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CompTIA Network+ N10-005 Authorized Cert Guide

Kevin Wallace, CCIE #7945

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800 East 96th Street
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CompTIA Network+ N10-005 Authorized Cert Guide

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Contents at a Glance

Introduction	xxvi
CHAPTER 1	Introducing Computer Networks 3
CHAPTER 2	Dissecting the OSI Model 29
CHAPTER 3	Identifying Network Components 59
CHAPTER 4	Understanding Ethernet 107
CHAPTER 5	Working with IP Addresses 139
CHAPTER 6	Routing Traffic 189
CHAPTER 7	Introducing Wide-Area Networks 221
CHAPTER 8	Connecting Wirelessly 257
CHAPTER 9	Optimizing Network Performance 285
CHAPTER 10	Using Command-Line Utilities 315
CHAPTER 11	Managing a Network 357
CHAPTER 12	Securing a Network 385
CHAPTER 13	Troubleshooting Network Issues 437
CHAPTER 14	Final Preparation 461
APPENDIX A	Answers to Review Questions 469
APPENDIX B	CompTIA Network+ N10-005 Exam Updates, Version 1.0 473
	Glossary 475
	Index 503
APPENDIX C	Memory Tables (DVD Only) 3
APPENDIX D	Memory Table Answer Key (DVD Only) 3

Table of Contents

Introduction	xxvi
Chapter 1 Introducing Computer Networks	3
Foundation Topics	4
Defining a Network	4
The Purpose of Networks	4
Overview of Network Components	5
Networks Defined by Geography	7
LAN	7
WAN	8
Other Categories of Networks	9
CAN	9
MAN	9
PAN	9
Networks Defined by Topology	9
Physical Versus Logical Topology	10
Bus Topology	11
Ring Topology	13
Star Topology	15
Hub-and-Spoke Topology	16
Full-Mesh Topology	18
Partial-Mesh Topology	19
Networks Defined by Resource Location	20
Client-Server Networks	20
Peer-to-Peer Networks	22
Summary	24
Exam Preparation Tasks	25
Review All the Key Topics	25
Complete Tables and Lists from Memory	25
Define Key Terms	25
Review Questions	26
Chapter 2 Dissecting the OSI Model	29
Foundation Topics	30
The Purpose of Reference Models	30

The OSI Model	31
Layer 1: The Physical Layer	33
Layer 2: The Data Link Layer	36
Media Access Control	37
Logical Link Control	37
Layer 3: The Network Layer	39
Layer 4: The Transport Layer	42
Layer 5: The Session Layer	44
Layer 6: The Presentation Layer	45
Layer 7: The Application Layer	46
The TCP/IP Stack	47
Layers of the TCP/IP Stack	47
Common Application Protocols in the TCP/IP Stack	51
Summary	53
Exam Preparation Tasks	54
Review All the Key Topics	54
Complete Tables and Lists from Memory	54
Define Key Terms	55
Review Questions	55
Chapter 3	Identifying Network Components
Foundation Topics	60
Media	60
Coaxial Cable	60
Twisted-Pair Cable	62
Shielded Twisted Pair	62
Unshielded Twisted Pair	63
Plenum Versus Non-Plenum Cable	66
Fiber-Optic Cable	66
Multimode Fiber	67
Single-Mode Fiber	68
Cable Distribution	70
Wireless Technologies	73
Network Infrastructure Devices	74
Hubs	74
Bridges	75

Switches	77
Multilayer Switches	83
Routers	84
Infrastructure Device Summary	85
Specialized Network Devices	86
VPN Concentrators	86
Firewalls	87
DNS Servers	88
DHCP Servers	90
Proxy Servers	92
Content Engines	93
Content Switches	94
Virtual Network Devices	95
Virtual Servers	95
Virtual Switches	96
Virtual Desktops	97
Other Virtualization Solutions	98
Voice over IP Protocols and Components	99
Summary	101
Exam Preparation Tasks	102
Review All the Key Topics	102
Complete Tables and Lists from Memory	103
Define Key Terms	103
Review Questions	104
Chapter 4 Understanding Ethernet	107
Foundation Topics	108
Principles of Ethernet	108
Ethernet Origins	108
Carrier Sense Multiple Access Collision Detect	110
Distance and Speed Limitations	113
Ethernet Switch Features	116
Virtual LANs	116
Trunks	118
Spanning Tree Protocol	119

Corruption of a Switch’s MAC Address Table	119
Broadcast Storms	120
STP Operation	122
Link Aggregation	124
Power over Ethernet	126
Port Monitoring	127
User Authentication	129
First-Hop Redundancy	130
Other Switch Features	131
Summary	132
Exam Preparation Tasks	133
Review All the Key Topics	133
Complete Tables and Lists from Memory	133
Define Key Terms	134
Review Questions	134
Chapter 5 Working with IP Addresses	139
Foundation Topics	140
Binary Numbering	140
Principles of Binary Numbering	140
Converting a Binary Number to a Decimal Number	141
Converting a Decimal Number to a Binary Number	141
Binary Numbering Practice	143
Binary Conversion Exercise #1	143
Binary Conversion Exercise #1: Solution	144
Binary Conversion Exercise #2	144
Binary Conversion Exercise #2: Solution	144
Binary Conversion Exercise #3	145
Binary Conversion Exercise #3: Solution	145
Binary Conversion Exercise #4	146
Binary Conversion Exercise #4: Solution	146
IPv4 Addressing	147
IPv4 Address Structure	147
Classes of Addresses	149
Types of Addresses	151

Unicast	151
Broadcast	152
Multicast	152
Assigning IPv4 Addresses	153
IP Addressing Components	154
Static Configuration	154
Dynamic Configuration	159
BOOTP	159
DHCP	160
Automatic Private IP Addressing	161
Subnetting	162
Purpose of Subnetting	162
Subnet Mask Notation	163
Subnet Notation: Practice Exercise #1	165
Subnet Notation: Practice Exercise #1 Solution	165
Subnet Notation: Practice Exercise #2	165
Subnet Notation: Practice Exercise #2 Solution	165
Extending a Classful Mask	166
Borrowed Bits	166
Calculating the Number of Created Subnets	166
Calculating the Number of Available Hosts	167
Basic Subnetting Practice: Exercise #1	167
Basic Subnetting Practice: Exercise #1 Solution	168
Basic Subnetting Practice: Exercise #2	169
Basic Subnetting Practice: Exercise #2 Solution	169
Calculating New IP Address Ranges	170
Advanced Subnetting Practice: Exercise #1	172
Advanced Subnetting Practice: Exercise #1 Solution	172
Advanced Subnetting Practice: Exercise #2	173
Advanced Subnetting Practice: Exercise #2 Solution	174
Additional Practice	176
Classless Inter-Domain Routing	177
IP Version 6	178
Need for IPv6	178
IPv6 Address Structure	178

IPv6 Data Flows	179
Unicast	179
Multicast	180
Anycast	181
Summary	182
Exam Preparation Tasks	183
Review All the Key Topics	183
Complete Tables and Lists from Memory	184
Define Key Terms	184
Review Questions	184
Chapter 6 Routing Traffic	189
Foundation Topics	190
Basic Routing Processes	190
Sources of Routing Information	193
Directly Connected Routes	193
Static Routes	194
Dynamic Routing Protocols	195
Routing Protocol Characteristics	197
Believability of a Route	198
Metrics	198
Interior Versus Exterior Gateway Protocols	199
Route Advertisement Method	200
Distance Vector	200
Link State	202
Routing Protocol Examples	202
Address Translation	204
NAT	204
PAT	206
Multicast Routing	208
IGMP	208
PIM	210
PIM-DM	211
PIM-SM	213
Summary	215

Exam Preparation Tasks	216
Review All the Key Topics	216
Complete Tables and Lists from Memory	216
Define Key Terms	216
Review Questions	217
Chapter 7 Introducing Wide-Area Networks	221
Foundation Topics	222
WAN Properties	222
WAN Connection Types	222
WAN Data Rates	224
WAN Media Types	225
Physical Media	225
Wireless Media	226
WAN Technologies	227
Dedicated Leased Line	228
T1	228
E1	229
T3	229
E3	229
CSU/DSU	230
Point-to-Point Protocol	230
Digital Subscriber Line	234
Cable Modem	236
Synchronous Optical Network	237
Satellite	239
Plain Old Telephone Service	241
Integrated Services Digital Network	243
Frame Relay	245
Asynchronous Transfer Mode	246
Multiprotocol Label Switching	249
Summary	250
Exam Preparation Tasks	251
Review All the Key Topics	251
Complete Tables and Lists from Memory	251

Define Key Terms	252
Review Questions	252
Chapter 8 Connecting Wirelessly 257	
Foundation Topics	258
Introducing Wireless LANs	258
WLAN Concepts and Components	258
Wireless Routers	258
Wireless Access Point	259
Antennas	260
Frequencies and Channels	262
CSMA/CA	265
Transmission Methods	265
WLAN Standards	266
802.11a	266
802.11b	267
802.11g	267
802.11n	267
Deploying Wireless LANs	268
Types of WLANs	268
IBSS	269
BSS	269
ESS	270
Sources of Interference	271
Wireless AP Placement	272
Securing Wireless LANs	273
Security Issues	273
Approaches to WLAN Security	275
Security Standards	277
WEP	277
WPA	278
WPA2	278
Summary	278
Exam Preparation Tasks	279
Review All the Key Topics	279
Complete Tables and Lists from Memory	280

Define Key Terms 280

Review Questions 280

Chapter 9 Optimizing Network Performance 285

Foundation Topics 286

High Availability 286

 High-Availability Measurement 286

 Fault-Tolerant Network Design 286

 Hardware Redundancy 288

 Layer 3 Redundancy 288

 Design Considerations for High-Availability Networks 290

 High-Availability Best Practices 290

 Content Caching 291

 Load Balancing 291

QoS Technologies 292

 Introduction to QoS 292

 QoS Configuration Steps 294

 QoS Components 295

 QoS Mechanisms 296

 Classification 296

 Marking 297

 Congestion Management 298

 Congestion Avoidance 298

 Policing and Shaping 299

 Link Efficiency 301

Case Study: SOHO Network Design 302

 Case Study Scenario 302

 Suggested Solution 304

 IP Addressing 304

 Layer 1 Media 305

 Layer 2 Devices 306

 Layer 3 Devices 307

 Wireless Design 307

 Environmental Factors 308

 Cost Savings Versus Performance 308

 Topology 309

Summary	309
Exam Preparation Tasks	310
Review All the Key Topics	310
Complete Tables and Lists from Memory	310
Define Key Terms	311
Review Questions	311

Chapter 10 Using Command-Line Utilities 315

Foundation Topics	316
Windows Commands	316
arp	316
ipconfig	318
nbtstat	321
netstat	324
nslookup	326
ping	328
route	330
tracert	334
UNIX Commands	336
arp	337
dig and nslookup	340
host	341
ifconfig	341
traceroute	342
netstat	343
ping	345
Summary	348
Exam Preparation Tasks	349
Review All the Key Topics	349
Complete Tables and Lists from Memory	350
Define Key Terms	350
Review Questions	350

Chapter 11 Managing a Network 357

Foundation Topics	358
Maintenance Tools	358
Bit-Error Rate Tester	358
Bott Set	359

Cable Certifier	359
Cable Tester	360
Connectivity Software	360
Crimper	360
Electrostatic Discharge Wrist Strap	361
Environmental Monitor	362
Loopback Plug	362
Multimeter	363
Protocol Analyzer	364
Punch-Down Tool	365
Throughput Tester	365
Time Domain Reflectometer/Optical Time Domain Reflectometer	366
Toner Probe	366
Configuration Management	367
Monitoring Resources and Reports	369
SNMP	369
Syslog	373
Logs	375
Application Logs	376
Security Logs	376
System Logs	377
Summary	378
Exam Preparation Tasks	379
Review All the Key Topics	379
Complete Tables and Lists from Memory	379
Define Key Terms	380
Review Questions	380
Chapter 12 Securing a Network	385
Foundation Topics	386
Security Fundamentals	386
Network Security Goals	386
Confidentiality	386
Integrity	390
Availability	391
Categories of Network Attacks	391

Confidentiality Attacks	391
Integrity Attacks	394
Availability Attacks	397
Defending Against Attacks	402
User Training	402
Patching	402
Security Policies	403
Governing Policy	404
Technical Policies	405
End User Policies	405
More Detailed Documents	405
Incident Response	406
Vulnerability Scanners	407
Nessus	407
Nmap	408
Honey Pots and Honey Nets	409
Access Control Lists	410
Remote Access Security	411
Firewalls	413
Firewall Types	413
Firewall Inspection Types	414
Packet-Filtering Firewall	414
Stateful Firewall	415
Firewall Zones	416
Virtual Private Networks	417
Overview of IPsec	419
IKE Modes and Phases	420
Authentication Header and Encapsulating Security Payload	422
The Five Steps in Setting Up and Tearing Down an IPsec Site-to-Site VPN	423
Other VPN Technologies	425
Intrusion Detection and Prevention	425
IDS Versus IPS	426
IDS and IPS Device Categories	427

Detection Methods	427
Deploying Network-Based and Host-Based Solutions	428
Summary	430
Exam Preparation Tasks	431
Review All the Key Topics	431
Complete Tables and Lists from Memory	432
Define Key Terms	432
Review Questions	432
Chapter 13 Troubleshooting Network Issues	437
Foundation Topics	438
Troubleshooting Basics	438
Troubleshooting Fundamentals	438
Structured Troubleshooting Methodology	440
Physical Layer Troubleshooting	443
Physical Layer Troubleshooting: Scenario	444
Physical Layer Troubleshooting: Solution	445
Data Link Layer Troubleshooting	445
Data Link Layer Troubleshooting: Scenario	446
Data Link Layer Troubleshooting: Solution	447
Network Layer Troubleshooting	447
Layer 3 Data Structures	448
Common Layer 3 Troubleshooting Issues	449
Network Layer Troubleshooting: Scenario	451
Network Layer Troubleshooting: Solution	451
Wireless Troubleshooting	452
Wireless Network Troubleshooting: Scenario	454
Wireless Network Troubleshooting: Solution	455
Summary	455
Exam Preparation Tasks	456
Review All the Key Topics	456
Complete Tables and Lists from Memory	456
Define Key Terms	456
Review Questions	457

Chapter 14 Final Preparation 461

Tools for Final Preparation 461

Pearson Cert Practice Test Engine and Questions on the DVD 461

 Install the Software from the DVD 462

 Activate and Download the Practice Exam 463

 Activating Other Exams 463

 Premium Edition 463

 Video Training on DVD 464

 Memory Tables 464

 End-of-Chapter Review Tools 465

 Suggested Plan for Final Review and Study 465

 Summary 467

APPENDIX A Answers to Review Questions 469**APPENDIX B CompTIA Network+ N10-005 Exam Updates, Version 1.0 473**

 Glossary 475

 Index 503

APPENDIX C Memory Tables (DVD Only) 3**APPENDIX D Memory Table Answer Key (DVD Only) 3**

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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.

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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

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CompTIA Network+

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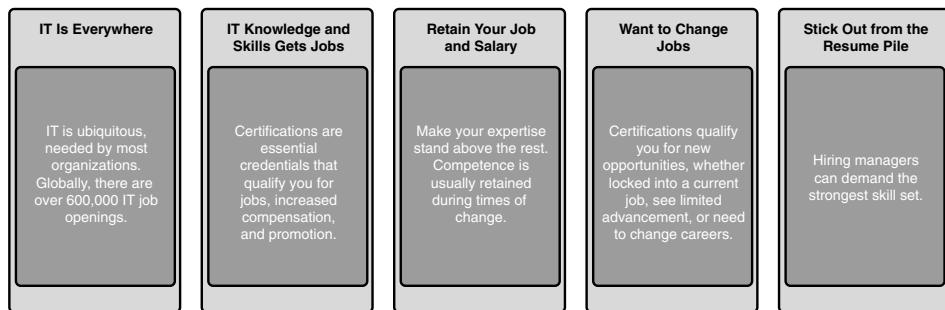
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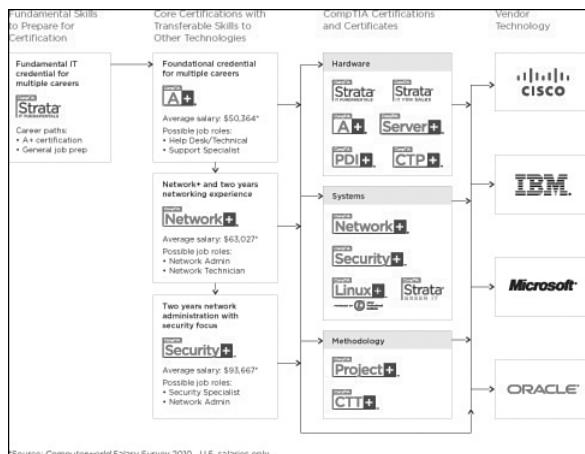
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Introduction

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 5.0 Network Security	4.1 Explain the purpose and features of various network appliances. 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 2.0 Network Installation and Configuration 3.0 Network Media and Topologies	1.8 Given a scenario, implement a given troubleshooting methodology. 2.4 Given a scenario, troubleshoot common wireless problems. 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 is 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.



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?

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.

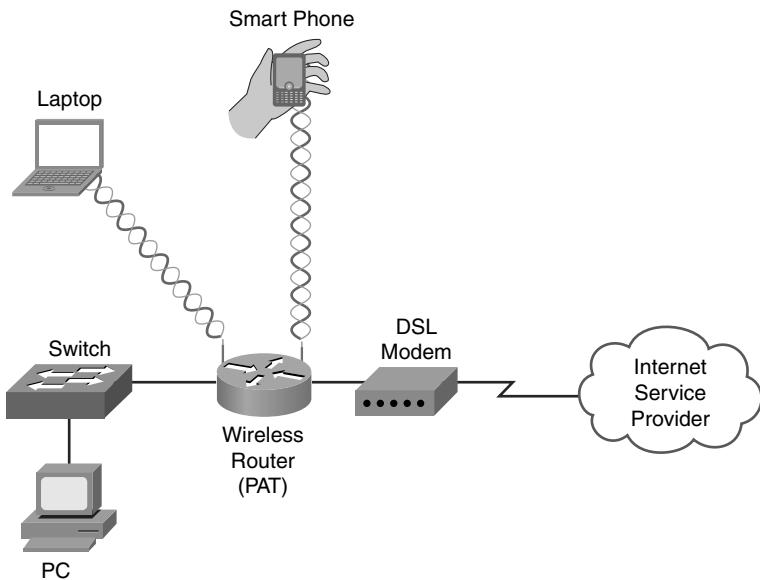
Key Topic

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.

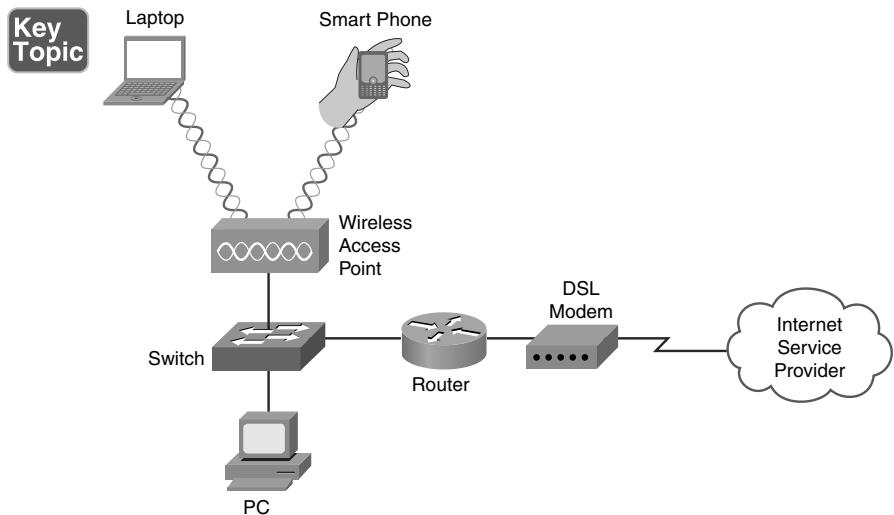


Figure 8-2 Basic WLAN Topology with a Wireless AP

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:

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

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.

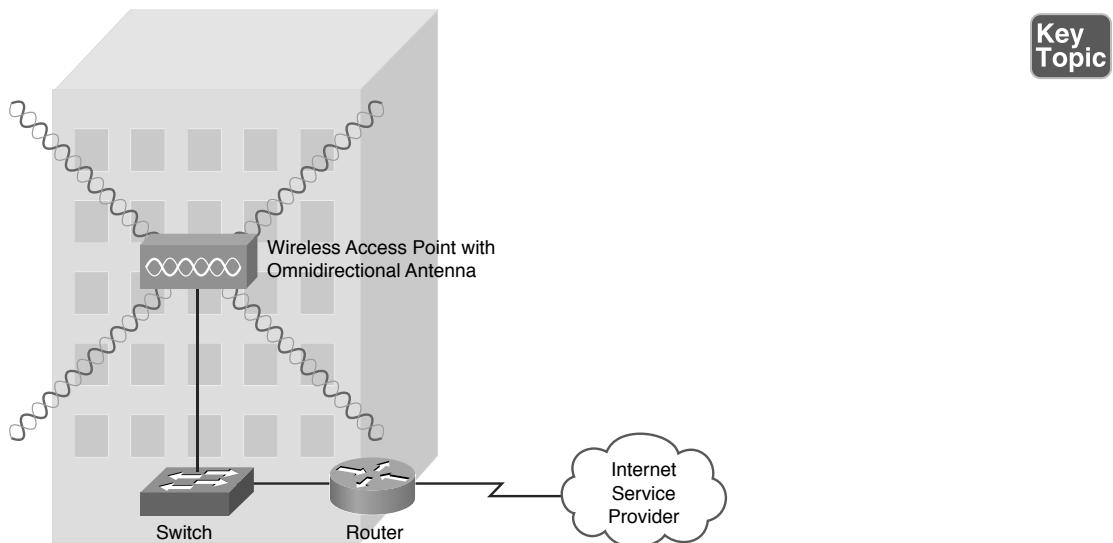


Figure 8-3 Omnidirectional Antenna Coverage

- **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

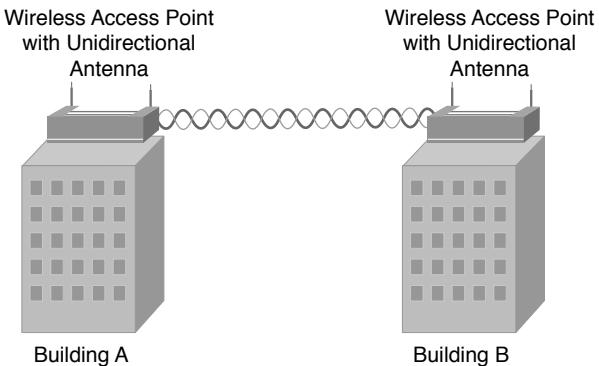


Figure 8-4 Unidirectional Antenna Coverage

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 *industrial, scientific, and medical*.

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.

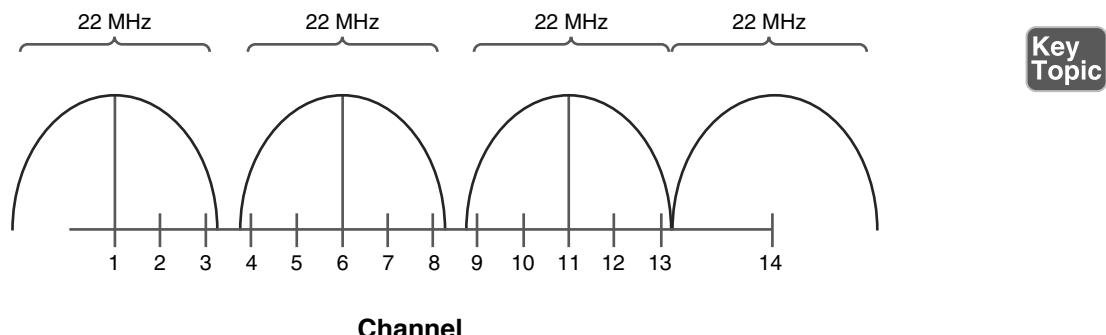


Figure 8-5 Nonoverlapping Channels in the 2.4 GHz Band

Key Topic

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

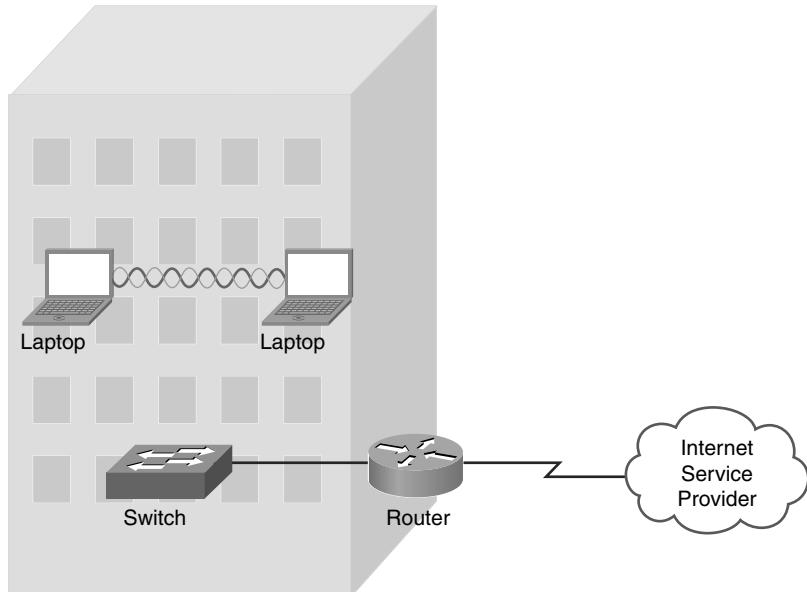


Figure 8-6 Independent Basic Service Set (IBSS) WLAN

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.

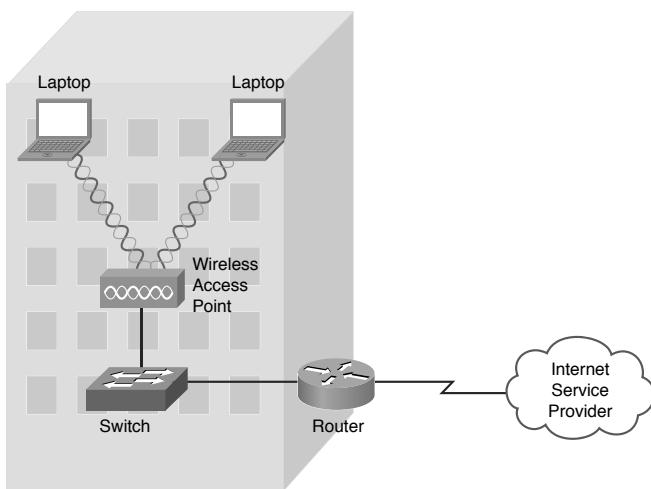
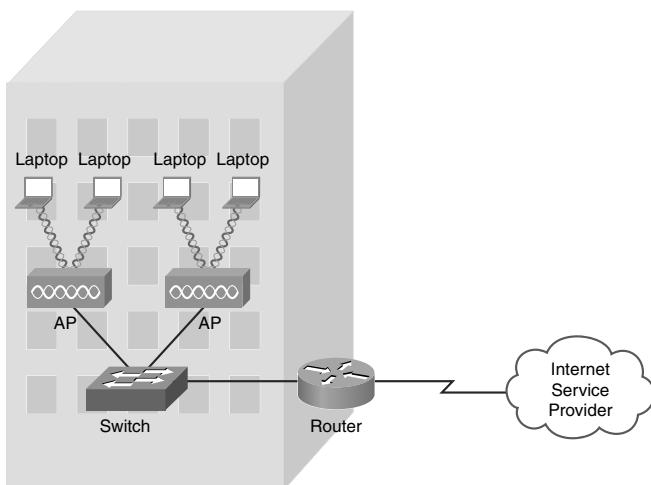
Key Topic**Figure 8-7** Basic Service Set (BSS) WLAN**ESS**

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

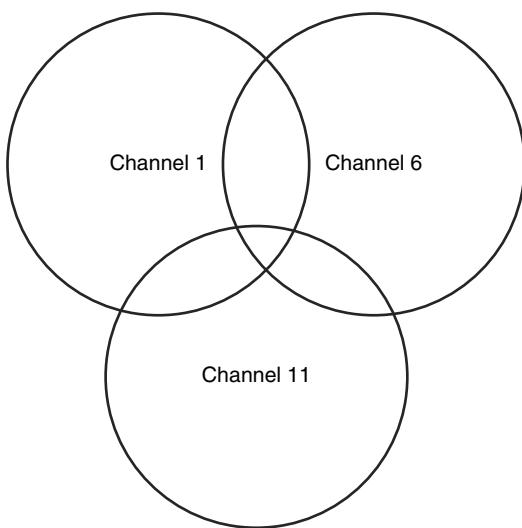


Figure 8-9 10–15 Percent Coverage Overlap in Coverage Areas for Nonoverlapping Channels

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.

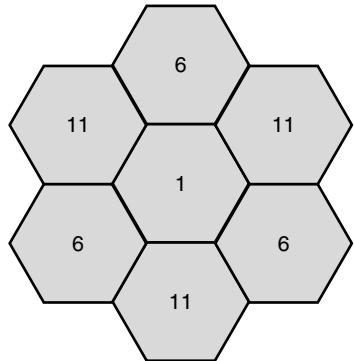


Figure 8-10 Nonoverlapping Coverage Cells for the 2.4-GHz Band

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.

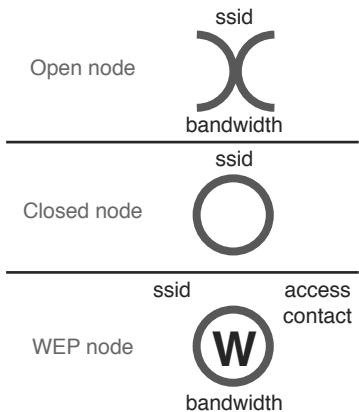


Figure 8-11 Warchalking Symbols

- **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:

- **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.

Key Topic

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 802.1x.

Key Topic

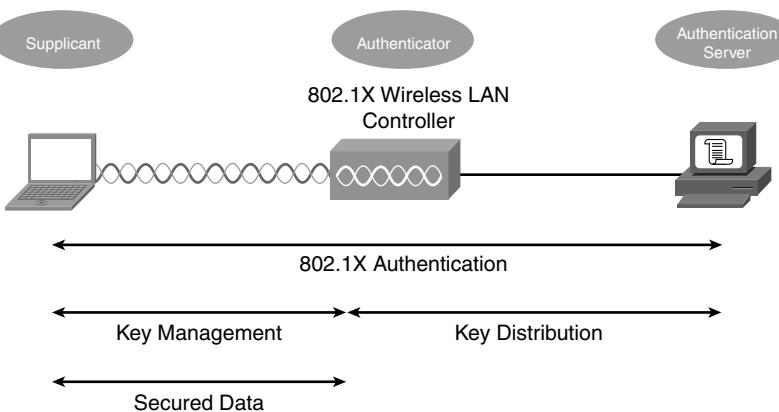


Figure 8-12 IEEE 802.1x Security for a WLAN

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 (IBSS) 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



Index

A

-
- A (address) record**, 89
 - AAA (authentication, authorization, and accounting)**, 412
 - AAAA (IPv6 address) record**, 89
 - acceptable use policy (AUP)**, 403
 - ACL (access control lists)**, 410-411
 - action plan**, 442
 - active hubs**, 74
 - active-active NIC redundancy**, 288
 - active-standby NIC redundancy**, 288
 - AD (administrative distance)**, 198
 - Adleman, Leonard M.**, 388
 - ADSL (asymmetric DSL)**, 234-236
 - AES (Advanced Encryption Standard)**, 387
 - AH (Authentication Header) protocol**, 422
 - AM (amplitude modulation)**, 34
 - analog phone**, 100
 - anomaly-based detection**, 428
 - antennas**
 - omnidirectional, 261
 - orientation of, 262
 - overview, 260-261
 - unidirectional, 262
 - anycast transmission**, 181
 - AP (access points)**
 - rogue access point, 274
 - troubleshooting**, 454
 - wireless access point**, 259-260
 - APIPA (Automatic Private IP Addressing)**, 151, 161-162
 - application layer**
 - OSI model, 46-47
 - TCP/IP stack, 50-53
 - application logs (Microsoft Windows)**, 376
 - application services**, 47
 - ARIN (American Registry for Internet Numbers)**, 150
 - arp command**
 - UNIX commands, 337-339
 - Windows commands, 316-318
 - asset management**, 367
 - assigning IP addresses**, 153-162
 - asymmetric encryption**, 388-390
 - asynchronous transmissions**, 35, 38
 - ATM (Asynchronous Transfer Mode)**, 224, 246-248
 - attacks**
 - availability attacks
 - buffer overflow*, 399
 - DDoS (distributed denial of service) attack*, 398
 - DoS (denial of service) attack*, 398
 - electrical disturbances*, 400-401
 - environmental threats*, 401-402
 - ICMP attacks*, 399-400

- overview, 397*
- physical environment, attacks on a system's, 401-402*
- ping of death, 399*
- Smurf attack, 399*
- TCP SYN flood, 398*
- categories of, 391-394
- confidentiality attacks
 - dumpster diving, 394*
 - EMI (electromagnetic interference) interception, 394*
 - FTP bounce, 394*
 - overview, 391-392*
 - packet capture, 394*
 - ping sweep and port scan, 394*
 - sending information over covert channels, 394*
 - sending information over overt channels, 394*
 - social engineering, 394*
 - wiretapping, 394*
- defending against attacks
 - ACL (access control lists), 410-411*
 - AUP (acceptable use policy), 403 documentation, 405-406*
 - end user policies, 405*
 - governing policy, 404*
 - honey nets, 409*
 - honey pots, 409*
 - incident response, 406*
 - patching, 402-403*
 - security policies, 403-406*
 - technical policies, 405*
 - user training, 402*
 - vulnerability scanners, 407-408*
- DoS (denial of service) attacks, 391
- integrity attacks
 - botnet, 397*
 - brute force, 396*
 - data diddling, 396*
 - dictionary attack, 397*
 - hijacking a session, 397*
 - keylogger, 396*
 - overview, 393-395*
 - packet capture, 396*
 - password attack, 396-397*
 - salami attack, 395*
 - Trojan horse, 396*
 - trust relationship exploitation, 396*
 - virus, 396*
 - worm, 396*
- AUP (acceptable use policy), 403**
- authentication, 372**
- authentication server, 130**
- authenticator, 130**
- availability attacks**
 - buffer overflow, 399*
 - DDoS (distributed denial of service) attack, 398*
 - DoS (denial of service) attack, 398*
 - electrical disturbances, 400-401*
 - environmental threats, 401-402*
 - ICMP attacks, 399-400*
 - overview, 397*
 - physical environment, attacks on a system's, 401-402*
 - ping of death, 399*
 - Smurf attack, 399*
 - TCP SYN flood, 398*

B**bandwidth**

Ethernet network, 113-114

physical layer (OSI Layer 1), 35

WAN (wide-area network), 225

Base-10 numbering system, 140**baseband technologies, 35****baselining, 367****believability of a route, 198****BER (bit error rate), 358****BERT (bit-error rate tester), 358****BGP (Border Gateway Protocol), 199, 203****binary expressions, 32****binary numbering**

conversion from decimal to binary, 141-143

conversion to decimal, 140-141

overview, 140

practice exercises, 143-146

binary representation, 147**bit-error rate tester, 358****blackouts, 400****BNC (Bayonet Neill-Concelman) connector, 61****bookshelf analogy for OSI model, 30-31****BOOTP (Bootstrap Protocol), 159-161****borrowed bits, 166****botnet, 397****BPDU (bridge protocol data units), 124****bridges, 75-77, 85****broadband technologies, 35****broadcast storms, 120-121****broadcast transmission, 152****brownout, 400****brute force, 396****BSS (basic service set), 269****buffer overflow, 399****buffering, 43****bus topology**

advantages of, 13

characteristics, 13

disadvantages of, 13

Ethernet network using shared, 110

overview, 11-13

butt set, 359**C****cable****coaxial cable**

connectors used on, 61

overview, 60

RG-6 cable, 61

RG-58 cable, 61

RG-59 cable, 61

types of, 61

distribution, 70-73

fiber-optic cable

connectors for, 69

multimode fiber (MMF), 67-68

overview, 66-67

single-mode fiber (SMF), 68-69

troubleshooting, 444

twisted-pair cable

connectors for, 65

crossover cable, 65

fire codes and, 66

overview, 62

shielded twisted-pair (STP) cable, 62
straight-through cable, 64-65
 unshielded twisted-pair (UTP) cable,
 63-64
Cat 3 cable, 64
Cat 5 cable, 64
Cat 6 cable, 64
Cat 6a cable, 64
Cat 5e cable, 64
categories of, 64
overview, 63

cable certifier, 360

cable distribution, 70-73

cable management, 368

cable modem, 236-237

cable tester, 360

calculator, subnet, 176

call agent, 100

CAN (campus-area network), 9

CARP (Common Address Redundancy Protocol), 131, 289

carrier sense, 112

carrier sense multiple access collision avoidance (CSMA/CA), 265

carrier sense multiple access collision detect (CSMA/CD), 110-113

case study: SOHO Network Design, 302-309

Cat 3 cable, 64

Cat 5 cable, 64

Cat 6 cable, 64

Cat 6a cable, 64

Cat 5e cable, 64

cellular phone technology for WAN (wide-area network), 227

Challenge-Response Authentication Mechanism Message Digest 5 (CRAM-MD5), 390

change management, 368

channel service unit/data service unit (CSU/DSU), 230

channels (wireless network), 262

CHAP (Challenge-Handshake Authentication Protocol), 231, 412

chassis, 290

CIDR (Classless Inter-Domain Routing), 177

circuit switching, 40

circuit-switched connection, 223

Cisco IOS, 372,

Class A addresses, 149-150

Class B addresses, 149-150

Class C addresses, 149-150

Class D addresses, 149-150

Class E addresses, 149-150

classes of IP addresses, 149-151

classful mask, extending, 166

client, 5

client-server network

- advantages of, 21
- characteristics of, 21
- disadvantages of, 21
- overview, 20-22

client-to-site VPN, 418-419

CM (configuration management)

- asset management, 367
- baselining, 367
- cable management, 368
- change management, 368
- described, 367
- network documentation, 368-369

CNAME (canonical name) record, 89

CO (central office), 242

coaxial cable

- connectors used on, 61

- overview, 60
- RG-6 cable, 61
- RG-58 cable, 61
- RG-59 cable, 61
- types of, 61
- for WAN, 226
- collision detect**, 112
- collision domain**, 75
- commands**
 - UNIX
 - arp command*, 337-339
 - dig command*, 340-341
 - host command*, 341
 - ifconfig command*, 341-342
 - netstat command*, 343-345
 - nslookup command*, 340-341
 - overview*, 336-337
 - ping command*, 345-346
 - route command*, 347-348
 - traceroute command*, 342-343
 - Windows
 - arp command*, 316-318
 - ipconfig command*, 318-321
 - nbstat command*, 321-324
 - netstat command*, 324-326
 - nslookup command*, 326-328
 - overview*, 316
 - ping command*, 328-330
 - route command*, 330-334
 - tracert command*, 334-336
- Common Address Redundancy Protocol (CARP)**, 131, 289
- companion website**, downloading updates from, 472
- components (network)**
 - client, 5
 - hub, 6
- media, 6
- overview, 4-5
- router, 6
- server, 5
- switch, 6
- WAN link, 6
- confidentiality**
 - with asymmetric encryption, 388-390
 - overview, 386-387
 - with symmetric encryption, 387
- confidentiality attacks**
 - dumpster diving, 394
 - EMI (electromagnetic interference) interception, 394
 - FTP bounce, 394
 - overview, 391-392
 - packet capture, 394
 - ping sweep and port scan, 394
 - sending information over covert channels, 394
 - sending information over overt channels, 394
 - social engineering, 394
 - wiretapping, 394
- configuration (network)**, 294-295
- configuration management**. See CM (configuration management)
- congestion**
 - avoidance, 299
 - control, 41
 - management, 298
- connection services**, 37-38, 41
- connection types for WAN**, 222-224
- connectivity software**, 360
- connectors**
 - coaxial cable, 61
 - fiber-optic cable, 69

- troubleshooting, 444
 - twisted-pair cable, 65
 - contact information included in network documentation, 368**
 - content caching, 93, 291**
 - content engines, 93**
 - content switching, 291**
 - converged networks, 4**
 - convergence (routers), 197**
 - conversion**
 - from binary to decimal, 140-141
 - from decimal to binary, 141-143
 - converters, 73**
 - CRAM-MD5 (Challenge-Response Authentication Mechanism Message Digest 5), 390**
 - crimper, 361**
 - crossover cable, 65**
 - crosstalk, 444**
 - CSMA/CA (carrier sense multiple access collision avoidance), 265**
 - CSMA/CD (carrier sense multiple access collision detect), 110-113**
 - CSU/DSU (channel service unit/data service unit), 230**
 - current state modulation, 33**
-
- ## D
- data diddling, 396**
 - data flows, 179-181**
 - data formatting, 46**
 - data link control (DLC), 36**
 - data link layer (OSI Layer 2)**
 - devices defined by, 39
 - Logical Link Control (LLC) sublayer, 37-39
 - Media Access Control (MAC) sublayer, 37
 - overview, 36-37**
 - troubleshooting, 445-447**
 - data rates, 225**
 - data service unit, 32**
 - Data-Over-Cable Service Interface Specification (DOCSIS), 237**
 - DB-9 connector, 65**
 - dB (decibel) loss, 444**
 - DDNS (dynamic DNS), 90**
 - DDoS (distributed denial of service) attack, 398**
 - dedicated leased lines, 222, 228**
 - default gateway**
 - overview, 154
 - troubleshooting, 450
 - default subnet masks, 149**
 - defending against attacks**
 - ACL (access control lists), 410-411
 - AUP (acceptable use policy), 403
 - documentation, 405-406
 - end user policies, 405
 - governing policy, 404
 - honey nets, 409
 - honey pots, 409
 - incident response, 406
 - patching, 402-403
 - security policies, 403-406
 - technical policies, 405
 - user training, 402
 - vulnerability scanners, 407-408
 - delay, 292**
 - demarc, 242**
 - DEMILITARIZED zone firewalls, 417**
 - DES (Data Encryption Standard), 387**
 - design considerations, 290**
 - designated ports, 122**
 - detection methods, 427-428**

- device categories**, 427
 - DHCP (Dynamic Host Configuration Protocol)**
 - for IP address assignment, 160-161
 - overview, 53
 - servers, 90-92
 - dictionary attack**, 397
 - DiffServ**, 295
 - dig command**, 340-341
 - digital subscriber lines**. See **DSL**
 - directly connected routes**, 193-194
 - distance limitations**
 - Ethernet network, 113-114
 - troubleshooting, 444
 - distance-vector routing**, 200-202
 - distributed denial of service (DDoS) attack**, 398
 - DLC (data link control)**, 36
 - DNAT (dynamic NAT)**, 206
 - DNS (Domain Name System)**
 - overview, 53, 154
 - record types, 89
 - servers, 88-90
 - troubleshooting, 450
 - DNS based Service Discovery (DNS-SD)**, 162
 - DOCSIS (Data-Over-Cable Service Interface Specification)**, 237
 - documentation**
 - of guidelines, 405
 - network documentation
 - contact information*, 368
 - network maps*, 369
 - policies*, 369
 - wiring schemes*, 369
 - of procedures, 406
 - for security policies, 405-406
 - of standards, 405
 - DoD model**. See **TCP/IP stack**
 - DoS (denial of service) attacks**, 391, 398
 - dotted-decimal notation for subnetting**, 163-164
 - drops**, 292
 - DSL (digital subscriber lines)**
 - asymmetric, 234-236
 - overview, 234
 - symmetric, 236
 - very high bit-rate, 236
 - DSLAM (DSL access multiplexer)**, 235-236
 - DSSS (direct-sequence spread spectrum)**, 266
 - DUAL (Diffusing-Update Algorithm)**, 203
 - dumpster diving**, 394
 - DVD**
 - activating exams, 463
 - contents of, 461-462
 - installation of software on, 462
 - video training on, 464
 - dynamic configuration (IPv4 addressing)**, 159-162
 - dynamic DNS (DDNS)**, 90
 - Dynamic Host Configuration Protocol**. See **DHCP**
 - dynamic NAT (DNAT)**, 206
 - dynamic routing**, 195-197
-
- ## **E**
-
- E1 circuits**, 229
 - E3 circuits**, 229
 - EAP (Extensible Authentication Protocol)**, 276, 412

- EDNS (Extension Mechanism for DNS), 90**
- EGP (Exterior Gateway Protocols), 199**
- EIGRP (Enhanced Interior Gateway Routing Protocol), 203**
- electric power lines for WAN, 226
- electrical disturbances, 400-401
- electrical surges, 400
- electrostatic discharge wrist strap, 361-362
- EMI (electromagnetic interference)**
overview, 60
troubleshooting, 394
- encryption**
AES (Advanced Encryption Standard), 387
asymmetric, 388-390
DES (Data Encryption Standard), 387
overview, 387
RSA, 388
symmetric, 387
3DES (Triple DES), 387
- end user policies, 405**
- enterprise mode, 276**
- environmental factors, 308**
- environmental monitor, 362**
- environmental threats, 401-402**
- ephemeral ports, 51**
- error control, 38**
- ESP (Encapsulating Security Payload protocol, 422**
- ESS (extended service set), 270**
- Ethernet**
bandwidth capacity, 113-114,
CSMA/CD (carrier sense multiple access collision detect), 110-113
distance limitations, 113-114
- origins of, 108-109
overview, 108
speed limitations, 113-114
types of, 114-116
- Ethernet switches. See switches**
- Event Viewer, 376-377**
- Evolved High-Speed Packet Access (HSPA+), 227**
- exam topics, expansion of most troublesome, 472**
- Extensible Authentication Protocol (EAP), 276, 412**
- Extension Mechanism for DNS (EDNS), 90**
- Exterior Gateway Protocols (EGP), 199**
-
- F**
-
- fault-tolerant network design, 286-288**
- F-connector, 61**
- FDM (frequency-division multiplexing), 36**
- FHSS (frequency-hopping spread spectrum), 266**
- fiber-optic cable**
connectors for, 69
multimode fiber (MMF), 67-68
overview, 66-67
single-mode fiber (SMF), 68-69
WAN (wide-area network), 226
- final preparation**
DVD
activating exams, 463
contents of, 461-462
installation of software on, 462
video training on, 464
- end-of-chapter review tools, 465
- memory tables, 464-465
- study and review plan, 465-466

fire codes and twisted-pair cable, 66
firewalls, 87
 DEMILITARIZED zone, 417
 hardware, 414
 INSIDE zone, 416
 inspection types, 414-415
 OUTSIDE zone, 416
 overview, 411
 packet-filtering, 414-415
 software, 414
 stateful, 415
 types of, 411-414
 zones, 416-417
first-hop redundancy, 130-131
flow control, 37, 41-43
FM (frequency modulation), 34
FQDN (fully-qualified domain name), 88-89, 154
Frame Relay, 244-246
Free Kiwi Syslog Server, 375
frequencies, 262
frequency-division multiplexing (FDM), 36
FTP (File Transfer Protocol), 394
full-mesh WAN topology
 advantages of, 19
 characteristics of, 19
 disadvantages of, 19
 overview, 18-19

G

gas manipulation as method of attack, 401
gateway, 100
GBIC (Gigabit Interface Converter), 114

geography used to define networks
 CAN (campus-area network), 9
 LAN (local-area network), 7
 MAN (metropolitan-area network), 9
 overview, 7
 PAN (personal-area network), 9
 WAN (wide-area network), 8
GET message, 370
GoToMyPC, 360
governing policy, 404
guidelines, documentation of, 405

H

H.323, 45, 50
hardware firewalls, 414
hardware redundancy, 288
hashing, 390
HDLC (High-Level Data Link Control), 228
high-availability
 best practices, 290
 content caching, 291
 content switching, 291
 design considerations, 290
 fault-tolerant network design, 286-288
 hardware redundancy, 288
 Layer 3 redundancy, 288-289
 load balancing, 291
 measurement, 286
 overview, 286
hijacking a session, 397
HIPS (host-based intrusion prevention system), 428-429
HMAC (hash-based message authentication code), 390
honey nets, 409

- honey pots, 409**
 - host command, 341**
 - host IP address, 148**
 - host-based solutions, 428-429**
 - hosts, calculating number of available, 167**
 - HSPA+ (Evolved High-Speed Packet Access), 227**
 - HSRP (Hot Standby Router Protocol), 131, 288-289**
 - HTTP (Hypertext Transfer Protocol), 53,**
 - HTTPS (Hypertext Transfer Protocol Secure), 53,**
 - hub-and-spoke WAN topology**
 - advantages of, 16
 - characteristics of, 16
 - disadvantages of, 16
 - overview, 16
 - hubs**
 - active, 74
 - characteristics of, 85
 - disadvantages of, 75
 - overview, 6, 74
 - passive, 74
 - smart, 74
 - types of, 74
 - humidity manipulation as method of attack, 401**
 - hybrid networks, 23**
-
- IANA (Internet Assigned Numbers Authority), 150**
 - IBSS (Independent Basic Service Set), 269**
 - ICA (Independent Computing Architecture), 412**
 - ICANN (Internet Corporation for Assigned Names and Numbers), 150**
 - ICMP (Internet Control Message Protocol), 44, 399-400**
 - ICS (Internet connection sharing), 227**
 - IDF (intermedia distribution frames), 71-72**
 - IDS (intrusion detection system)**
 - anomaly-based detection, 428
 - detection methods, 427-428
 - device categories, 427
 - IPS compared, 426-427
 - network-based solutions, 428-429
 - overview, 426
 - policy-based detection, 428
 - signature-based detection, 427
 - IEEE (Institute of Electrical and Electronics Engineers), 8**
 - ifconfig command, 341-342**
 - IGMPv1 (Internet Group Management Protocol version 1), 208**
 - IGMPv2 (Internet Group Management Protocol version 2), 209**
 - IGMPv3 (Internet Group Management Protocol version 3), 209**
 - IGP (Interior Gateway Protocols), 199**
 - IKE (Internet Key Exchange) modes, 420**
 - IMAP4 (Internet Message Access Protocol version 4), 53**
 - incident response, 406**
 - Independent Basic Service Set (IBSS), 269**
 - Independent Computing Architecture (ICA), 412**
 - inside global address, 205**
 - inside local address, 205-206**

- INSIDE zone firewalls, 416**
- Integrated Services Digital Network.**
 - See **ISDN**
- integrity, 372**
- integrity attacks**
 - botnet, 397
 - brute force, 396
 - data diddling, 396
 - dictionary attack, 397
 - hijacking a session, 397
 - keylogger, 396
 - overview, 393-395
 - packet capture, 396
 - password attack, 396-397
 - salami attack, 395
 - Trojan horse, 396
 - trust relationship exploitation, 396
 - virus, 396
 - worm, 396
- interface diagnostics for switches, 132**
- interference in WAN, sources of, 271-272**
- intermedia distribution frames (IDF), 71-72**
- Intermediate System to Intermediate System (IS-IS), 203**
- International Organization for Standardization (ISO), 28**
- Internet Assigned Numbers Authority (IANA), 150**
- Internet connection sharing (ICS), 227**
- Internet Control Message Protocol (ICMP), 44**
- Internet Corporation for Assigned Names and Numbers (ICANN), 150**
- Internet layer (TCP/IP stack), 48-49**
- Internetwork Packet Exchange (IPX), 41**
- InterNIC (Internet Network Information Center), 150**
- intrusion detection system. See IDS (intrusion detection system)**
- IntServ, 295**
- IP address**
 - case study: SOHO Network Design, 304-305
 - DHCP server, obtaining IP address information from, 91-92
 - new IP address range, calculating, 170-176
 - port numbers and, 51
 - troubleshooting, 450-452
- IP phone, 100**
- IP routing table, 193**
- ipconfig command, 318-321**
- IPS (intrusion prevention system)**
 - anomaly-based detection, 428
 - detection methods, 427-428
 - device categories, 427
 - host-based solutions, 428-429
 - IDS compared, 426-427
 - network-based solutions, 428-429
 - overview, 426
 - policy-based detection, 428
 - signature-based detection, 427
- IPsec VPN (virtual private networks)**
 - AH (Authentication Header) protocol, 422
 - ESP (Encapsulating Security Payload) protocol, 422
 - IKE (Internet Key Exchange) modes, 420
 - overview, 419-420
 - steps for setting up and tearing down, 423-424

IPv4 addressing

- APIPA (Automatic Private IP Addressing), 161-162
- assigning addresses, 153-162
- binary representation, 147
- BOOTP for IP address assignment, 159-161
- broadcast transmission, 152
- categories of, 151-153
- CIDR (Classless Inter-Domain Routing), 177
- Class A addresses, 149-150
- Class B addresses, 149-150
- Class C addresses, 149-150
- Class D addresses, 149-150
- Class E addresses, 149-150
- classes of addresses, 149-151
- components of, 154-158
- default gateway, 154
- default subnet masks, 149
- DHCP for IP address assignment, 160-161
- dynamic configuration, 159-162
- host address, 148
- multicast transmission, 152-153
- network address, 148-149
- overview, 147
- private IP networks, 151
- route aggregation, 177
- server addresses, 154
- static configuration, 154-158
- structure, 147-149
- subnet masks, 154
- subnetting,
 - borrowed bits*, 166
 - created subnets, calculating number of*, 166-167
- dotted-decimal notation*, 163-164
- extending a classful mask*, 166
- hosts, calculating number of available*, 167
- new IP address range, calculating*, 170-176
- octet values*, 163-165
- overview*, 162
- practice exercises*, 165-176
- prefix notation*, 163-164
- purpose of*, 162-163
- subnet mask notation*, 163-165
- unicast transmission, 151

IPv6 addressing

- anycast transmission, 181
- data flows, 179-181
- features of, 178
- multicast transmission, 180-181
- overview, 178
- structure of, 178-179
- unicast transmission, 179-180

IPX (Internetwork Packet Exchange), 41

ISDN (Integrated Services Digital Network)

- BRI (basic rate interface) circuits, 243
- endpoints, 245
- overview, 243-245
- PRI (primary rate interface) circuits, 243
- reference points, 245
- WAN (wide-area network), 243-245

IS-IS (Intermediate System to Intermediate System), 203

- ## ISO (International Organization for Standardization), 28
- ## isochronous transmissions, 38

J

jitter, 292

K

Kerberos, 412

keylogger, 396

L

LACP (Link Aggregation Control Protocol), 289

LAN (local area networks)

 overview, 7

 VLAN Trunking Protocol (VTP), 118

 VLANs (virtual LANs)

 switches, 116-118

 troubleshooting, 446

 WLAN (wireless LAN)

 BSS (*basic service set*), 269

 channels, 262

 CSMA/CA, 265

 deploying, 268-273

 DSSS (*direct-sequence spread spectrum*), 266

 ESS (*extended service set*), 270

 FHSS (*frequency-hopping spread spectrum*), 266

 frequencies, 262

 IBSS (*independent basic service set*), 269

 interference, *sources of*, 271-272

 OFDM (*orthogonal frequency division multiplexing*), 266

 overview, 258

 security, 273-278

 standards, 266-267

transmission methods, 265-266

types of, 268-270

wireless AP placement, 272-273

latency, 454

Layer 1 (OSI). See **physical layer**

Layer 2 (OSI). See **data link layer**

Layer 2 Tunneling Protocol (L2TP), 425

Layer 3 (OSI). See **network layer**

Layer 4 (OSI). See **transport layer**

Layer 5 (OSI). See **session layer**

Layer 6 (OSI). See **presentation layer**

Layer 7 (OSI). See **application layer**

layers in TCP/IP stack

 application layer, 50-53

 described, 47, 50

 Internet layer, 48-49

 network interface layer, 48

 transport layer, 49-50

LC (Lucent) connector, 69

LDAP (Lightweight Directory Access Protocol), 53,

L2F (Layer 2 Forwarding Protocol), 425

LFI (link fragmentation and interleaving), 301-302

link aggregation, 124-126

Link Aggregation Control Protocol (LACP), 289

link efficiency, 301-302

link-state routing, 202

load balancing, 291

local area network. See **LAN**

local loop, 242

logical addressing, 40

Logical Link Control (LLC) sublayer

 characteristics of, 37-39

- connection services, 37-38
 - synchronizing transmissions, 38-39
 - logical topology**
 - overview, 37
 - physical topology compared, 10-11
 - logs (Microsoft Windows)**
 - application, 376
 - overview, 376
 - security, 376
 - system, 377
 - long STP, 124**
 - loopback plug, 362**
 - loops, routing, 200-202**
 - LSA (link-state advertisements), 202**
 - LTE (Long-Term Evolution), 226**
 - L2TP (Layer 2 Tunneling Protocol), 425**
-
- ## M
- MAC (media access control) address, 37**
 - filtering, 275
 - table, corruption of, 119-120
 - mail exchange (MX) record, 89**
 - maintenance tools**
 - bit-error rate tester, 358
 - butt set, 359
 - cable certifier, 360
 - cable tester, 360
 - connectivity software, 360
 - crimper, 361
 - electrostatic discharge wrist strap, 361-362
 - environmental monitor, 362
 - loopback plug, 362
 - multimeter, 363-364
 - optical time domain reflectometer, 366**
 - protocol analyzer, 364**
 - punch-down tool, 365**
 - throughput tester, 365**
 - time domain reflectometer, 366**
 - toner probe, 367**
 - MAN (metropolitan-area network), 9, 225**
 - Management Information Base (MIB), 370**
 - maximum transmission unit (MTU)**
 - overview, 203
 - troubleshooting, 450
 - MD5 (Message Digest 5), 390**
 - MDF (main distribution frame), 73**
 - MDI (media-dependent interface), 65**
 - MDIX (media-dependent interface crossover)**
 - mDNS (Multicast Domain Name Service), 162**
 - media**
 - cable distribution, 70-73
 - coaxial cable
 - connectors used on, 61*
 - overview, 60*
 - RG-6 cable, 61*
 - RG-58 cable, 61*
 - RG-59 cable, 61*
 - types of, 61*
 - converters, 73
 - fiber-optic cable
 - connectors for, 69*
 - multimode fiber (MMF), 67-68*
 - overview, 66-67*
 - single-mode fiber (SMF), 68-69*
 - overview, 6, 60
 - twisted-pair cable

connectors for, 65
crossover cable, 65
fire codes and, 66
overview, 62
shielded twisted-pair (STP) cable, 62
straight-through cable, 64-65
unshielded twisted-pair (UTP) cable, 63-64
 wireless technologies, 73-74

Media Access Control (MAC) sublayer
 characteristics of, 37
 logical topology, 37
 method of transmitting on the media, 37
 physical addressing, 37

media termination recommended jack (MTRJ) connector, 69

message switching, 40

metrics, routing, 198-199

metropolitan-area network (MAN), 9, 225

MIB (Management Information Base), 370

Microsoft Challenge-Handshake Authentication Protocol (MS-CHAP), 232, 412

Microsoft Remote Access Server (RAS), 412

Microsoft Routing and Remote Access Server (RRAS), 233-234, 412

MMF (multimode fiber), 67-68

mnemonics for memorizing layers in OSI model, 32

modem, cable, 236-237

monitoring resources and reports
 Cisco IOS, 372,
 logs (Microsoft Windows)
application, 376

overview, 376
security, 376
system, 377
 overview, 369

SNMP (Simple Network Management Protocol)
agent, 370
components of, 370
described, 370
GET message, 370
manager, 370
message types, 370
MIB (Management Information Base), 370
security, 371-372
SET message, 370
SNMPv3, 371-372
trap message, 370

syslog,
components, 373-374
described, 373
severity levels, 374-375

MPLS (Multiprotocol Label Switching), 249-250

MS-CHAP (Microsoft Challenge-Handshake Authentication Protocol), 232, 412

MTRJ (media termination recommended jack) connector, 69

MTU (maximum transmission unit)
 overview, 203
 troubleshooting, 450

Multicast Domain Name Service (mDNS), 162

multicast routing
IGMP (Internet Group Management Protocol), 208-210
 overview, 208

- PIM (Protocol Independent Multicast), 210-214
 - dense mode (PIM-DM)*, 211-213
 - overview*, 210
 - sparse mode (PIM-SM)*, 213-214
- multicast transmission**
 - IPv4 addressing, 152-153
 - IPv6 addressing, 180-181
- multifactor authentication**, 412
- multilayer switches**, 83-85
- multimeter**, 363-364
- multimode fiber (MMF)**, 67-68
- multiple access**, 112
- multiple paths of propagation**, 454
- multiplexing**
 - frequency-division multiplexing (FDM), 36
 - overview*, 35
 - statistical time-division multiplexing (StatTDM), 36
 - time-division multiplexing (TDM), 35
- MX (mail exchange) record**, 89

N

- NaaS (Network as a Service)**, 98
- NAC (Network Admission Control)**, 130, 412
- NAS (network-attached storage) device**, 22
- NAT (Network Address Translation)**, 151
 - dynamic NAT (DNAT), 206
 - inside global address, 205
 - inside local address, 205-206
 - outside global address, 205
 - outside local address, 205
 - overview*, 204-205
- PAT (Port Address Translation)**, 206-208
- static NAT (SNAT)**, 206
- native VLAN**, 118
- nbstat command**, 321-324
- NCP (Network Control Protocol)**, 47
- Nessus**, 407
- NetBIOS (Network Basic Input/Output System)**, 45
- netstat command**
 - UNIX commands, 343-345
 - Windows commands, 324-326
- network address in IPv4 addressing**, 148-149
- Network as a Service (NaaS)**, 98
- Network Control Protocol (NCP)**, 47
- network elements**, 100
- network infrastructure devices**,
 - bridges**
 - characteristics of*, 85
 - overview*, 75-77
 - hubs**
 - active*, 74
 - characteristics of*, 85
 - disadvantages of*, 75
 - overview*, 74
 - passive*, 74
 - smart*, 74
 - types of*, 74
 - overview*, 74
 - routers**
 - characteristics of*, 85
 - overview*, 84-85
 - switches**
 - characteristics of*, 85
 - Layer 2*, 77-83
 - Layer 3*, 83-84

- multilayer*, 83-85
- overview*, 77-83
- network interface layer (TCP/IP stack)**, 48
- network layer (OSI Layer 3)**
 - connection services, 41
 - described, 39
 - devices defined by, 41
 - logical addressing, 40
 - route discovery and selection, 40-41
 - switching, 40
 - troubleshooting, 447-452
- network maps**, 369
- network sniffer**, 127-128
- network-based solutions**, 428-429
- networks**
 - components, 5-6
 - components of, 4
 - converged, 4
 - documentation
 - contact information*, 368
 - network maps*, 369
 - overview*, 368-369
 - policies*, 369
 - wiring schemes*, 369
 - geography used to define
 - CAN (campus-area network)*, 9
 - LAN*, 7
 - MAN (metropolitan-area network)*, 9
 - overview*, 7
 - PAN (personal-area network)*, 9
 - WAN*, 8
 - hybrid, 23
 - overview, 4
- purpose of, 4
- resource location used to define
 - client-server networks*, 20-22
 - overview*, 20
 - peer-to-peer networks*, 22-23
- security goals
 - availability*, 391
 - confidentiality*, 386-390
 - integrity*, 390
 - overview*, 386
- topology used to define
 - bus topology*, 11-13
 - full-mesh topology*, 18-19
 - hub-and-spoke topology*, 16
 - overview*, 9-11
 - partial-mesh topology*, 18-20
 - physical topology versus logical topology*, 10-11
 - ring topology*, 12-15
 - star topology*, 14-16
- NIC (network interface cards)**, 287-288
- NIDS (network-based intrusion detection system)**, 428-429
- NIPS (network-based intrusion prevention system)**, 428-429
- Nmap**, 408
- NNTP (Network News Transport Protocol)**, 53
- non-designated ports**, 122-124
- non-root bridges**, 122
- nslookup command**
 - UNIX commands, 340-341
 - Windows commands, 326-328
- NTP (Network Time Protocol)**, 53

O

octet values, 163-165

OFDM (orthogonal frequency division multiplexing), 266

off-site options for virtual network devices, 98-99

omnidirectional antennas, 261

Open Systems Interconnection model.
See **OSI model**

opens, 444

optical time domain reflectometer (OTDR), 366

optimizing network performance

case study: SOHO Network Design,
302-309

high-availability

best practices, 290

content caching, 291

content switching, 291

design considerations, 290

*fault-tolerant network design,
286-288*

hardware redundancy, 288

Layer 3 redundancy, 288-289

load balancing, 291

measurement, 286

overview, 286

QoS

best-effort, 295

categories, 295

classification, 296

configuration, 294-295

congestion avoidance, 299

congestion management, 298

DiffServ, 295

IntServ, 295

link efficiency, 301-302

marking, 297

mechanisms, 296-302

overview, 292-294

policing, 299-301

traffic shaping, 299-301

types of quality issues, 292

orientation of antennas, 262

origins of Ethernet network, 108-109

OSI model

application layer (Layer 7), 46-47

bookshelf analogy, 30-31

data link layer (Layer 2)

devices defined by, 39

*Logical Link Control (LLC) sublayer,
37-39*

*Media Access Control (MAC) sublayer,
37*

overview, 36-37

mnemonics for memorizing layers
in, 32

network layer (Layer 3)

connection services, 41

described, 39

devices defined by, 41

logical addressing, 40

route discovery and selection, 40-41

switching, 40

overview, 30-32

physical layer (Layer 1)

bandwidth usage, 35

bits represented on medium, 33-34

devices defined by, 36

multiplexing strategy, 35-36
overview, 33
physical topology, 34
synchronizing bits, 35
wiring standards for connectors and jacks, 34

presentation layer (Layer 6), 45-46
 session layer (Layer 5), 44-45
 TCP/IP stack compared, 48-50
 transport layer (Layer 4)
flow control, 43
overview, 42
protocols, 42

OSPF (Open Shortest Path First), 196, 202-203

OTDR (optical time domain reflectometer), 366

outside global address, 205

outside local address, 205

OUTSIDE zone firewalls, 416

P

packet capture, 394-396
packet reordering, 41
packet switching, 40
packet-filtering, 414-415
packet-switched connection, 223
PAN (personal-area network), 9
PAP (Password Authentication Protocol), 231
Pareto, Vilfredo, 220
Pareto Principle, 220
partial-mesh topology
 advantages of, 20
 characteristics of, 20
 disadvantages of, 20
 overview, 18-20

passive hubs, 74
password attack, 396-397
PAT (Port Address Translation), 206-208
patching, 402-403
PBX (Private Branch Exchange), 99-100
PDU (protocol data unit), 32
Pearson IT Certification Practice Test engine
 activating exams, 463
 installation, 462
 overview, 461
 practice exam mode use of, 466
 study mode use of, 466
peer-to-peer networks
 advantages of, 23
 characteristics of, 23
 disadvantages of, 23
 overview, 22-23
performance, optimizing. See **optimizing network performance**
permanent virtual circuit (PVC), 246
personal mode, 275
physical addressing, 37
physical environment, attacks on a system's, 401-402
physical layer (OSI Layer 1)
 bandwidth usage, 35
 bits represented on medium, 33-34
 devices defined by, 36
multiplexing strategy, 35-36
overview, 33
physical topology, 34
synchronizing bits, 35
troubleshooting, 443-445
wiring standards for connectors and jacks, 34

- physical media for WAN**
 - (wide-area network), 225-226
- physical topology**
 - logical topology compared, 10-11
 - overview, 34
- PIM (Protocol Independent Multicast), 210**
- PIM-DM (PIM dense mode), 211-213**
- PIM-SM (PIM sparse mode), 213-214**
- ping command**
 - UNIX commands, 345-346
 - Windows commands, 328-330
- ping of death, 399**
- ping sweep and port scan, 394**
- plenum cabling, 66**
- PoE (Power over Ethernet), 126-127**
- pointer (PTR) record, 89**
- poison reverse feature, 202**
- policies, documenting, 369**
- policy-based detection, 428**
- POP3 (Post Office Protocol version 3), 53**
- ports**
 - monitoring, 127-128
 - numbers
 - for common application layer protocols, 52-53*
 - ephemeral ports, 51*
 - and IP addresses, 51*
 - well-known ports, 51*
 - roles, 123
 - troubleshooting, 446
 - types, 122-123
- POTS (Plain Old Telephone Service) connection, 241-242**
- power failure, 446**
- power fault, 400**
- power sag, 400**
- power spikes, 400**
- PPP (Point-to-Point Protocol), 228, 231-232, 412**
- PPPoE (Point-to-Point Protocol over Ethernet), 232, 412**
- PPTP (Point-to-Point Tunneling Protocol) VPN, 425**
- practice exercises**
 - binary number conversion to decimal number, 143-144
 - binary numbering, 143-146
 - decimal number conversion to binary number, 145-146
 - subnet mask notation, 165
 - subnetting, 165-176
 - subnetting (advanced), 172-176
- prefix notation (subnetting), 163-164**
- Premium Edition eBook and Practice Test, 464**
- presentation layer (OSI Layer 6), 45-46**
- preshared keys (PSK), 275**
- Private Branch Exchange (PBX), 99**
- private IP networks, 151**
- problem, defining, 441**
- procedures, documentation of, 406**
- protocol analyzer, 364**
- protocol data unit (PDU), 32**
- proxy servers, 92-93**
- PSTN (Public Switched Telephone Network), 241**
- PTR (pointer) record, 89**
- punch-down tool, 365**
- PVC (permanent virtual circuit), 246**

Q

QoS (quality of service)

best-effort, 295
 categories, 295
 classification, 296
 configuration, 294-295
 congestion avoidance, 299
 congestion management, 298
 DiffServ, 295
 IntServ, 295
 link efficiency, 301-302
 marking, 297
 mechanisms, 296-302
 overview, 292-294
 policing, 299-301
 settings, 132
 traffic shaping, 299-301
 types of quality issues, 292
queuing, 298

R

radio frequency interference (RFI), 60, 454
radio technology for WAN, 227
RADIUS (Remote Authentication Dial-In User Service), 412
RARP (Reverse Address Resolution Protocol), 161
RAS (Microsoft Remote Access Server), 412
RC4, 277
RDP (Remote Desktop Protocol), 53, 412
RealVNC, 360
RED (random early detection), 298-299

redundancy, 290

reference models. See also OSI model; TCP/IP stack

purpose of, 30-31

remote access security

AAA (authentication, authorization, and accounting), 412
CHAP (Challenge-Handshake Authentication Protocol), 412
EAP (Extensible Authentication Protocol), 412
ICA (Independent Computing Architecture), 412
IEEE 8021X, 412
Kerberos, 412
MS-CHAP (Microsoft Challenge-Handshake Authentication Protocol), 412
multifactor authentication, 412
NAC (Network Admission Control), 412
 overview, 411
PPP (Point-to-Point Protocol), 412
PPPoE (Point-to-Point Protocol over Ethernet), 412
RADIUS (Remote Authentication Dial-In User Service), 412
RDP (Remote Desktop Protocol), 412
RRAS (Microsoft Routing and Remote Access Server), 233-234, 412
SSH (Secure Shell), 412
SSO (single sign-on), 412
TACACS+ (Terminal Access Controller Access-Control System Plus), 412
two-factor authentication, 412
Remote Desktop Connection, 360
remote desktop control, 234
remote-access VPN, 418-419

report, creating post-mortem, 442
resolution, verifying problem, 442
resource location used to define networks
client-server networks, 20-22
overview, 20
peer-to-peer networks, 22-23
RFI (radio frequency interference), 60, 454
RG-6 cable, 61
RG-58 cable, 61
RG-59 cable, 61
ring topology
advantages of, 15
characteristics of, 15
disadvantages of, 15
Fiber Distributed Data Interface (FDDI), 14
overview, 12-15
RIP (Routing Information Protocol), 196, 203
Rivest, Ron, 277, 388
RJ-11 connector, 65
RJ-45 connector, 65
RJ-45 jack, 64
rogue access point, 274
root bridges, 122
root ports, 122
route aggregation, 177
route command
UNIX commands, 347-348,
Windows commands, 330-334
routed protocols and routing protocols compared, 197
routers
characteristics of, 85
overview, 6, 40-41, 84-85
wireless, 258-259
routing. See also NAT (Network Address Translation)
administrative distance (AD), 198
advertisement methods, 200-202
believability of a route, 198
BGP (Border Gateway Protocol), 199, 203
convergence, 197
directly connected routes, 193-194
distance-vector, 200-202
dynamic routes, 195-197
EGP (Exterior Gateway Protocols), 199
EIGRP (Enhanced Interior Gateway Routing Protocol), 203
IGP (Interior Gateway Protocols), 199
IP routing table, 193
IS-IS (Intermediate System to Intermediate System), 203
Layer 3 to Layer 2 mapping, 193
link-state, 202
loops, 200-202
metrics, 198-199
multicast
IGMP (Internet Group Management Protocol), 208-210
overview, 208
PIM (Protocol Independent Multicast), 210-214
OSPF (Open Shortest Path First), 196, 202-203
overview, 190-193
protocols, 197-204
RIP (Routing Information Protocol), 196, 203
routed protocols and routing protocols compared, 197
sources of routing information, 193-197

- static routes, 194-195
 - steps for, 190-192
 - troubleshooting, 447-449
 - Routing and Remote Access Server (Microsoft RRAS), 233-234**
 - Routing Information Protocol (RIP), 196, 203**
 - RP (rendezvous point), 213**
 - RRAS (Microsoft Routing and Remote Access Server), 233-234, 412**
 - RSA encryption, 388**
 - rsh (Remote Shell), 53**
 - RSSI (Received Signal Strength Indicator), 454**
 - RTP (Real-time Transport Protocol), 100**
 - RTSP (Real Time Streaming Protocol), 53**
-
- ## S
- SaaS (Software as a Service), 98**
 - salami attack, 395**
 - satellite connection for WAN, 227, 239-240**
 - SC connector, 69**
 - SCP (Secure Copy), 53,**
 - SDH (Synchronous Digital Hierarchy), 238**
 - SDSL (symmetric DSL), 236**
 - Secure FTP (SFTP),**
 - Secure Hash Algorithm 1 (SHA-1), 390**
 - Secure Sockets Layer (SSL), 425**
 - security**
 - attack categories, 391-394
 - authentication, 372
 - availability attacks
 - buffer overflow, 399*
 - DDoS (distributed denial of service) attack, 398*
 - DoS (denial of service) attack, 398*
 - electrical disturbances, 400-401*
 - environmental threats, 401-402*
 - ICMP attacks, 399-400*
 - overview, 397*
 - physical environment, attacks on a system's, 401-402*
 - ping of death, 399*
 - Smurf attack, 399*
 - TCP SYN flood, 398*
 - confidentiality attacks**
 - dumpster diving, 394*
 - EMI (electromagnetic interference) interception, 394*
 - FTP bounce, 394*
 - overview, 391-392*
 - packet capture, 394*
 - ping sweep and port scan, 394*
 - sending information over covert channels, 394*
 - sending information over overt channels, 394*
 - social engineering, 394*
 - wiretapping, 394*
 - defending against attacks**
 - ACL (access control lists), 410-411*
 - AUP (acceptable use policy), 403*
 - documentation, 405-406*
 - end user policies, 405*
 - governing policy, 404*
 - honey nets, 409*
 - honey pots, 409*
 - incident response, 406*
 - patching, 402-403*

- security policies*, 403-406
- technical policies*, 405
- user training*, 402
- vulnerability scanners*, 407-408
- documentation for security policies, 405-406
- DoS (denial of service) attacks, 391
- encryption, 372
 - AES (Advanced Encryption Standard)*, 387
 - asymmetric*, 388-390
 - DES (Data Encryption Standard)*, 387
 - described*, 46
 - overview*, 387
 - RSA*, 388
 - symmetric*, 387
 - 3DES (Triple DES)*, 387
- firewalls
 - DEMILITARIZED zone*, 417
 - hardware*, 414
 - INSIDE zone*, 416
 - inspection types*, 414-415
 - OUTSIDE zone*, 416
 - overview*, 411
 - packet-filtering*, 414-415
 - software*, 414
 - stateful*, 415
 - types of*, 411-414
 - zones*, 416-417
- hashing, 390
- HIPS (host-based intrusion prevention system), 428-429
- IDS (intrusion detection system)
 - anomaly-based detection*, 428
 - detection methods*, 427-428
 - device categories*, 427
- IPS (intrusion prevention system)
 - anomaly-based detection*, 428
 - detection methods*, 427-428
 - device categories*, 427
 - host-based solutions*, 428-429
 - IDS compared*, 426-427
 - network-based solutions*, 428-429
 - overview*, 426
 - policy-based detection*, 428
 - signature-based detection*, 427
- logs (Microsoft Windows), 376
- network security goals
 - availability*, 391
 - confidentiality*, 386-390
 - integrity*, 390
 - overview*, 386

- network sniffer, 127-128
- NIDS (network-based intrusion detection system), 428-429
- NIPS (network-based intrusion prevention system), 428-429
- remote access security
 - AAA (authentication, authorization, and accounting)*, 412
 - CHAP (Challenge-Handshake Authentication Protocol)*, 412
 - EAP (Extensible Authentication Protocol)*, 412
 - ICA (Independent Computing Architecture)*, 412
 - IEEE 8021X*, 412
 - Kerberos*, 412
 - MS-CHAP (Microsoft Challenge-Handshake Authentication Protocol)*, 412
 - multifactor authentication*, 412
 - NAC (Network Admission Control)*, 412
 - overview*, 411
 - PPP (Point-to-Point Protocol)*, 412
 - PPPoE (Point-to-Point Protocol over Ethernet)*, 412
 - RADIUS (Remote Authentication Dial-In User Service)*, 412
 - RAS (Microsoft Remote Access Server)*, 412
 - RDP (Remote Desktop Protocol)*, 412
 - RRAS (Microsoft Routing and Remote Access Server)*, 412
 - SSH (Secure Shell)*, 412
 - SSO (single sign-on)*, 412
 - TACACS+ (Terminal Access Controller Access-Control System Plus)*, 412
 - two-factor authentication*, 412
- SNMP (Simple Network Management Protocol), 371-372
- user authentication, 129-130
- VPN (virtual private networks)
 - client-to-site*, 418-419
 - IPsec*, 419-424
 - L2F (Layer 2 Forwarding Protocol)*, 425
 - L2TP (Layer 2 Tunneling Protocol)*, 425
 - overview*, 418-419
 - PPTP (Point-to-Point Tunneling Protocol)*, 425
 - remote-access*, 418-419
 - site-to-site*, 418-419
 - SSL (Secure Sockets Layer)*, 425
 - TLS (Transport Layer Security)*, 425
- WLAN (wireless LAN)
 - enterprise mode*, 276
 - IEEE 802.1X*, 276
 - MAC address filtering*, 275
 - overview*, 273
 - personal mode*, 275
 - preshared keys (PSK)*, 275
 - rogue access point*, 274
 - SSID broadcast, disabling*, 275
 - standards*, 277-278
 - warchalking*, 274
 - WEP*, 277
 - WEP cracking*, 274
 - WPA*, 278
 - WPA2*, 278
 - WPA cracking*, 274
- security policies, 403-406**
- Seifert, Rich, 31**

server
addresses, 154
authentication server, 130
client-server network
advantages of, 21
characteristics of, 21
disadvantages of, 21
overview, 20-22
DHCP servers, 90-92
DNS (Domain Name System) servers, 88-90
Free Kiwi Syslog Server, 375
Microsoft RRAS (Routing and Remote Access Server), 233-234
overview, 5
proxy servers, 92-93
RAS (Microsoft Remote Access Server), 412
RRAS (Microsoft Routing and Remote Access Server), 412
virtual servers, 95-96
service advertisement, 47
service discovery protocols, 162
Service Location Protocol (SLP), 162
Session Initiation Protocol (SIP), 100
session layer (OSI Layer 5), 44-45
sessions
described, 44
maintaining, 44
setting up, 44
tearing down, 45
SET message, 370
severity levels, 374-375
SFTP (Secure FTP)
SHA-1 (Secure Hash Algorithm 1), 390
Shamir, Adi, 388
shielded twisted-pair (STP) cable, 62
shorts, 444
signal strength, 454
signature-based detection, 427
Simple Service Discovery Protocol (SSDP), 162
single-mode fiber (SMF), 68-69
SIP (Session Initiation Protocol), 100
site-to-site VPN, 418-419
smart hubs, 74
smart jack, 242
SMF (single-mode fiber), 68-69
SMTP (Simple Mail Transfer Protocol), 53
Smurf attack, 399
SNMP (Simple Network Management Protocol)
agent, 370
components of, 370
described, 370
GET message, 370
manager, 370
message types, 370
MIB (Management Information Base), 370
security, 371-372
SET message, 370
SNMPv3, 371-372
trap message, 370
SNMPv3, 371-372
SNTP (Simple Network Time Protocol), 53
SOA (start of authority) record, 89
social engineering, 394
Software as a Service (SaaS), 98
software firewalls, 414
SONET (Synchronous Optical Network), 238-239

- sources of routing information, 193-197**
- specialized network devices**
 - content engines, 93
 - content switches, 94-95
 - DHCP servers, 90-92
 - DNS (Domain Name System) servers, 88-90
 - firewalls, 87
 - overview, 86
 - proxy servers, 92-93
 - VPN concentrators, 86-87
- speed limitations for Ethernet network, 113-114**
- split horizon feature, 202**
- splitting pairs in a cable, 444**
- SPS (standby power supply), 401**
- SPT (shortest path tree), 214**
- SPX (Sequenced Packet Exchange), 42**
- SSDP (Simple Service Discovery Protocol), 162**
- SSH (Secure Shell), 53, 412**
- SSID (service set identifier), 274-275**
- SSID broadcast, disabling, 275**
- SSL (Secure Sockets Layer), 425**
- SSO (single sign-on), 412**
- ST (straight tip) connector, 69**
- stack, OSI. See OSI model**
- star topology**
 - advantages of, 16
 - characteristics of, 16
 - disadvantages of, 16
 - overview, 14-16
- stateful firewalls, 415**
- static addressing, 154-158**
- static NAT (SNAT), 206**
- static routing, 194-195**
- statistical time-division multiplexing (StatTDM), 36**
- steganography, 394**
- STP (spanning tree protocol)**
 - designated ports, 122
 - long STP, 124
 - non-designated ports, 122-124
 - non-root bridges, 122
 - overview, 119-120
 - port costs, 123-124
 - port roles, 123
 - port types, 122-123
 - root bridges, 122
 - root ports, 122
- straight-through cable, 64-65**
- structured methodology for troubleshooting**
 - create action plan, 442
 - define problem, 441
 - hypothesize probable cause, 441
 - implement action plan, 442
 - report, creating post-mortem, 442
 - test hypothesis, 441
 - verify problem resolution, 442
- study and review plan, 465-466**
- subnet calculator, 176**
- subnet masks**
 - notation, 163-165
 - overview, 154
 - troubleshooting, 450
- subnetting**
 - borrowed bits, 166
 - created subnets, calculating number of, 166-167
 - dotted-decimal notation, 163-164
 - extending a classful mask, 166

- hosts, calculating number of available, 167
- new IP address range, calculating, 170-176
- octet values, 163-165
- overview, 162
- practice exercises, 165-176
- prefix notation, 163-164
- purpose of, 162-163
- subnet mask notation, 163-165
- supplicant, 130**
- SVC (switched virtual circuit), 246**
- switches**
 - broadcast storms, 120-121
 - characteristics of, 85
 - features, 116-132
 - first-hop redundancy, 130-131
 - interface diagnostics, 132
 - Layer 2, 77-83
 - Layer 3, 83-84
 - link aggregation, 124-126
 - MAC address table, corruption of, 119-120
 - MAC filtering, 132
 - multilayer, 83-85
 - overview, 6, 77-83
 - PoE (Power over Ethernet), 126-127
 - port monitoring, 127-128
 - QoS (quality of service) settings, 132
 - STP (spanning tree protocol)
 - designated ports, 122*
 - long STP, 124*
 - non-designated ports, 122-124*
 - non-root bridges, 122*
 - overview, 119-120*
 - port costs, 123-124*
- port roles, 123*
- port types, 122-123*
- root bridges, 122*
- root ports, 122*
- traffic filtering, 132
- troubleshooting, 127-128
- trunks, 118-119
- user authentication, 129-130
- VLANs (virtual LANs), 116-118
- switching**
 - circuit, 40
 - described, 40
 - message, 40
 - network layer (OSI Layer 3), 40
 - packet, 40
- The Switch Book (Seifert), 31**
- symmetric DSL (SDSL), 236**
- symmetric encryption, 387**
- synchronizing bits, 35**
- synchronizing transmissions**
 - asynchronous, 38
 - described, 38
 - isochronous, 38
 - synchronous, 35, 39
- Synchronous Digital Hierarchy (SDH), 238**
- syslog**
 - components, 373-374
 - described, 373
 - severity levels, 374-375
- system logs (Microsoft Windows), 377**

T

- T1 circuits, 228-229**
- T3 circuits, 229**

TACACS+ (Terminal Access Controller Access-Control System Plus), 412

TCP (Transmission Control Protocol), 42, 49-50

TCP SYN flood, 398

TCP/IP stack

- application layer protocols, common, 51-53
- layers in
 - application layer, 50-53*
 - described, 47, 50*
 - Internet layer, 48-49*
 - network interface layer, 48*
 - transport layer, 49-50*
- OSI model compared, 48-50
- overview, 47

TDM (time-division multiplexing), 35

TDR (time domain reflectometer), 366

tearing down sessions, 45

technical content, 472

technical policies, 405

telco, 242

Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA), 62

Telnet, 53,

temperature manipulation as method of attack, 401

tethering, 227

TFTP (Trivial File Transfer Protocol), 53,

throughput tester, 365

TIA/EIA-568 standard, 62

TIA/EIA-568-A standard, 62

TIA/EIA-568-B standard, 62

time domain reflectometer, 366

tip and ring, 242

TKIP (Temporal Key Integrity Protocol), 278

TLS (Transport Layer Security), 425

Token Ring networks, 110

toner probe, 367

topology used to define networks

- bus topology, 11-13
- full-mesh topology, 18-19
- hub-and-spoke topology, 16
- overview, 9-11
- partial-mesh topology, 18-20
- physical topology versus logical topology, 10-11
- ring topology, 12-15
- star topology, 14-16

traceroute command, 342-343

tracert command, 334-336

traffic filtering, 132

traffic shaping, 299-301

transition modulation, 34

Transmission Control Protocol (TCP), 42, 49-50

transmission methods for wireless networks, 265-266

transport layer (OSI Layer 4)

- flow control, 43
- overview, 42
- protocols, 42

transport layer (TCP/IP stack), 49-50

transposed Tx/Rx leads, 444

trap message, 370

Trojan horse, 396

troubleshooting

- cable, 444
- cable placement, 444
- connectors, 444
- crosstalk, 444

- data link layer (Layer 2), 445-447,
 - dB (decibel) loss, 444
 - default gateway, 450
 - distance limitations exceeded, 444
 - DNS configuration, 450
 - IP address, duplicate, 450
 - IP address, invalid, 451-452
 - Layer 2 loop, 446
 - module, bad, 446
 - MTU (maximum transmission unit), mismatched, 450
 - network layer (Layer 3), 447-452
 - opens, 444
 - overview, 438-439, 452-455
 - physical layer (Layer 1), 443-445
 - port configuration, 446
 - power failure, 446
 - routing protocols, 447-449
 - shorts, 444
 - splitting pairs in a cable, 444
 - steps for, 439
 - structured methodology for
 - create action plan*, 442
 - define problem*, 441
 - hypothesize probable cause*, 441
 - implement action plan*, 442
 - overview*, 440
 - report, creating post-mortem*, 442
 - test hypothesis*, 441
 - verify problem resolution*, 442
 - subnet mask, 450
 - switches, 127-128
 - transposed Tx/Rx leads, 444
 - VLAN configuration, 446
 - wireless networks,
 - AP placement, incorrect*, 454
 - latency*, 454
 - misconfiguration of wireless parameters*, 454
 - multiple paths of propagation*, 454
 - overview*, 452-455
 - RFI (radio frequency interference)*, 454
 - signal strength*, 454
 - trunks, 118-119**
 - trust relationship exploitation, 396**
 - TTL (Time-to-Live) value, 49**
 - twisted-pair cable**
 - connectors for, 65
 - crossover cable, 65
 - fire codes and, 66
 - overview, 62
 - shielded twisted-pair (STP) cable, 62
 - straight-through cable, 64-65
 - unshielded twisted-pair (UTP) cable, 63-64
 - two-factor authentication, 412**
-
- ## U
-
- UDP (User Datagram Protocol), 42, 50**
 - unicast transmission**
 - IPv4 addressing, 151
 - IPv6 addressing, 179-180
 - unidirectional antennas, 262**
 - UNIX commands**
 - arp command, 337-339
 - dig command, 340-341
 - host command, 341
 - ifconfig command, 341-342
 - netstat command, 343-345
 - nslookup command, 340-341

- overview, 336-337
 - ping command, 345-346
 - route command, 347-348
 - traceroute command, 342-343
 - UPS (uninterruptable power supply), 401**
 - uptime, 286**
 - user authentication**
 - authentication server, 130
 - authenticator, 130
 - overview, 129-130
 - supplicant, 130
 - switches, 129-130
 - user training, 402**
 - UTP (unshielded twisted-pair) cable, 63-64, 226**
 - Cat 3 cable, 64
 - Cat 5 cable, 64
 - Cat 6 cable, 64
 - Cat 6a cable, 64
 - Cat 5e cable, 64
 - categories of, 64
-
- V**
- VDSL (very high bit-rate DSL), 236**
 - vendor codes, 37**
 - virtual desktops, 97**
 - virtual network devices, 95-99**
 - virtual PBX, 99-100**
 - virtual servers, 95-96**
 - virtual switches, 96-97**
 - virus, 396**
 - VLAN Trunking Protocol (VTP), 118**
 - VLANs (virtual LANs)**
 - switches, 116-118
 - troubleshooting, 446

- Voice over IP (VoIP)**
 - analog phone, 100
 - call agent, 100
 - gateway, 100
 - IP phone, 100
 - network elements, 100
 - overview, 99-100
 - PBX (Private Branch Exchange), 100
 - RTP (Real-time Transport Protocol), 100
 - SIP (Session Initiation Protocol), 100
- VoIP network elements,**
- VPN (virtual private networks),**
 - client-to-site, 418-419
 - described, 86
 - IPsec, 419-424
 - AH (Authentication Header) protocol, 422*
 - ESP (Encapsulating Security Payload) protocol, 422*
 - IKE (Internet Key Exchange) modes, 420*
 - overview, 419-420*
 - steps for setting up and tearing down, 423-424*
 - L2F (Layer 2 Forwarding Protocol), 425
 - L2TP (Layer 2 Tunneling Protocol), 425
 - overview, 418-419
 - PPTP (Point-to-Point Tunneling Protocol), 425
 - remote-access, 418-419
 - site-to-site, 418-419
 - SSL (Secure Sockets Layer), 425
 - TLS (Transport Layer Security), 425
 - VPN concentrators, 86-87**

VTP (VLAN Trunking Protocol), 118
vulnerability scanners, 407-408

W-X

WAN (wide-area network),

- ATM (Asynchronous Transfer Mode), 224, 246-248
 - bandwidths for, 225
 - cable modem, 236-237
 - cellular phone technology for, 227
 - circuit-switched connection, 223
 - coaxial cable for, 226
 - connection types, 222-224
 - CSU/DSU, 230
 - data rates, 225
 - dedicated leased lines, 222, 228
 - described, 220
 - DSL (digital subscriber lines)
 - asymmetric*, 234-236
 - overview*, 234
 - symmetric*, 236
 - very high bit-rate*, 236
 - E1 circuits for, 229
 - E3 circuits for, 229
 - electric power lines for, 226
 - fiber-optic cable for, 226
 - Frame Relay, 244-246
 - HSPA+ technology for, 227
 - ISDN (Integrated Services Digital Network), 243-245
 - media types, 225-227
 - Microsoft RRAS (Routing and Remote Access Server), 233-234
 - MPLS (Multiprotocol Label Switching), 249-250
 - overview, 8
- packet-switched connection, 223
 - physical media for, 225-226
 - POTS (Plain Old Telephone Service) connection, 241-242
 - PPP (Point-to-Point Protocol), 231-232
 - PPPoE (Point-to-Point Protocol over Ethernet), 232
 - radio technology for, 227
 - satellite connection, 227, 239-240
 - SONET networks, 238-239
 - T1 circuits for, 228-229
 - T3 circuits for, 229
 - UTP (unshielded twisted pair) cabling for, 226
 - WiMAX technology for, 227
 - wireless media for, 226-227
- warchalking, 274**
- well-known ports, 51**
- WEP (Wired Equivalent Privacy), 274, 277**
- WiMAX (Worldwide Interoperability for Microwave Access), 227**
- windowing, 43**
- Windows commands**
- arp command, 316-318
 - ipconfig command, 318-321
 - nbstat command, 321-324
 - netstat command, 324-326
 - nslookup command, 326-328
 - overview, 316
 - ping command, 328-330
 - route command, 330-334
 - tracert command, 334-336
- wireless access point, 259-260.** See also *antennas*
- wireless AP placement, 272-273**

- wireless design (case study: SOHO Network Design), 307-308**
- wireless media for WAN (wide-area network), 226-227**
- wireless networks**
- BSS (basic service set), 269
 - channels, 262
 - CSMA/CA, 265
 - deploying, 268-273
 - DSSS (direct-sequence spread spectrum), 266
 - ESS (extended service set), 270
 - FHSS (frequency-hopping spread spectrum), 266
 - frequencies, 262
 - IBSS (independent basic service set), 269
 - interference, sources of, 271-272
 - OFDM (orthogonal frequency division multiplexing), 266
 - overview, 258
 - security
 - enterprise mode*, 276
 - IEEE 802.1X*, 276
 - MAC address filtering*, 275
 - overview*, 273
 - personal mode*, 275
 - preshared keys (PSK)*, 275
 - rogue access point*, 274
 - SSID broadcast, disabling*, 275
 - standards*, 277-278
 - warchalking*, 274
 - WEP*, 274, 277
 - WPA*, 274, 278
 - WPA2*, 278
 - standards, 266-267
 - transmission methods, 265-266
- troubleshooting,
- AP placement, incorrect*, 454
 - latency*, 454
 - misconfiguration of wireless parameters*, 454
 - multiple paths of propagation*, 454
 - overview*, 452-455
 - RFI (radio frequency interference)*, 454
 - signal strength*, 454
 - types of, 268-270
 - wireless AP placement, 272-273
- wireless routers, 258-259.** See also antennas
- wireless technologies, 73-74**
- Wireshark, 127, 364**
- wiretapping, 394**
- wiring schemes, documenting, 369**
- wiring standards for connectors and jacks, 34**
- WLAN.** See wireless networks
- worm, 396**
- WPA (Wi-Fi Protected Access), 274, 278**

Z

-
- Zero Configuration (Zeroconf), 162**