router and the firewall to the outside network (Internet).

7. C. Hope you answered C! A port scanner is just a piece of software designed to search a network for open hosts. Administrators of networks use port scanners to ensure security and bad guys use them to compromise it.

8. D. Wire-map testing is the most basic type of testing for twisted-pair cables. It detects transposed wires, opens (broken or unconnected wires), and shorts (wires or pins improperly connected to each other).

9. B. A time-domain reflectometer (TDR) is a tool that finds and describes faults in metallic cables like twisted wire pairs and coaxial cables. The equivalent device for optical fiber is an optical time-domain reflectometer (OTDR). A TDR can also check the speed and condition of the signal on the cable.

10. B. A certifier is a combination cable tester and network analyzer, only better. It can test the performance and response times of network resources and certify your full Category 6 cable installation at the same time.

11. D. Unlike port scanners, packet sniffers actually look inside every packet on a network segment at the frame level.

12. C. Due to sensitivity to any variation and impedance, options A, B, D, and E are all reasons you'd use a TDR.

13. A. A multimeter, or a volt/ohm meter (VOM), is used to measure voltage, current, and resistance.

14. D. Otherwise known as a "fox and hound" wire tracer, a toner probe would be useful in this situation. A toner probe will emit an audible tone when it touches the other end of the cable.

15. A. I hope you said A! A punch-down tool would be used if you needed to connect wire to a punch-down block. Most networks today have wiring closets, and to terminate the cables, you're certain to need a punch-down tool.

16. B. A wire crimper, or crimper, is used for attaching ends onto different types of network cables.

17. C. A punch-down tool is used to punch down an RJ-45 cable to an insulation displacement connector, typically a 110 block.

18. D. An everyday surge protector monitors the incoming voltage level and trips a circuit breaker when the voltage reaches a certain level, known as the overvoltage threshold.

19. B. A loopback test is a diagnostic procedure in which a signal is transmitted and returned to the sending device after passing through all or a portion of a network or circuit. A loopback plug makes this test possible.

20. B. Electronic devices are prone to overheating, which is why you should use a temperature monitor.

Chapter 19: Network Troubleshooting

1. A, F. Rebooting servers and routers are not part of the troubleshooting model.

2. B. You need to check basic connectivity. The link light indicates that the network card is making a basic-level connection to the rest of the network. It is a very easy item to check, and if the link light is not lit, it is usually a very simple fix (like plugging in an unplugged cable).

3. B. When wireless users complain that the network is slow (latency) or that they are losing their connection to applications during a session, it is usually latency arising from a capacity issue.

4. B. Although all of these are good tests for network connectivity, checking the server console for user connections will tell you whether other users are able to log into the server. If they can, the problem is most likely related to one of those users' workstations. If they can't, the problem is either the server or network connection. This helps narrow down the problem.

5. B. Because of all the tests given and their results, you can narrow the problem down to the network connectivity of that workstation. And because no other users in her area are having the same problem, it can't be the hub or server. You can log in as the user from your workstation, so you know it isn't a rights issue or username/password issue. The only possible answer listed is a bad patch cable.

6. A. Because other users in the same area aren't having a problem, it can't be a downed server, network hub, or jabbering NIC. And because both you and the user can't log in, more than likely it's a problem specific to that workstation. The only one that would affect your ability to log in from that station is the Caps Lock key being pressed. That will cause the password to be in all uppercase (which most server operating systems treat as a different password), and thus it will probably be rejected.

7. D. Since this is a new connection, you need to start by troubleshooting and identify the symptoms and potential causes.

8. B. According to the Network+ troubleshooting model, the next step would be step 2, establishing the most probable cause.

9. C. After determining the affected area, you need to find out if any changes have taken place.

10. A. Because the user can't log in correctly from any machine, more than likely he is using the wrong procedure for logging in. Because no one else is having that problem (including yourself), the problem must be related to that user.

11. C. After you have implemented a solution, you need to test if the solution works and identify other effects it may have.

12. B. Because you cannot reach the web page that resides on the server, the problem is most likely related to your browser.

13. A, B, C. From a design standpoint, the physical environment for a server should be optimized for items such as placement, temperature, and humidity. When troubleshooting, don't forget to check the physical conditions under which the network device is operating. Check for problems such as those mentioned here as well as EMI/RFI problems, power problems, and unplugged cables.

14. D. Because most of today's networks still consist of large amounts of copper cable, networks can suffer from the physical issues that have plagued all networks since the very beginning of networking (and the answers here are not a complete list). Newer technologies and protocols have lessened these issues but have not resolved them completely.

15. A. Once you have determined that the switch or the configuration of the switch is the problem, you need to escalate the issue.

16. D. Because other people are experiencing the problem, most likely it is either network or server related. Because you can transfer files to and from another server, it can't be the network. Thus, the problem is related to the web server.

17. D. After investigating the problem thoroughly and successfully testing and resolving an issue, you need to document the solution.

18. B. Since users can get to the Internet, this means the DNS server is working and they have the correct default gateway. The intranet server is probably down.

19. C. Performance-monitoring tools can give you an idea of how busy the server and the rest of the network are. These tools use graphs to indicate how much traffic is going through the server.

20. C. Once you escalate the problem, you are done with the seven-step model. Meet with the escalation team to determine the next step.

Chapter 20: Management, Monitoring, and Optimization

1. C. UTP cables use an RJ-45 connector. RJ-11 and RJ-25 are often used for terminating telephone lines.

2. B. Straight-through cables, known as drop cables or patch cables, will have the pins in the same order on both connectors.

3. B. On a crossover cable, one connector has flipped the wires. Specifically, pins 1 and 3 get switched, and pins 2 and 6 get switched.

4. C. If you are going to make your own UTP cables (drop/patch cables) to customize length, you need to make sure that the right wires get to the right pins.

5. C. *Electrostatic discharge (ESD)* is the technical term for what happens when two objects of dissimilar charge come in contact.

6. C. Policies govern how the network is configured and operated as well as how people are expected to behave on the network, such as how users are able to access resources and which types of employees get network access.

7. A. A physical network diagram contains all the physical devices and connectivity paths on your network and should accurately picture how your network physically fits together in detail. This document will also have the firmware revision on all the switches and access points in your network.

8. A. An ICS server, also called a data acquisition server, uses coded signals over communication channels to acquire information about the status of the remote equipment for display or for recording functions.

9. B. Network monitoring can have several names, including load testing, connectivity testing, and throughput testing. You will also hear network monitors referred to as protocol analyzers.

10. D. QoS provides different priority levels to different applications, data flows, or users so that they can be guaranteed a certain performance level.

11. A. Those making the changes should be completely briefed in rollback procedures, and they should exhibit a clear understanding of them prior to implementing the changes.

12. D. The job isn't complete until the paperwork is complete. In this case, network configurations, additions to the network, and physical location changes should be updated to reflect the changed state of the network.

13. B. Common Address Redundancy Protocol (CARP) can be used to increase availability of gateways and firewalls.

14. B. If you add a new cable segment to the network, you need to update the wiring schematics document.

15. C, E. Quality of service (QoS) is basically the ability to provide different priority to one or more types of traffic over other levels for different applications, data flows, or users so that they can be guaranteed a certain performance level.

16. A. Traffic shaping, also known as packet shaping, is a form of bandwidth optimization. It delays packets that meet a certain criteria to guarantee usable bandwidth for other applications. Essentially, with traffic shaping, you're delaying some traffic so other traffic can get through. Traffic shaping uses bandwidth throttling to ensure that certain data streams don't send too much data in a specified period of time.

17. C. Common Address Redundancy Protocol (CARP) can be used to increase availability of gateways and firewalls. It is not related to virtualization.

18. A, B, C, D. There are many bandwidth-intensive programs, like VoIP and video streaming. These are just a few of the reasons it's necessary to try to optimize network performance.

19. C. *Voice over Internet Protocol (VoIP)* is a general term that describes several technologies that are able to deliver voice communications over the Internet or other data networks.

20. A, B, C, D. There are many theories and strategies you can apply to optimize performance on your network. All of them deal with controlling the traffic in some way. Strategies include QoS, traffic shaping, load balancing, high availability, and the use of caching servers. You want to ensure that you have plenty of bandwidth available for those applications that need it, such as critical service operations, VoIP, and real-time multimedia streaming.

Appendix C

Subnetting Class A

Class A subnetting is not performed any differently than subnetting with Classes B and C, but there are 24 bits to play with instead of the 16 in a Class B address and the 8 in a Class C address.

Let's start by listing all the Class A masks:

```
255.0.0.0    (/8)
255.128.0.0  (/9)           255.255.240.0  (/20)
255.192.0.0  (/10)          255.255.248.0  (/21)
255.224.0.0  (/11)          255.255.252.0  (/22)
255.240.0.0  (/12)          255.255.254.0  (/23)
255.248.0.0  (/13)          255.255.255.0  (/24)
255.252.0.0  (/14)          255.255.255.128  (/25)
255.254.0.0  (/15)          255.255.255.192  (/26)
255.255.0.0  (/16)          255.255.255.224  (/27)
255.255.128.0  (/17)        255.255.255.240  (/28)
255.255.192.0  (/18)        255.255.255.248  (/29)
255.255.224.0  (/19)        255.255.255.252  (/30)
```

That's it. You must leave at least 2 bits for defining hosts. And I hope you can see the pattern by now. Remember, we're going to do this the same way as a Class B or C subnet. It's just that, again, we simply have more host bits, and we use the same subnet numbers we used with Class B and Class C, but we start using these numbers in the second octet.

Subnetting Practice Examples: Class A Addresses

When you look at an IP address and a subnet mask, you must be able to distinguish the bits used for subnets from the bits used for determining hosts. This is imperative. If you're still struggling with this concept, please reread Chapter 6, "Introduction to the Internet Protocol." It shows you how to determine the difference between the subnet and host bits and should help clear things up.

Practice Example #1A: 255.255.0.0 (/16)

Class A addresses use a default mask of 255.0.0.0, which leaves 22 bits for subnetting since you must leave 2 bits for host addressing. The 255.255.0.0 mask with a Class A address is using 8 subnet bits.

- *Subnets?* $2^8 = 256$.
- *Hosts?* $2^{16} - 2 = 65{,}534$.

- *Valid subnets?* What is the interesting octet? 256 – 255 = 1. 0, 1, 2, 3, etc. (all in the second octet). The subnets would be 10.0.0.0, 10.1.0.0, 10.2.0.0, 10.3.0.0, etc., up to 10.255.0.0.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first two and last two subnets, valid host range, and broadcast addresses for the private Class A 10.0.0.0 network:

Subnet	**10.0.0.0**	**10.1.0.0**	**…**	**10.254.0.0**	**10.255.0.0**
First host	10.0.0.1	10.1.0.1	…	10.254.0.1	10.255.0.1
Last host	10.0.255.254	10.1.255.254	…	10.254.255.254	10.255.255.254
Broadcast	10.0.255.255	10.1.255.255	…	10.254.255.255	10.255.255.255

Practice Example #2A: 255.255.240.0 (/20)

255.255.240.0 gives us 12 bits of subnetting and leaves us 12 bits for host addressing.

- *Subnets?* 2^{12} = 4096.
- *Hosts?* 2^{12} – 2 = 4094.
- *Valid subnets?* What is your interesting octet? 256 – 240 = 16. The subnets in the second octet are a block size of 1 and the subnets in the third octet are 0, 16, 32, etc.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows some examples of the host ranges—the first three and the last subnets:

Subnet	**10.0.0.0**	**10.0.16.0**	**10.0.32.0**	**…**	**10.255.240.0**
First host	10.0.0.1	10.0.16.1	10.0.32.1	…	10.255.240.1
Last host	10.0.15.254	10.0.31.254	10.0.47.254	…	10.255.255.254
Broadcast	10.0.15.255	10.0.31.255	10.0.47.255	…	10.255.255.255

Practice Example #3A: 255.255.255.192 (/26)

Let's do one more example using the second, third, and fourth octets for subnetting.

- *Subnets?* 2^{18} = 262,144.
- *Hosts?* 2^{6} – 2 = 62.

- *Valid subnets?* In the second and third octet, the block size is 1, and in the fourth octet, the block size is 64.
- *Broadcast address for each subnet?*
- *Valid hosts?*

The following table shows the first four subnets and their valid hosts and broadcast addresses in the Class A 255.255.255.192 mask:

Subnet	**10.0.0.0**	**10.0.0.64**	**10.0.0.128**	**10.0.0.192**
First host	10.0.0.1	10.0.0.65	10.0.0.129	10.0.0.193
Last host	10.0.0.62	10.0.0.126	10.0.0.190	10.0.0.254
Broadcast	10.0.0.63	10.0.0.127	10.0.0.191	10.0.0.255

The following table shows the last four subnets and their valid hosts and broadcast addresses:

Subnet	**10.255.255.0**	**10.255.255.64**	**10.255.255.128**	**10.255.255.192**
First host	10.255.255.1	10.255.255.65	10.255.255.129	10.255.255.193
Last host	10.255.255.62	10.255.255.126	10.255.255.190	10.255.255.254
Broadcast	10.255.255.63	10.255.255.127	10.255.255.191	10.255.255.255

Subnetting in Your Head: Class A Addresses

This sounds hard, but as with Class C and Class B, the numbers are the same; we just start in the second octet. What makes this easy? You only need to worry about the octet that has the largest block size (typically called the interesting octet; one that is something other than 0 or 255)—for example, 255.255.240.0 (/20) with a Class A network. The second octet has a block size of 1, so any number listed in that octet is a subnet. The third octet is a 240 mask, which means we have a block size of 16 in the third octet. If your host ID is 10.20.80.30, what is your subnet, broadcast address, and valid host range?

The subnet in the second octet is 20 with a block size of 1, but the third octet is in block sizes of 16, so we'll just count them out: 0, 16, 32, 48, 64, 80, 96 . . . voilà! (By the way, you can count by 16s by now, right?) This makes our subnet 10.20.80.0, with a broadcast of 10.20.95.255 because the next subnet is 10.20.96.0. The valid host range is 10.20.80.1 through 10.20.95.254. And yes, no lie! You really can do this in your head if you just get your block sizes nailed!

Okay, let's practice on one more, just for fun!

Host IP: 10.1.3.65/23

First, you can't answer this question if you don't know what a /23 is. It's 255.255.254.0. The interesting octet here is the third one: 256 – 254 = 2. Our subnets in the third octet are 0, 2, 4, 6, etc. The host in this question is in subnet 2.0, and the next subnet is 4.0, so that makes the broadcast address 3.255. And any address between 10.1.2.1 and 10.1.3.254 is considered a valid host.

Written Lab 1

Given a Class A network and the net bits identified (CIDR), complete the following table to identify the subnet mask and the number of host addresses possible for each mask.

Classful Address	Subnet Mask	Number of Hosts per Subnet (2x – 2)
/16		
/17		
/18		
/19		
/20		
/21		
/22		
/23		
/24		
/25		
/26		
/27		
/28		
/29		
/30		

Written Lab 2

Given the decimal IP address, write in the address class, number of subnet and host bits, number of subnets, and number of hosts for each IP address.

Decimal IP Address	Address Class	Number of Subnet and Host Bits	Number of Subnets (2x)	Number of Hosts (2x – 2)
10.25.66.154/23				
172.31.254.12/24				
192.168.20.123/28				
63.24.89.21/18				
128.1.1.254/20				
208.100.54.209/30				

Answers to Written Lab 1

Classful Address	Subnet Mask	Number of Hosts per Subnet (2x – 2)
/16	255.255.0.0	65,534
/17	255.255.128.0	32,766
/18	255.255.192.0	16,382
/19	255.255.224.0	8,190
/20	255.255.240.0	4,094
/21	255.255.248.0	2,046
/22	255.255.252.0	1,022
/23	255.255.254.0	510
/24	255.255.255.0	254
/25	255.255.255.128	126

Classful Address	Subnet Mask	Number of Hosts per Subnet (2x – 2)
/26	255.255.255.192	62
/27	255.255.255.224	30
/28	255.255.255.240	14
/29	255.255.255.248	6
/30	255.255.255.252	2

Answers to Written Lab 2

Decimal IP Address	Address Class	Number of Subnet and Host Bits	Number of Subnets (2x)	Number of Hosts (2x – 2)
10.25.66.154/23	A	15/9	32768	510
172.31.254.12/24	B	8/8	256	254
192.168.20.123/28	C	4/4	16	14
63.24.89.21/18	A	10/14	1,024	16,382
128.1.1.254/20	B	4/12	16	4094
208.100.54.209/30	C	6/2	64	2

Index

Note to the Reader: Throughout this index **boldfaced** page numbers indicate primary discussions of a topic. *Italicized* page numbers indicate illustrations.

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