KEVIN WALLACE
CCIE No. 7945

CompTIA APPROVED QUALITY CONTENT AUTHORIZED

Authorized Cert Guide

Learn, prepare, and practice for exam success

CompTIA Network+®

N10-005

- Master Network+ exam topics
- Assess your knowledge with chapter-ending quizzes
- Review key concepts with exam preparation tasks
- Practice with realistic exam questions on the DVD

PEARSON

CompTIA Network+ N10-005 Authorized Cert Guide

Kevin Wallace, CCIE #7945

PEARSON

800 East 96th Street
Indianapolis, Indiana 46240 USA

CompTIA Network+ N10-005 Authorized Cert Guide

Library of Congress Cataloging-in-Publication Data

Wallace, Kevin, CCNP.

CompTIA Network+ N10-005 cert guide / Kevin Wallace.

p. cm.

Includes index.

ISBN 978-0-7897-4821-8 (hardcover w/dvd)

1. Computer networks—Examinations—Study guides. 2. Electronic data processing personnel—Certification. I. Title.

TK5105.5.W345 2012

004.6—dc23

2011037792

ISBN-13: 978-0-7897-4821-8
ISBN-10: 0-7897-4821-5
Printed in the United States of America
Fifth Printing: August 2014

Trademarks

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Pearson IT Certification cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

Warning and Disclaimer

Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied. The information provided is on an “as is” basis. The authors and the publisher shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book or from the use of the DVD or programs accompanying it.

Bulk Sales

Pearson IT Certification offers excellent discounts on this book when ordered in quantity for bulk purchases or special sales. For more information, please contact

U.S. Corporate and Government Sales
1-800-382-3419
corpsales@pearsontechgroup.com

For sales outside of the U.S., please contact

International Sales
international@pearson.com

Associate Publisher
David Dusthimer

Executive Editor
Brett Bartow

Senior Development Editor
Christopher Cleveland

Managing Editor
Sandra Schroeder

Project Editor
Mandie Frank

Copy Editor
Sheri Cain

Indexer
Christine Karpeles

Proofreader
Water Crest Publishing

Technical Editors
Michelle Plumb
Theodor Richardson

Publishing Coordinator
Vanessa Evans

Multimedia Developer
Tim Warner

Designer
Gary Adair

Composition
Mark Shirar

Contents at a Glance

Table of Contents

About the Author

Kevin Wallace, CCIE No. 7945, is a certified Cisco instructor, and he holds multiple certifications, including CCNP, CCNP Voice, CCNP Security, and CCDP, in addition to multiple security and voice specializations. With networking experience dating back to 1989 (and computer experience dating back to 1982), Kevin is a senior technical instructor for SkillSoft. Kevin has been a network design specialist for the Walt Disney World Resort and a network manager for Eastern Kentucky University. Kevin holds a bachelor's of science degree in electrical engineering from the University of Kentucky. Also, Kevin has authored multiple books for Cisco Press, including *Implementing Cisco Unified Communications Voice over IP and QoS (CVOICE)*, *TSHOOT Official Certification Guide*, *Routing Video Mentor*, and *TSHOOT Video Mentor*. Kevin lives in central Kentucky with his wife (Vivian) and two daughters (Sabrina and Stacie). You can follow Kevin online through the following social-media outlets:

Web page: http://1ExamAMonth.com

Facebook fan page: Kevin Wallace Networking

Twitter: http://twitter.com/kwallaceccie

YouTube: http://youtube.com/kwallaceccie

Network World blog: http://nww.com/community/wallace

iTunes podcast: 1ExamAMonth.com

Dedication

This book is dedicated to my beautiful (inside and out) wife, Vivian. As of this writing, we are 17 years along on our way to forever together.

Acknowledgments

Huge thanks go out to my editor, Brett Bartow, and all the other professionals at Pearson IT Certification. It is my great pleasure to have been associated with you for the past eight years, and I look forward to more exciting projects in the future.

My director at SkillSoft, Dan Young, has been super-supportive of my writing efforts, and I extend my gratitude to him.

Thanks to my technical editors, Michelle Plumb and Theodor Richardson. In a book such as this, with all of its terminology, I'm grateful that you guys were looking over my shoulder and pointing out errors.

In the "Dedication" section, I mentioned my wife, Vivian. I once again want to acknowledge her. Being the parents of two teenage daughters can be time-intensive, and she is always willing to take on more than her fair share so that I can immerse myself in writing.

Speaking of our girls, Stacie and Sabrina, I also want to acknowledge you two. I am very proud of the young ladies you are becoming. Your character and your love for God are an inspiration to others.

As I've grown in my own personal faith, I've discovered that my spiritual gift is teaching. The book you now hold in your hands is a manifestation of that gift. My desire is to be a good steward of that God-given gift. So, with His guidance and continued blessings, I plan to continue demystifying complex concepts to my students and readers.

Albert Einstein once said, "If you can't explain it simply, you don't understand it well enough." My goal for you, the reader, is that you will understand the concepts in this book so well, you will be able to explain them simply to others.

About the Reviewers

Michelle Plumb is a full-time Cisco certified instructor for SkillSoft. Michelle has 22+ years of experience in the field as an IT professional and telephony specialist. She maintains a high level of Cisco, Microsoft, and CompTIA certifications, including A+, Network+, and Project+. Michelle has been a technical reviewer for numerous books related to the Cisco CCNP, CCNP Voice, and CompTIA course material tracks. Michelle currently lives in Phoenix, Arizona, with her husband and two dogs.

Theodor D. Richardson is an author, *Choice* magazine book reviewer, Online Program Director, and Assistant Professor for a private university. He has served as an Assistant Professor for five years in the area of security and multimedia/web design. Theodor has authored *Secure Software Design* (Jones and Bartlett Learning, 2012) and *Microsoft Office and Beyond* (Mercury Learning and Information, 2011). Theodor earned his Ph.D. degree in Computer Science and Engineering from the University of South Carolina in 2006 with a concentration in multimedia and image processing (Graduate Student of the Year 2005). Theodor received an NSF Graduate Research Fellowship and an NSF GK-12 Graduate/K-12 Teaching Fellowship during his graduate studies. He has earned the NSA Graduate Certificate in Information Assurance and Security from the University of South Carolina.

We Want to Hear from You!

As the reader of this book, you are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

As an Associate Publisher for Pearson Certification, I welcome your comments. You can e-mail or write me directly to let me know what you did or didn't like about this book—as well as what we can do to make our books better. Please note that I cannot help you with technical problems related to the topic of this book. We do have a User Services group, however, where I will forward specific technical questions related to the book.

When you write, please be sure to include this book's title and author as well as your name, e-mail address, and phone number. I will carefully review your comments and share them with the author and editors who worked on the book.

E-mail: feedback@pearsonitcertification.com

Mail: David Dusthimer
Associate Publisher
Pearson
800 East 96th Street
Indianapolis, IN 46240 USA

Reader Services

Visit our website and register this book at www.pearsonitcertification.com/title/9780789748218 for convenient access to any updates, downloads, or errata that might be available for this book.

CompTIA Network+

The CompTIA Network+ (2011 Edition) certification ensures that the successful candidate has the important knowledge and skills necessary to manage, maintain, troubleshoot, install, operate, and configure basic network infrastructure, describe networking technologies, basic design principles, and adhere to wiring standards and use testing tools.

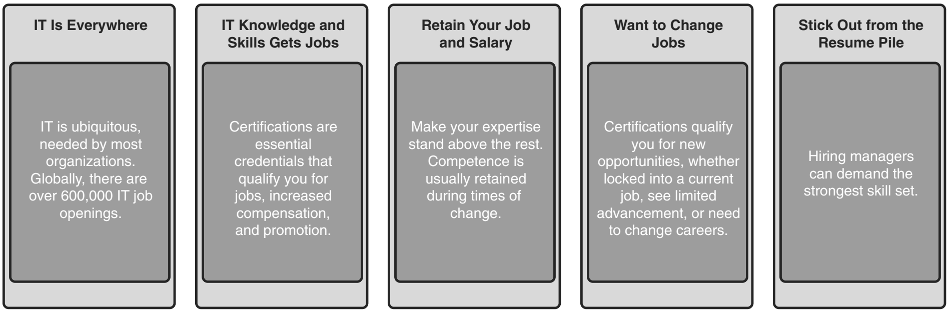
It Pays to Get Certified

In a digital world, digital literacy is an essential survival skill—Certification proves you have the knowledge and skill to solve business problems in virtually any business environment. Certifications are highly valued credentials that qualify you for jobs, increased compensation, and promotion.

CompTIA Network+ certification held by many IT staff in organizations— 21% of IT staff within a random sampling of U.S. organizations within a cross section of industry verticals hold Network+ certification.

- **The CompTIA Network+ credential—**Proves knowledge of networking features and functions and is the leading vendor-neutral certification for networking professionals.
- **Starting Salary—**The average starting salary of network engineers can be up to $70,000.
- **Career Pathway—**CompTIA Network+ is the first step in starting a networking career and is recognized by Microsoft as part of their MS program. Other corporations, such as Novell, Cisco, and HP, also recognize CompTIA Network+ as part of their certification tracks.
- **More than 260,000—**Individuals worldwide are CompTIA Network+ certified.
- **Mandated/recommended by organizations worldwide—**Such as Cisco, HP, Ricoh, the U.S. State Department, and U.S. government contractors such as EDS, General Dynamics, and Northrop Grumman.

How Certification Helps Your Career



IT Is Everywhere

IT is ubiquitous, needed by most organizations. Globally, there are over 600,000 IT job openings.

IT Knowledge and Skills Gets Jobs

Certifications are essential credentials that qualify you for jobs, increased compensation, and promotion.

Retain Your Job and Salary

Make your expertise stand above the rest. Competence is usually retained during times of change.

Want to Change Jobs

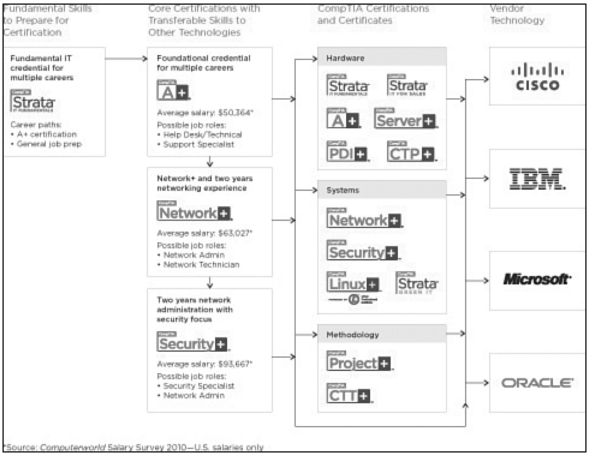
Certifications qualify you for new opportunities, whether locked into a current job, see limited advancement, or need to change careers.

Stick Out from the Resume Pile

Hiring managers can demand the strongest skill set.

CompTIA Career Pathway

CompTIA offers a number of credentials that form a foundation for your career in technology and allow you to pursue specific areas of concentration. Depending on the path you choose to take, CompTIA certifications help you build upon your skills and knowledge, supporting learning throughout your entire career.



*Source: *Computerworld* Salary Survey 2010—U.S. salaries only

Steps to Getting Certified and Staying Certified	
Review Exam Objectives	Review the certification objectives to make sure you know what is covered in the exam: http://certification.comptia.org/Training/testingcenters/examobjectives.aspx
Practice for the Exam	After you have studied for the certification, take a free assessment and sample test to get an idea of what type of questions might be on the exam: http://certification.comptia.org/Training/testingcenters/samplequestions.aspx
Purchase an Exam Voucher	Purchase your exam voucher on the CompTIA Marketplace, which is located at: http://www.comptiastore.com/
Take the Test!	Select a certification exam provider and schedule a time to take your exam. You can find exam providers at the following link: http://certification.comptia.org/Training/testingcenters.aspx
Stay Certified! Continuing education	Effective January 1, 2011, CompTIA Network+ certifications are valid for three years from the date of certification. There are a number of ways the certification can be renewed. For more information, go to: http://certification.comptia.org/getCertified/steps_to_certification/stayCertified.aspx

Join the Professional Community

Join IT Pro Community http://itpro.comptia.org	The free IT Pro online community provides valuable content to students and professionals. Career IT Job Resources: ■ Where to start in IT ■ Career Assessments ■ Salary Trends ■ U.S. Job Board Forums on networking, security, computing, and cutting-edge technologies. Access to blogs written by industry experts. Current information on cutting-edge technologies. Access to various industry resource links and articles related to IT and IT careers.

Content Seal of Quality

This courseware bears the seal of **CompTIA Approved Quality Content.** This seal signifies this content covers 100% of the exam objectives and implements important instructional design principles. CompTIA recommends multiple learning tools to help increase coverage of the learning objectives.

CompTIA APPROVED QUALITY CONTENT AUTHORIZED

Why CompTIA?

- **Global Recognition—**CompTIA is recognized globally as the leading IT non-profit trade association and has enormous credibility. Plus, CompTIA's certifications are vendor-neutral and offer proof of foundational knowledge that translates across technologies.
- **Valued by Hiring Managers—**Hiring managers value CompTIA certification, because it is vendor- and technology-independent validation of your technical skills.
- **Recommended or Required by Government and Businesses—**Many government organizations and corporations either recommend or require technical staff to be CompTIA certified. (For example, Dell, Sharp, Ricoh, the U.S. Department of Defense, and many more.)
- **Three CompTIA Certifications Ranked in the Top 10—**In a study by DICE of 17,000 technology professionals, certifications helped command higher salaries at all experience levels.

How to Obtain More Information

- **Visit CompTIA online—**www.comptia.org to learn more about getting CompTIA certified.
- **Contact CompTIA—**Call 866-835-8020 ext. 5 or email questions@comptia.org.
- **Join the IT Pro community—**http://itpro.comptia.org to join the IT community to get relevant career information.
- **Connect with us—**in f 🐦 •• You Tube

Introduction

The CompTIA Network+ certification is a popular certification for those entering the computer-networking field. Although many vendor-specific networking certifications are popular in the industry, the CompTIA Network+ certification is unique in that it is vendor-neutral. The CompTIA Network+ certification often acts as a stepping-stone to more specialized and vendor-specific certifications, such as those offered by Cisco Systems.

Notice in your CompTIA Network+ study that the topics are mostly generic, in that they can apply to networking equipment regardless of vendor. However, as you grow in your career, I encourage you to seek specialized training for the equipment you work with on a daily basis.

Goals and Methods

The goal of this book is twofold. The #1 goal of this book is a simple one: to help you pass the N10-005 version of the CompTIA Network+ exam.

To aid you in mastering and understanding the Network+ certification objectives, this book uses the following methods:

- **Opening topics list:** This defines the topics that are covered in the chapter.
- **Foundation topics:** At the heart of a chapter, this section explains the topics from a hands-on and a theory-based standpoint. This includes in-depth descriptions, tables, and figures that build your knowledge so that you can pass the N10-005 exam. The chapters are each broken into multiple sections.
- **Key topics:** This indicates important figures, tables, and lists of information that you need to know for the exam. They are sprinkled throughout each chapter and are summarized in table format at the end of each chapter.
- **Memory tables:** These can be found on the DVD within Appendices C and D. Use them to help memorize important information.
- **Key terms:** Key terms without definitions are listed at the end of each chapter. Write down the definition of each term, and check your work against the complete key terms in the Glossary.

For current information about the CompTIA Network+ certification exam, you can visit http://certification.comptia.org/getCertified/certifications/network.aspx.

Who Should Read This Book?

The CompTIA Network+ exam measures the necessary competencies for an entry-level networking professional with the equivalent knowledge of at least 500 hours of hands-on experience in the lab or field. This book was written for people who have that amount of experience working with computer networks. Average readers will have connected a computer to a network, configured IP addressing on that computer, installed software on that computer, used command-line utilities (for example, the **ping** command), and used a browser to connect to the Internet.

Readers will range from people who are attempting to attain a position in the IT field to people who want to keep their skills sharp or perhaps retain their job because of a company policy that mandates they take the new exams.

This book also targets the reader who wants to acquire additional certifications beyond the Network+ certification (for example, the Cisco Certified Network Associate [CCNA] certification and beyond). The book is designed in such a way to offer easy transition to future certification studies.

Strategies for Exam Preparation

Strategies for exam preparation vary, depending on your existing skills, knowledge, and equipment available. Of course, the ideal exam preparation would include building and configuring a computer network from scratch. Preferably, the network would contain both Microsoft Windows® and UNIX hosts, at least two Ethernet switches, and at least two routers.

However, not everyone has access to this equipment, so the next best step you can take is to read the chapters in this book, jotting down notes with key concepts or configurations on a separate notepad. For more visual learners, you might consider the Network+ Video Mentor product by Anthony Sequeira, which is available from Pearson IT Certification, where you get to watch an expert perform multiple configurations.

After you read the book, you can download the current exam objectives by submitting a form on the following web page: http://certification.comptia.org/Training/testingcenters/examobjectives.aspx

If there are any areas shown in the certification exam outline that you still want to study, find those sections in this book and review them.

When you feel confident in your skills, attempt the practice exam, which is included on this book's DVD. As you work through the practice exam, note the areas where you lack confidence and review those concepts or configurations in this book. After you review these areas, work through the practice exam a second time, and rate your skills. Keep in mind that the more you work through the practice exam, the more familiar the questions become, and the practice exam becomes a less accurate judge of your skills.

After you work through the practice exam a second time and feel confident with your skills, schedule the real CompTIA Network+ exam (N10-005). The following website provides information about registering for the exam: http://certification.comptia.org/Training/testingcenters.aspx

To prevent the information from evaporating out of your mind, you should typically take the exam within a week of when you consider yourself ready to take it.

CompTIA Network+ Exam Topics

Table I-1 lists general exam topics (objectives) and specific topics under each general topic (subobjectives) for the CompTIA Network+ N10-005 exam. This table also lists the chapter in which each exam topic is covered. Note that some objectives and subobjectives are addressed in multiple chapters.

Table I-1 CompTIA Network+ Exam Topics

Chapter	N10-005 Exam Objective	N10-005 Exam Subobjective
1 (Introducing Computer Networks)	3.0 Network Media and Topologies	3.5 Describe different network topologies.
2 (Dissecting the OSI Model)	1.0 Network Technologies	1.1 Compare the layers of the OSI and TCP/IP models.
		1.2 Classify how applications, devices, and protocols relate to the OSI layers.
		1.5 Identify common TCP and UDP default ports.
		1.6 Explain the function of common network protocols.

Table I-1 CompTIA Network+ Exam Topics

Chapter	N10-005 Exam Objective	N10-005 Exam Subobjective
3 (Identifying Network Components)	1.0 Network Technologies 2.0 Network Installation and Configuration 3.0 Network Media and Topologies 4.0 Network Management	1.7 Summarize DNS concepts and its components. 1.9 Identify virtual desktop components. 2.3 Explain the purpose and properties of DHCP. 3.1 Categorize standard media types and associated properties. 3.2 Categorize standard connector types based on network media. 3.8 Identify components of wiring distribution. 4.1 Explain the purpose and features of various network appliances.
4 (Understanding Ethernet)	1.0 Network Technologies 2.0 Network Installation and Configuration 3.0 Network Media and Topologies	1.4 Explain the purpose of routing and switching. 2.1 Given a scenario, install and configure routers and switches. 3.7 Compare and contrast different LAN technologies.
5 (Working with IP Addresses)	1.0 Network Technologies	1.3 Explain the purpose and properties of IP addressing.
6 (Routing Traffic)	1.0 Network Technologies 2.0 Network Installation and Configuration	1.4 Explain the purpose and properties of routing and switching. 2.1 Given a scenario, install and configure routers and switches.
7 (Introducing Wide-Area Networks)	3.0 Network Media and Topologies	3.4 Categorize WAN technology types and properties.
8 (Connecting Wirelessly)	2.0 Network Installation and Configuration 3.0 Network Media and Topologies 5.0 Network Security	2.2 Given a scenario, install and configure a wireless network. 2.4 Given a scenario, troubleshoot common wireless problems. 3.3 Compare and contrast different wireless standards. 5.1 Given a scenario, implement appropriate wireless security measures. 5.4 Explain common threats, vulnerabilities, and mitigation techniques.

Table I-1 CompTIA Network+ Exam Topics

Chapter	N10-005 Exam Objective	N10-005 Exam Subobjective
9 (Optimizing Network Performance)	2.0 Network Installation and Configuration	2.6 Given a set of requirements, plan and implement a basic SOHO network.
	4.0 Network Management	4.6 Explain different methods and rationales for network performance optimization.
10 (Using Command-Line Utilities)	4.0 Network Management	4.3 Given a scenario, use appropriate software tools to troubleshoot connectivity issues.
11 (Managing a Network)	4.0 Network Management	4.2 Given a scenario, use appropriate hardware tools to troubleshoot connectivity issues.
		4.3 Given a scenario, use appropriate software tools to troubleshoot connectivity issues.
		4.4 Given a scenario, use the appropriate network resource to analyze traffic.
		4.5 Describe the purpose of configuration management documentation.
12 (Securing a Network)	4.0 Network Management	4.1 Explain the purpose and features of various network appliances.
	5.0 Network Security	5.2 Explain the methods of network access security.
		5.3 Explain methods of user authentication.
		5.4 Explain common threats, vulnerabilities, and mitigation techniques.
		5.5 Given a scenario, install and configure a basic firewall.
		5.6 Categorize different types of network security appliances and methods.
13 (Troubleshooting Network Issues)	1.0 Network Technologies	1.8 Given a scenario, implement a given troubleshooting methodology.
	2.0 Network Installation and Configuration	2.4 Given a scenario, troubleshoot common wireless problems.
	3.0 Network Media and Topologies	2.5 Given a scenario, troubleshoot common router and switch problems.
		3.6 Given a scenario, troubleshoot common physical connectivity problems.

How This Book Is Organized

Although this book could be read cover-to-cover, it is designed to be flexible and allow you to easily move between chapters and sections of chapters to cover just the material that you need more work with. However, if you do intend to read all the chapters, the order in the book is an excellent sequence to use:

- **Chapter 1, "Introducing Computer Networks,"** introduces the purpose of computer networks and their constituent components. Additionally, networks are categorized by their geography, topology, and resource location.
- **Chapter 2, "Dissecting the OSI Model,"** presents the two network models: the OSI model and the TCP/IP stack. These models categorize various network components from a network cable up to and including an application, such as e-mail. These models are contrasted, and you are given a listing of well-known TCP and UDP port numbers used for specific applications.
- **Chapter 3, "Identifying Network Components."** A variety of network components are introduced in this chapter. You are given an explanation of various media types, the roles of specific infrastructure components, and the features provided by specialized network devices (for example, a firewall or content switch).
- **Chapter 4, "Understanding Ethernet."** The most widely deployed LAN technology is Ethernet, and this chapter describes the characteristics of Ethernet networks. Topics include media access, collision domains, broadcast domains, and distance/speed limitations for popular Ethernet standards. Additionally, you are introduced to some of the features available on Ethernet switches, such as VLANs, trunks, STP, link aggregation, PoE, port monitoring, and user authentication.
- **Chapter 5, "Working with IP Addresses."** One of the most challenging concepts for many CompTIA Network+ students is IP subnetting. This chapter demystifies IP subnetting by reviewing the basics of binary numbering, before delving into basic subnetting and then advanced subnetting. Although most of the focus of this chapter is on IP version 4 (IPv4) addressing, the chapter concludes with an introduction to IP version 6 (IPv6).
- **Chapter 6, "Routing Traffic."** A primary job of a computer network is to route traffic between subnets. This chapter reviews the operation of routing IP traffic and discusses how a router obtains routing information. One way a router can populate its routing table is through the use of dynamic routing protocols, several of which are discussed in this chapter. Many environments (such as a home network connecting to the Internet via a cable modem) use NAT to convert between private IP addresses inside a network and public IP addresses outside a network. This chapter discusses DNAT, SNAT, and PAT.

Although the primary focus on this chapter is on unicast routing, the chapter concludes with a discussion of multicast routing.

- **Chapter 7, "Introducing Wide-Area Networks."** Many corporate networks need to interconnect multiple sites separated by large distances. Connections between such geographically dispersed sites make up a WAN. This chapter discusses three categories of WAN connections and contrasts various WAN connection types, based on supported data rates and media types. Finally, this chapter lists characteristics for multiple WAN technologies.
- **Chapter 8, "Connecting Wirelessly."** In this increasingly mobile world, wireless technologies are exploding in popularity. This chapter discusses the basic operation of WLANs. Additionally, WLAN design and security considerations are addressed.
- **Chapter 9, "Optimizing Network Performance."** This chapter explains the importance of high availability for a network and what mechanisms help provide a high level of availability. Network performance optimization strategies are addressed, including a section on QoS. Finally, this chapter allows you to use what you have learned in this and preceding chapters to design a SOHO network.
- **Chapter 10, "Using Command-Line Utilities."** In your daily administration and troubleshooting of computer networks, you need familiarity with various command-line utilities available on the operating systems present in your network. This chapter presents a collection of popular command-line utilities for both Microsoft Windows® and UNIX platforms.
- **Chapter 11, "Managing a Network,"** reviews some of the more common tools used to physically maintain a network. The components of configuration management are also presented. Finally, this chapter discusses some of the network-monitoring tools available to network administrators and what types of information are included in various logs.
- **Chapter 12, "Securing a Network."** Network security is an issue for most any network, and this chapter covers a variety of network security technologies. You begin by understanding the goals of network security and the types of attacks you must defend against. Then, you review a collection of security best practices. Next, the chapter discusses specific security technologies, including firewalls, VPNs, IDSs, and IPSs.
- **Chapter 13, "Troubleshooting Network Issues."** Troubleshooting network issues in an inherent part of network administration, and this chapter presents a structured approach to troubleshooting various network technologies. Specifically, you learn how to troubleshoot common Layer 2, Layer 3, and wireless network issues.

- **Chapter 14, "Final Preparation,"** reviews the exam-preparation tools available in this book and the enclosed DVD. For example, the enclosed DVD contains a practice exam engine and a collection of ten training videos presented by the author. Finally, a suggested study plan is presented to assist you in preparing for the CompTIA Network+ exam (N10-005).

In addition to the 13 main chapters, this book includes tools to help you verify that you are prepared to take the exam. The DVD includes a practice test and memory tables that you can work through to verify your knowledge of the subject matter. The DVD also contains ten training videos that cover some of the most fundamental and misunderstood content in the CompTIA Network+ curriculum, specifically the OSI model and IP addressing.

This page intentionally left blank

After completion of this chapter, you will be able to answer the following questions:

- How do various *wireless LAN* (WLAN) technologies function, and what wireless standards are in common use?
- What are some of the most important WLAN design considerations?
- What WLAN security risks exist, and how can those risks be mitigated?

CHAPTER 8

Connecting Wirelessly

The popularity of *wireless LANs* (WLAN) has exploded over the past decade, allowing users to roam within a WLAN coverage area, allowing users to take their laptops with them and maintain network connectivity as they move throughout a building or campus environment. Many other devices, however, can take advantage of wireless networks, such as gaming consoles, smart phones, and printers.

This chapter introduces WLAN technology, along with various wireless concepts, components, and standards. WLAN design considerations are then presented, followed by a discussion of WLAN security.

Foundation Topics

Introducing Wireless LANs

This section introduces the basic building blocks of WLANs and discusses how WLANs connect into a wired local-area network (LAN). Various design options, including antenna design, frequencies, and communications channels are discussed, along with a comparison of today's major wireless standards, which are all some variant of IEEE 802.11.

WLAN Concepts and Components

Wireless devices, such as laptops and smart phones, often have a built-in wireless card that allows those devices to communicate on a WLAN. But, what is the device to which they communicate? It could be, as one example, another laptop with a wireless card. This would be an example of an *ad-hoc* WLAN. However, enterprise-class WLANs, and even most WLANs in homes, are configured in such a way that a wireless client connects to some sort of a wireless base station, such as a *wireless access point* (AP) or a *wireless router*.

This communication might be done using a variety of antenna types, frequencies, and communication channels. The following sections consider some of these elements in more detail.

Wireless Routers

Consider the basic WLAN topology shown in Figure 8-1. Such a WLAN might be found in a residence whose Internet access is provided by digital subscriber line (DSL) modem. In this topology, a wireless router and switch are shown as separate components. However, in many residential networks, a wireless router integrates switch ports and wireless routing functionality into a single device.

Key Topic

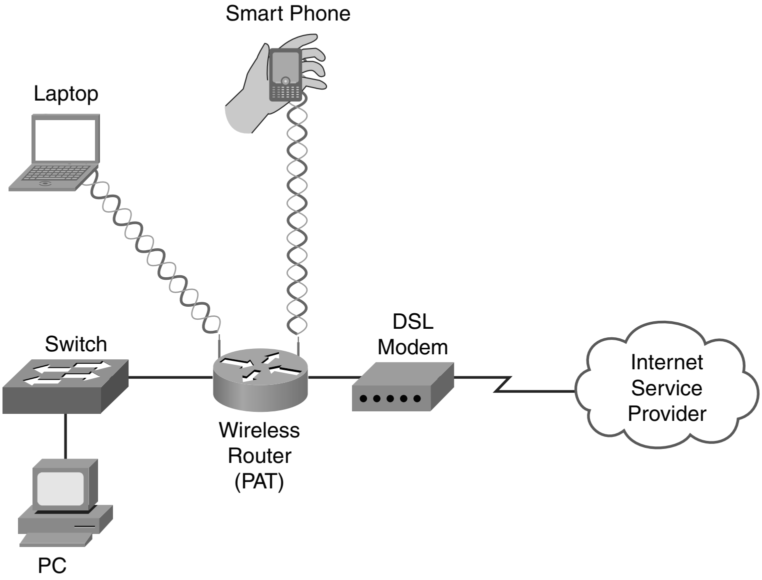


Figure 8-1 Basic WLAN Topology with a Wireless Router

In Figure 8-1, the wireless router obtains an IP address via DHCP from the *Internet service provider* (ISP). Then, the router uses Port Address Translation (PAT), as described in Chapter 6, "Routing Traffic," to provide IP addresses to devices attaching to it wirelessly or through a wired connection. The process through which a wireless client (for example, a laptop or a smart phone) attaches with a wireless router (or wireless AP) is called *association*. All wireless devices associating with a single AP share a collision domain. Therefore, for scalability and performance reasons, WLANs might include multiple APs.

Wireless Access Point

Although a *wireless access point* (AP) interconnects a wired LAN with a WLAN, it does not interconnect two networks (for example, the service provider's network with an internal network). Figure 8-2 shows a typical deployment of an AP.

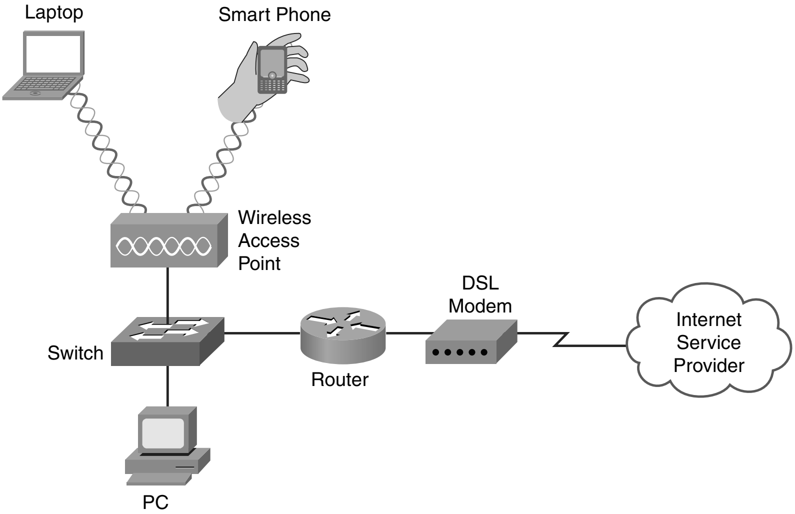


Figure 8-2 Basic WLAN Topology with a Wireless AP

The AP connects to the wired LAN, and the wireless devices that connect to the wired LAN via the AP are on the same subnet as the AP (no Network Address Translation [NAT] or PAT is being performed).

Antennas

The coverage area of a WLAN is largely determined by the type of antenna used on a wireless AP or a wireless router. Although some lower-end, consumer-grade wireless APs have fixed antennas, higher-end, enterprise-class wireless APs often support various antenna types.

Design goals to keep in mind when selecting an antenna include the following:

- Required distance between an AP and a wireless client
- Pattern of coverage area (for example, the coverage area might radiate out in all directions, forming a spherical coverage area around an antenna, or an antenna might provide increased coverage in only one or two directions)
- Indoor or outdoor environment
- Avoiding interference with other APs

The strength of the electromagnetic waves being radiated from an antenna is referred to as *gain*, which involves a measurement of both direction and efficiency of a transmission. For example, the gain measurement for a wireless AP's antenna transmitting a signal is a measurement of how efficiently the power being applied to the antenna is converted into electromagnetic waves being broadcast in a specific direction. Conversely, the gain measurement for a wireless AP's antenna receiving a signal is a measurement of how efficiently the received electromagnetic waves arriving from a specific direction are converted back into electricity leaving the antenna.

Gain is commonly measured using the *dBi* unit of measure. In this unit of measure, the *dB* stands for *decibels* and the *i* stands for *isotropic*. A decibel, in this context, is a ratio of radiated power to a reference value. In the case of dBi, the reference value is the signal strength (power) radiated from an *isotropic antenna*, which represents a theoretical antenna that radiates an equal amount of power in all directions (in a spherical pattern). An isotropic antenna is considered to have gain of 0 dBi.

The most common formula used for antenna gain is the following:

$$\text{GdBi} = 10 * \log^{10} (G)$$

Based on this formula, an antenna with a peak power gain of 4 (*G*) would have a gain of 6.02 dBi. Antenna theory can become mathematical (heavily relying on the use of *Maxwell's equations*). However, to put this discussion in perspective, generally speaking, if one antenna has 3 dB more gain than another antenna, it has approximately twice the effective power.

Antennas are classified not just by their gain but also by their coverage area. Two broad categories of antennas, which are based on coverage area, are as follows:

- **Omnidirectional:** An omnidirectional antenna radiates power at relatively equal power levels in all directions (somewhat similar to the theoretical isotropic antenna). Omnidirectional antennas, an example of which is depicted in Figure 8-3, are popular in residential WLANs and small office/home office (SOHO) locations.

Key Topic

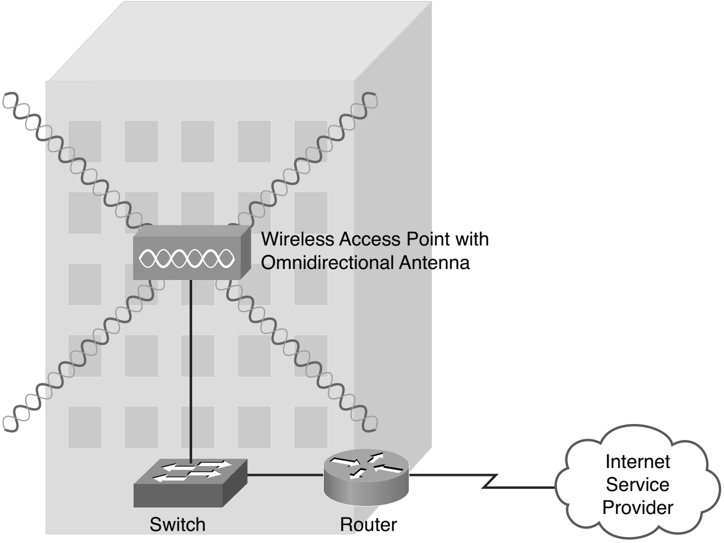

Wireless Access Point with Omnidirectional Antenna
Switch
Router
Internet Service Provider

Figure 8-3 Omnidirectional Antenna Coverage

- **Unidirectional:** Unidirectional antennas can focus their power in a specific direction, thus avoiding potential interference with other wireless devices and perhaps reaching greater distances than those possible with omnidirectional antennas. One application for unidirectional antennas is interconnecting two nearby buildings, as shown in Figure 8-4.

Key Topic

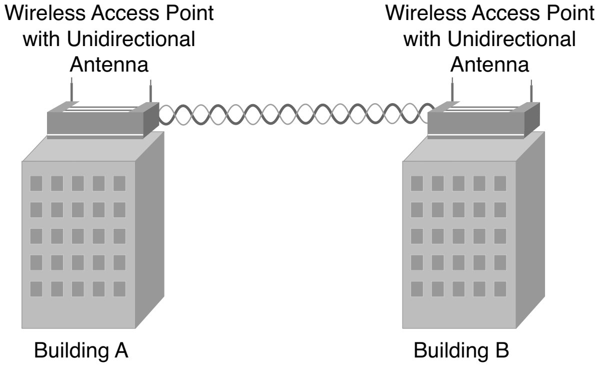

Wireless Access Point with Unidirectional Antenna
Wireless Access Point with Unidirectional Antenna
Building A
Building B

Figure 8-4 Unidirectional Antenna Coverage

Another consideration for antenna installation is the horizontal or vertical orientation of the antenna. For best performance, if two wireless APs communicate with one another, they should have matching antenna orientations, which is referred to as the *polarity* of the antenna.

Frequencies and Channels

Later in this chapter, you are introduced to a variety of wireless standards, which are all variants of the *IEEE 802.11* standard. As you contrast one standard versus another, a characteristic to watch out for is the frequencies at which these standards operate. Although there are some country-specific variations, certain frequency ranges (or *frequency bands*) have been reserved internationally for industrial, scientific, and medical purposes. These frequency bands are called the *ISM bands*, where ISM derives from *i*ndustrial, *s*cientific, and *m*edical.

Two of these bands are commonly used for WLANs. Specifically, WLANs can use the range of frequencies in the 2.4 GHz–2.5 GHz range (commonly referred to as the *2.4-GHz band*) or in the 5.725 GHz–5.875 GHz range (commonly referred to as the *5-GHz band*). In fact, some WLANs support a mixed environment, where 2.4 GHz devices run alongside 5-GHz devices.

Within each band are specific frequencies (or *channels*) at which wireless devices operate. To avoid interference, nearby wireless APs should use frequencies that do not overlap one another. Merely selecting different channels is not sufficient, however, because transmissions on one channel spill over into nearby channels.

As an example, consider the 2.4-GHz band. Here, channel frequencies are separated by 5 MHz (with the exception of channel 14, which has 12 MHz of separation from channel 13). However, a single channel's transmission can spread over a frequency range of 22 MHz. As a result, channels must have five channels of separation (5 * 5 MHz = 25 MHz, which is greater than 22 MHz). You can see from Figure 8-5 that, in the United States, you could select nonoverlapping channels of 1, 6, and 11.

Key Topic

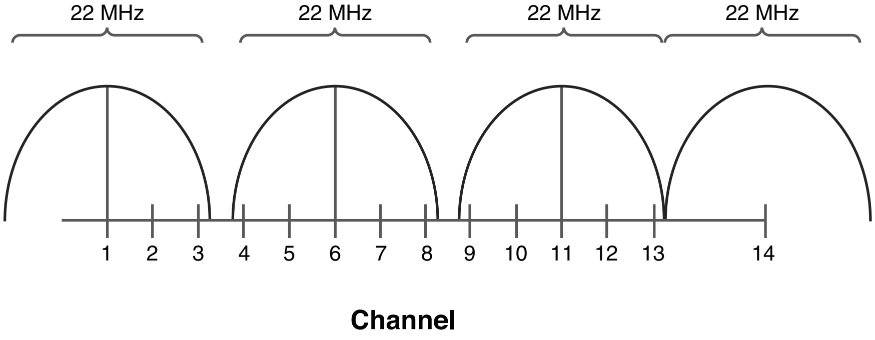


Figure 8-5 Nonoverlapping Channels in the 2.4 GHz Band

NOTE Even though some countries use channel 14 as a nonoverlapping channel, it is not supported in the United States.

As a reference, Table 8-1 shows the specific frequencies for each of the channels in the 2.4-GHz band.

Table 8-1 Channel Frequencies in the 2.4-GHz Band

Channel	Frequency (GHz)	Recommended as a Nonoverlapping Channel
1	2.412	Yes
2	2.417	No
3	2.422	No
4	2.427	No
5	2.432	No
6	2.437	Yes
7	2.442	No
8	2.447	No
9	2.452	No
10	2.457	No
11	2.462	Yes
12	2.467	No
13	2.472	No
14	2.484	Yes (not supported in the United States)

The 5-GHz band has a higher number of channels, as compared to the 2.4-GHz band. Table 8-2 lists the recommended nonoverlapping channels for the 5-GHz band in the United States. Note that additional channels are supported in some countries.

Table 8-2 Nonoverlapping Channels in the 5-GHz Band Recommended for Use in the United States

Channel	Frequency (GHz)
36	5.180
40	5.200
44	5.220
48	5.240
52	5.260*
56	5.280*
60	5.300*
64	5.320*

100	5.500**
104	5.520**
108	5.540**
112	5.560**
116	5.580**
136	5.680**
140	5.700**
149	5.745
153	5.765
157	5.785
161	5.805
165	5.825
*Must support dynamic frequency selection to prevent interference with RADAR	
**Must be professionally installed	

CSMA/CA

In Chapter 4, "Understanding Ethernet," you learned about Ethernet's *carrier sense multiple access collision detection* (CSMA/CD) technology. WLANs use a similar technology called *carrier sense multiple access collision avoidance* (CSMA/CA). Just as CSMA/CD is needed for half-duplex Ethernet connections, CSMA/CA is needed for WLAN connections, because of their half-duplex operation. Similar to how an Ethernet device listens to an Ethernet segment to determine if a frame exists on the segment, a WLAN device listens for a transmission on a wireless channel to determine if it is safe to transmit. Additionally, the collision avoidance part of the CSMA/CA algorithm causes wireless devices to wait for a random backoff time before transmitting.

Transmission Methods

In the previous discussion, you saw the frequencies used for various wireless channels. However, be aware that those frequencies are considered to be the *center frequencies* of a channel. In actual operation, a channel uses more than one frequency, which is a transmission method called *spread spectrum*. These frequencies are, however, very close to one another, which results in a *narrowband transmission*.

The three variations of spread-spectrum technology to be aware of for your study of WLANs include the following:

Key Topic

- **Direct-sequence spread spectrum (DSSS):** Modulates data over an entire range of frequencies using a series symbols called *chips*. A chip is shorter in duration than a bit, meaning that chips are transmitted at a higher rate than the actual data. These chips not only encode the data to be transmitted, but also what appears to be random data. Although both parties involved in a DSSS communication know which chips represent actual data and which chips do not, if a third party intercepted a DSSS transmission, it would be difficult for him to eavesdrop in on the data, because he would not easily know which chips represented valid bits. DSSS is more subject to environmental factors, as opposed to FHSS and OFDM, because of its use of an entire frequency spectrum.

- **Frequency-hopping spread spectrum (FHSS):** Allows the participants in a communication to hop between predetermined frequencies. Security is enhanced, because the participants can predict the next frequency to be used while a third party cannot easily predict the next frequency. FHSS can also provision extra bandwidth by simultaneously using more than one frequency.

- **Orthogonal frequency division multiplexing (OFDM):** While DSSS used a high modulation rate for the symbols it sends, OFDM uses a relatively slow modulation rate for symbols. This slower modulation rate, combined with the simultaneous transmission of data over 52 data streams, helps OFDM support high data rates while resisting interference between the various data streams.

Of these three wireless modulation techniques, only DSSS and OFDM are commonly used in today's WLANs.

WLAN Standards

Most modern WLAN standards are variations of the original IEEE 802.11 standard, which was developed in 1997. This original standard supported a DSSS and a FHSS implementation, both of which operated in the 2.4-GHz band. However, with supported speeds of 1 Mbps or 2 Mbps, the original 802.11 standard lacks sufficient bandwidth to meet the needs of today's WLANs. The most popular variants of the 802.11 standard in use today are 802.11a, 802.11b, 802.11g, and 802.11n, as described in detail in the following sections.

802.11a

The 802.11a WLAN standard, which was ratified in 1999, supports speeds as high as 54 Mbps. Other supported data rates (which can be used if conditions are not suitable for the 54 Mbps rate) include 6, 9, 12, 18, 24, 36, and 48 Mbps. The 802.11a standard uses the 5-GHz band and uses the OFDM transmission method.

Interestingly, 802.11a never gained widespread adoption, because it was not backwards compatible with 802.11b, while 802.11g was backwards compatible.

802.11b

The 802.11b WLAN standard, which was ratified in 1999, supports speeds as high as 11 Mbps. However, 5.5 Mbps is another supported data rate. The 802.11b standard uses the 2.4-GHz band and uses the DSSS transmission method.

802.11g

The 802.11g WLAN standard, which was ratified in 2003, supports speeds as high as 54 Mbps. Like 802.11a, other supported data rates include 6, 9, 12, 18, 24, 36, and 48 Mbps. However, like 802.11b, 802.11g operates in the 2.4-GHz band, which allows it to offer backwards compatibility to 802.11b devices. 802.11g can use either the OFDM or the DSSS transmission method.

802.11n

The 802.11n WLAN standard, which was ratified in 2009, supports a wide variety of speeds, depending on its implementation. Although the speed of an 802.11n network could exceed 300 Mbps (through the use of *channel bonding*, as discussed later), many 802.11n devices on the market have speed ratings in the 130–150 Mbps range. Interestingly, an 802.11n WLAN could operate in the 2.4 GHz band, the 5-GHz band, or both simultaneously. 802.11n uses the OFDM transmission method.

One way 802.11n achieves superior throughput is through the use of a technology called *multiple input, multiple output* (MIMO). MIMO uses multiple antennas for transmission and reception. These antennas do not interfere with one another, thanks to MIMO's use of *spatial multiplexing*, which encodes data based on the antenna from which the data will be transmitted. Both reliability and throughput can be increased with MIMO's simultaneous use of multiple antennas.

Yet another technology implemented by 802.11n is *channel bonding*. With channel bonding, two wireless bands can be logically bonded together, forming a band with twice the bandwidth of an individual band. Some literature refers to channel bonding as *40-MHz mode*, which refers to the bonding of two adjacent 20-MHz bands into a 40-MHz band.

Table 8-3 acts as a reference to help you contrast the characteristics of the 802.11 standards.

Table 8-3 Characteristics of 802.11 Standards

Standard	Band	Max. Bandwidth	Transmission Method	Max. Range
802.11	2.4 GHz	1 Mbps or 2 Mbps	DSSS or FHSS	20 m indoors/100 m outdoors
802.11a	5 GHz	54 Mbps	OFDM	35 m indoors/120 m outdoors
802.11b	2.4 GHz	11 Mbps	DSSS	32 m indoors/140 m outdoors
802.11g	2.4 GHz	54 Mbps	OFDM or DSSS	32 m indoors/140 m outdoors
802.11n	2.4 GHz or 5 GHz (or both)	> 300 Mbps (with channel bonding)	OFDM	70 m indoors/250 m outdoors

Deploying Wireless LANs

When designing and deploying WLANs, you have a variety of installation options and design considerations. This section delves into your available options and provides you with some best practice recommendations.

Types of WLANs

WLANs can be categorized based on their use of wireless APs. The three main categories are *independent basic service set* (IBSS), *basic service set* (BSS), and *extended service set* (ESS). An IBSS WLAN operates in an *ad-hoc* fashion, while BSS and ESS WLANs operate in *infrastructure mode*. The following sections describe the three types of WLANs in detail.

IBSS

As shown in Figure 8-6, a WLAN can be created without the use of an AP. Such a configuration, called an IBSS, is said to work in an ad-hoc fashion. An ad-hoc WLAN is useful for temporary connections between wireless devices. For example, you might temporarily interconnect two laptop computers to transfer a few files.

Key Topic

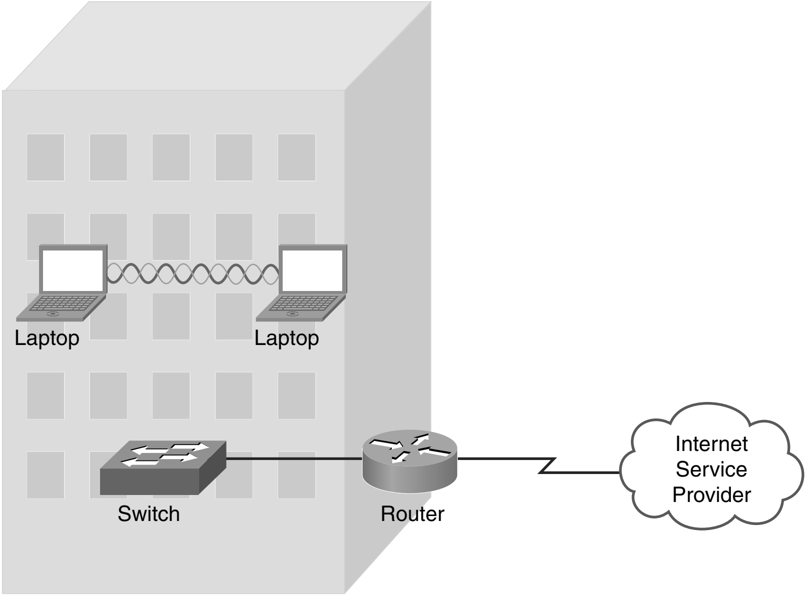


Figure 8-6 Independent Basic Service Set (IBSS) WLAN

BSS

Figure 8-7 depicts a WLAN using a single AP. WLANs that have just one AP are called BSS WLANs. BSS WLANs are said to run in infrastructure mode, because wireless clients connect to an AP, which is typically connected to a wired network infrastructure. A BSS network is often used in residential and SOHO locations, where the signal strength provided by a single AP is sufficient to service all the WLAN's wireless clients.

Key Topic

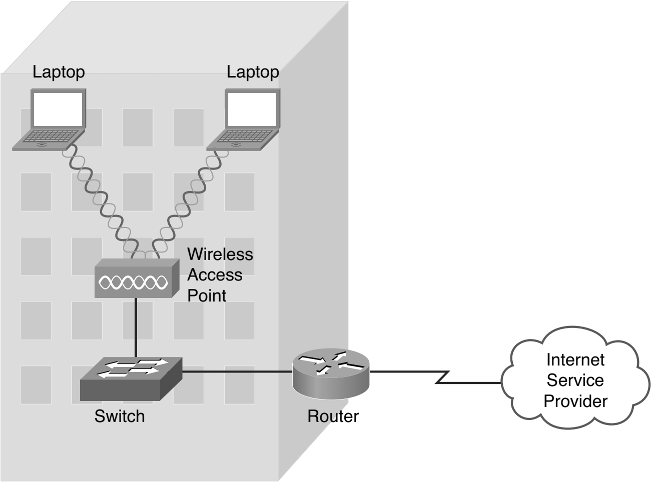


Figure 8-7 Basic Service Set (BSS) WLAN

ESS

Figure 8-8 illustrates a WLAN using two APs. WLANs containing more than one AP are called ESS WLANs. Like BSS WLANs, ESS WLANs operate in infrastructure mode. When you have more than one AP, take care to prevent one AP from interfering with another. Specifically, the previously discussed nonoverlapping channels (channels 1, 6, and 11 for the 2.4-GHz band) should be selected for adjacent wireless coverage areas.

Key Topic

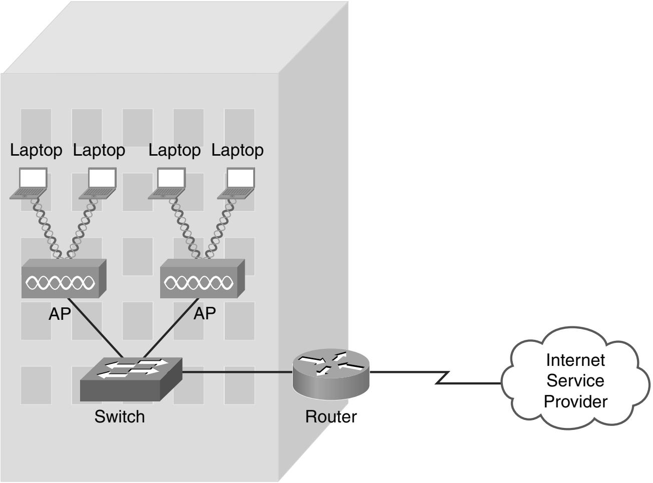


Figure 8-8 Extended Service Set (ESS) WLAN

Sources of Interference

A major issue for WLANs is *radio frequency interference* (RFI) caused by other devices using similar frequencies to the WLAN devices. Also, physical obstacles can impede or reflect WLAN transmissions. The following are some of the most common sources of interference:

Key Topic

- **Other WLAN devices:** Earlier in this chapter, you read about nonoverlapping channels for both the 2.4-GHz and 5-GHz bands. However, if two or more WLAN devices are in close proximity and use overlapping channels, those devices could interfere with one another.
- **Cordless phones:** Several models of cordless phones operate in the 2.4-GHz band and can interfere with WLAN devices. However, if you need cordless phones to coexist in an environment with WLAN devices using the 2.4-GHz band, consider the use of *digital enhanced cordless telecommunications* (DECT) cordless phones. Although the exact frequencies used by DECT cordless phones vary based on country, DECT cordless phones do not use the 2.4-GHz band. For example, in the United States, DECT cordless phones use frequencies in the range 1.92 GHz–1.93 GHz.
- **Microwave ovens:** Older microwave ovens, which might not have sufficient shielding, can emit relatively high-powered signals in the 2.4-GHz band, resulting in significant interference with WLAN devices operating in the 2.4-GHz band.
- **Wireless security system devices:** Most wireless security cameras operate in 2.4-GHz frequency range, which can cause potential issues with WLAN devices.
- **Physical obstacles:** In electromagnetic theory, radio waves cannot propagate through a perfect conductor. So, although metal filing cabinets and large appliances are not perfect conductors, they are sufficient to cause degradation of a WLAN signal. For example, a WLAN signal might hit a large air conditioning unit, causing the radio waves to be reflected and scattered in multiple directions. Not only does this limit the range of the WLAN signal, but radio waves carrying data might travel over different paths. This *multipath* issue can cause data corruption.
- **Signal strength:** The range of a WLAN device is a function of the device's signal strength. Lower-cost consumer-grade APs do not typically allow an administrative adjustment of signal strength. However, enterprise-class APs often allow signal strength to be adjusted to assure sufficient coverage of a specific area, while avoiding interference with other APs using the same channel.

As you can see from this list, most RFI occurs in the 2.4-GHz band as opposed to the 5-GHz band. Therefore, depending on the wireless clients you need to support, you might consider using the 5-GHz band, which is an option for 802.11a and 802.11n WLANs.

Wireless AP Placement

WLANs using more than one AP (an ESS WLAN) require careful planning to prevent the APs from interfering with one another, while still servicing a desired coverage area. Specifically, an overlap of coverage between APs should exist to allow uninterrupted roaming from one WLAN *cell* (which is the coverage area provided by an AP) to another. However, those overlapping coverage areas should not use overlapping frequencies.

Figure 8-9 shows how nonoverlapping channels in the 2.4-GHz band can overlap their coverage areas to provide seamless roaming between AP coverage areas. A common WLAN design recommendation is to have a 10–15 percent overlap of coverage between adjoining cells.

Key Topic

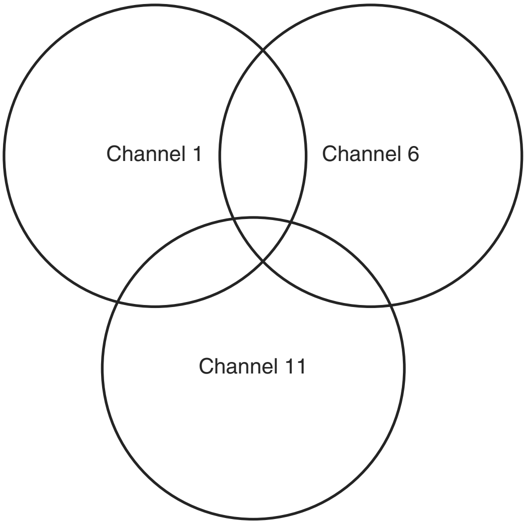


Figure 8-9 10–15 Percent Coverage Overlap in Coverage Areas for Nonoverlapping Channels

If a WLAN has more than three APs, the APs can be deployed in a honeycomb fashion to allow an overlap of AP coverage areas while avoiding an overlap of identical channels. The example shown in Figure 8-10 shows an approach to channel selection for adjoining cells in the 2.4-GHz band. Notice that cells using the same nonoverlapping channels (channels 1, 6, and 11) are separated by another cell. For example, notice that none of the cells using channel 11 overlap another cell using channel 11.

Key Topic

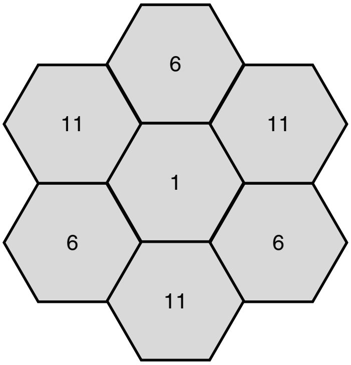


Figure 8-10 Nonoverlapping Coverage Cells for the 2.4-GHz Band

NOTE Although a honeycomb channel assignment scheme can be used for the 5-GHz band, identical channels should be separated by at least two cells, rather than the single cell shown for the 2.4 GHz band.

Securing Wireless LANs

WLANs introduce some unique concerns to your network. For example, improperly installed wireless APs are roughly equivalent to putting an Ethernet port in a building's parking lot, where someone can drive up and access to your network. Fortunately, a variety of features are available to harden the security of your WLAN, as discussed in this section.

Security Issues

In the days when dial-up modems were popular, malicious users could run a program on their computer to call all phone numbers in a certain number range. Phone numbers that answered with modem tone became targets for later attacks. This type of reconnaissance was known as *war dialing*. A modern-day variant of war dialing is *war driving*, where potentially malicious users drive around looking for unsecured WLANs. These users might be identifying unsecured WLANs for nefarious purposes or simply looking for free Internet access.

Other WLAN security threats include the following:

Key Topic

- **Warchalking:** Once an open WLAN (or a WLAN whose SSID and authentication credentials are known) is found in a public place, a user might write a symbol on a wall (or some other nearby structure), to let others know the characteristics of the discovered network. This practice, which is a variant of the decades-old practice of hobos leaving symbols as messages to fellow hobos, is called *warchalking*. Figure 8-11 shows common warchalking symbols.

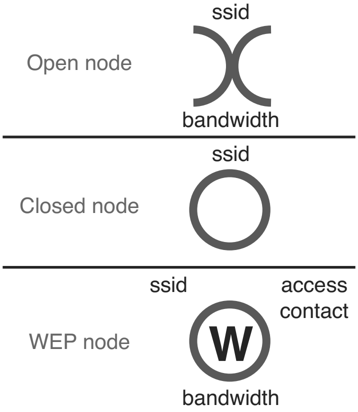


Figure 8-11 Warchalking Symbols

- **WEP and WPA security cracking:** As discussed later in this chapter, various security standards are available for encrypting and authenticating a WLAN client with an AP. Two of the less secure standards include *Wired Equivalent Privacy* (WEP) and *Wi-Fi Protected Access* (WPA). Although WPA is considered more secure than WEP, utilities are available on the Internet for cracking each of these approaches to wireless security. By collecting enough packets transmitted by a secure AP, these cracking utilities can use mathematical algorithms to determine the *preshared key* (PSK) configured on a wireless AP, with which an associating wireless client must also be configured.
- **Rogue access point:** A malicious user could set up his own AP to which legitimate users would connect. Such an AP is called a *rogue access point*. That malicious user could then use a *packet sniffer* (which displays information about unencrypted traffic, including the traffic's data and header information) to eavesdrop on communications flowing through their AP. To cause unsuspecting users to connect to the rogue AP, the malicious user could configure the rogue AP with the same *service set identifier* (SSID) as used by a legitimate AP. When a rogue AP is configured with the SSID of legitimate AP, the rogue AP is commonly referred to as an *evil twin*.

NOTE An SSID is a string of characters identifying a WLAN. APs participating in the same WLAN (in an ESS) can be configured with identical SSIDs. An SSID shared among multiple APs is called an *extended service set identifier* (ESSID).

Approaches to WLAN Security

A WLAN that does not require any authentication or provide any encryption for wireless devices (for example, a publicly available WLAN found in many airports) is said to be using *open authentication*. To protect WLAN traffic from eavesdroppers, a variety of security standards and practices have been developed, including the following:

Key Topic

- **MAC address filtering:** An AP can be configured with a listing of MAC addresses that are permitted to associate with the AP. If a malicious user attempts to connect via his laptop (whose MAC address is not on the list of trusted MAC addresses), that user is denied access. One drawback to MAC address filtering is the administrative overhead required to keep an approved list of MAC addresses up-to-date. Another issue with MAC address filtering is that a knowledgeable user could falsify the MAC address of his wireless network card, making his device appear to be approved.
- **Disabling SSID broadcast:** An SSID can be broadcast by an AP to let users know the name of the WLAN. For security purposes, an AP might be configured not to broadcast its SSID. However, knowledgeable users could still determine the SSID of an AP by examining captured packets.
- **Preshared key:** To encrypt transmission between a wireless client and an AP (in addition to authenticating a wireless client with an AP), both the wireless client and the AP could be preconfigured with a matching string of characters (a *preshared key* [PSK], as previously described). The PSK could be used as part of a mathematical algorithm to encrypt traffic, such that if an eavesdropper intercepted in the encrypted traffic, he would not be able to decrypt the traffic without knowing the PSK. Although using a PSK can be effective in providing security for a small network (for example, a SOHO network), it lacks scalability. For example, in a large corporate environment, a PSK being compromised would necessitate the reconfiguration of all devices configured with that PSK.

NOTE WLAN security based on a PSK technology is called *personal mode*.

- **IEEE 802.1X:** Rather than having all devices in a WLAN be configured with the same PSK, a more scalable approach is to require all wireless users to authenticate using their own credentials (for example, a username and password). Allowing each user to have his own set of credentials prevents the compromising of one password from impacting the configuration of all wireless devices. *IEEE 802.1x* is a technology that allows wireless clients to authenticate with an authentication server (typically, a *Remote Authentication Dial-In User Service* [RADIUS] server).

NOTE WLAN security based on IEEE 802.1x is called *enterprise mode*.

Chapter 4 discussed IEEE 802.1x in detail and described the role of a *supplicant*, an *authenticator*, and an *authentication server*; however, Chapter 4 showed how IEEE 802.1x was used in a wired network. Figure 8-12 shows a wireless implementation of IEEE 8021x.

Key Topic

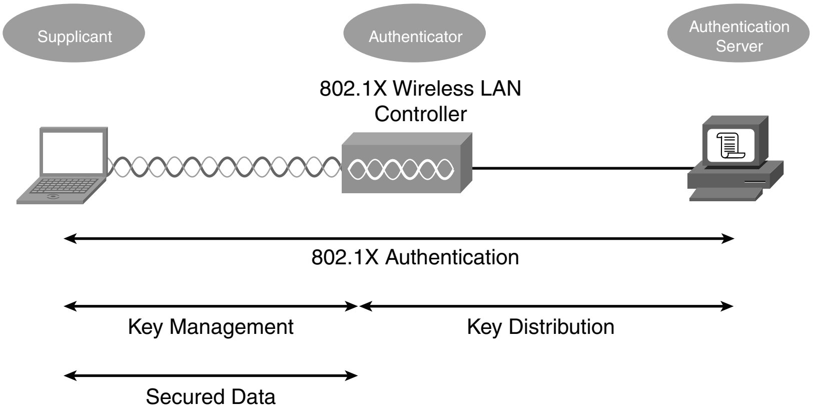


Figure 8-12 IEEE 802.1x Security for a WLAN

NOTE IEEE 802.1x works in conjunction with an *Extensible Authentication Protocol* (EAP) to perform its job of authentication. A variety of EAP types exist, including *Lightweight Extensible Authentication Protocol* (LEAP), *EAP-Flexible Authentication via Secure Tunneling* (EAP-FAST), *EAP-Transport Layer Security* (EAP-TLS), *Protected EAP–Generic Token Card* (PEAP-GTC), and *Protected EAP–Microsoft Challenge Handshake Authentication Protocol version 2* (PEAP-MSCHAPv2). Although these EAP types differ in their procedures, the overriding goal for each EAP type is to securely authenticate a supplicant and provide the supplicant and the authenticator a *session key* that can be used during a single session in the calculation of security algorithms (for example, encryption algorithms).

Security Standards

When configuring a wireless client for security, the most common security standards from which you can select are as follows:

- Wired Equivalent Privacy (WEP)
- Wi-Fi Protected Access (WPA)
- Wi-Fi Protected Access version 2 (WPA2)

The following sections describe these standards in detail.

WEP

The original 802.11 standard did address security; however, the security was a WEP key. With WEP, an AP is configured with a static WEP key. Wireless clients needing to associate with an AP are configured with an identical key (making this a PSK approach to security). The 802.11 standard specifies a 40-bit WEP key, which is considered to be a relatively weak security measure.

Because a WEP key is a static string of characters, it could be compromised with a brute-force attack, where an attacker attempts all possible character combinations until a match for the WEP key is found. Another concern, however, is that WEP uses *RC4* as its encryption algorithm.

> **NOTE** RC4 (which stands for *Ron's Code* or *Rivest Cipher*, because it was developed by Ron Rivest of RSA Security) is sometimes pronounced *arc 4*.

RC4 uses a 24-bit *initialization vector* (IV), which is a string of characters added to the transmitted data, such that the same plain text data frame will never appear as the same WEP-encrypted data frame. However, the IV is transmitted in clear text. So, if a malicious user, using packet-capture software, captures enough packets having the same WEP key, and because the malicious user can see the IV in clear text, he can use a mathematical algorithm (which can be performed with WEP-cracking software found on the Internet) to determine the static WEP key.

Some WEP implementations support the use of a longer WEP key (for example, 128 bits instead of 40 bits), making a WEP key more difficult to crack; however, both the wireless clients and their AP must support the longer WEP key.

WPA

The Wi-Fi Alliance (a nonprofit organization formed to certify interoperability of wireless devices) developed its own security standard, WPA, to address the weaknesses of WEP. Some of the security enhancements offered by WPA include the following:

- WPA operating in enterprise mode can require a user to be authenticated before keys are exchanged.
- In enterprise mode, the keys used between a wireless client and an access point are temporary session keys.
- WPA uses *Temporal Key Integrity Protocol* (TKIP) for enhanced encryption. Although TKIP does rely on an initialization vector, the IV is expanded from WEP's 24-bit IV to a 48-bit IV. Also, broadcast key rotation can be used, which causes a key to change so quickly, an eavesdropper would not have time to exploit a derived key.
- TKIP leverages *Message Integrity Check* (MIC), which is sometimes referred to as *Message Integrity Code* (MIC). MIC can confirm that data was not modified in transit.

Although not typically written as WPA1, when you see the term *WPA*, consider it to be WPA version 1 (WPA1). WPA version 2, however, is written as *WPA2*.

WPA2

In 2004, the *IEEE 802.11i* standard was approved, and required stronger algorithms for encryption and integrity checking than those seen in previous WLAN security protocols such as WEP and WPA. The requirements set forth in the IEEE 802.11i standard are implemented in the Wi-Fi Alliance's *WPA version 2* (WPA2) security standard. WPA2 uses *Counter Mode with Cipher Block Chaining Message Authentication Code Protocol* (CCMP) for integrity checking and *Advanced Encryption Standard* (AES) for encryption.

Summary

The main topics covered in this chapter are the following:

- Various components, technologies, and terms used in WLANs were identified.
- WLAN design considerations were presented, such as the selection of WLAN standards, bands, and nonoverlapping channels. Potential sources of interference were also identified.
- Some of the security risks posed by a WLAN were described and the technologies available for mitigating those risks were presented.

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics from inside the chapter, noted with the Key Topic icon in the outer margin of the page. Table 8-4 lists these key topics and the page numbers where each is found.

Table 8-4 Key Topics for Chapter 8

Key Topic Element	Description	Page Number
Figure 8-1	Basic WLAN topology with a wireless router	259
Figure 8-2	Basic WLAN topology with a wireless access point	260
Figure 8-3	Omnidirectional antenna coverage	261
Figure 8-4	Unidirectional antenna coverage	262
Figure 8-5	Nonoverlapping channels in the 2.4-GHz band	263
List	Spread spectrum transmission methods	266
Table 8-3	Characteristics of 802.11 standards	268
Figure 8-6	Independent basic service set (IBSS) WLAN	269
Figure 8-7	Basic service set (BSS) WLAN	270
Figure 8-8	Extended service set (ESS) WLAN	270
List	Sources of interference	271
Figure 8-9	10–15 percent coverage overlap in coverage areas for nonoverlapping channels	272
Figure 8-10	Nonoverlapping coverage cells for the 2.4-GHz band	273
List	Wireless security threats	274
List	Security standards and best practices	275
Figure 8-12	IEEE 802.1x security for a WLAN	276

Complete Tables and Lists from Memory

Print a copy of Appendix C, "Memory Tables" (found on the CD), or at least the section for this chapter, and complete the tables and lists from memory. Appendix D, "Memory Table Answer Key," also on the CD, includes the completed tables and lists so you can check your work.

Define Key Terms

Define the following key terms from this chapter, and check your answers in the Glossary:

wireless access point (AP), wireless router, decibel (dB), omnidirectional antenna, unidirectional antenna, carrier sense multiple access collision avoidance (CSMA/CA), direct-sequence spread spectrum (DSSS), frequency-hopping spread spectrum (FHSS), Orthogonal Frequency Division Multiplexing (OFDM), 802.11a, 802.11b, 802.11g, 802.11n, multiple input, multiple output (MIMO), channel bonding, independent basic service set (IBSS), basic service set (BSS), extended service set (ESS), warchalking, service set identifier (SSID), Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA), Wi-Fi Protected Access version 2 (WPA2)

Review Questions

The answers to these review questions are in Appendix A, "Answers to Review Questions."

1. What type of antenna, commonly used in wireless APs and wireless routers in SOHO locations, radiates relatively equal power in all directions?

   a. Unidirectional

   b. Yagi

   c. Parabolic

   d. Omnidirectional

2. When using the 2.4-GHz band for multiple access points in a WLAN located in the United States, which nonoverlapping channels should you select? (Choose three.)

   a. 0

   b. 1

   c. 5

   d. 6

e. 10

f. 11

g. 14

3. What technology do WLANs use to determine when they gain access to the wireless media?

   a. SPF

   b. CSMA/CA

   c. RSTP

   d. DUAL

4. What IEEE 802.11 variant supports a maximum speed of 54 Mbps and uses the 2.4-GHz band?

   a. 802.11a

   b. 802.11b

   c. 802.11g

   d. 802.11n

5. Which of the following is used by IEEE 802.11n to achieve high throughput through the use of multiple antennas for transmission and reception?

   a. MIMO

   b. DSSS

   c. FHSS

   d. LACP

6. A WLAN formed directly between wireless clients (without the use of a wireless AP) is referred to as what type of WLAN?

   a. Enterprise mode

   b. IBSS

   c. Personal mode

   d. BSS

7. When extended the range for a 2.4-GHz WLAN, you can use nonoverlapping channels for adjacent coverage cells. However, there should be some overlap in coverage between those cells (using nonoverlapping channels) to prevent a connection from dropping as a user roams from one coverage cell to another. What percentage of coverage overlap is recommended for these adjacent cells?

   a. 5–10 percent

   b. 10–15 percent

   c. 15–20 percent

   d. 20–25 percent

8. If a WLAN does not require a user to provide any credentials to associate with a wireless AP and access the WLAN, what type of authentication is said to be in use?

   a. WEP

   b. SSID

   c. Open

   d. IV

9. WEP's RC4 approach to encryption uses a 24-bit string of characters added to transmitted data, such that the same plain text data frame will never appear as the same WEP-encrypted data frame. What is this string of characters called?

   a. Initialization vector

   b. Chips

   c. Orthogonal descriptor

   d. Session key

10. What standard developed by the Wi-Fi Alliance implements the requirements of IEEE 802.11i?

    a. TKIP

    b. MIC

    c. WEP

    d. WPA2

This page intentionally left blank

This page intentionally left blank

Index