CCNA Wireless 640-722 Official Cert Guide

David Hucaby

Copyright© 2014 Cisco Systems, Inc.

Published by:
Cisco Press
800 East 96th Street
Indianapolis, IN 46240 USA

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without written permission from the publisher, except for the inclusion of brief quotations in a review.

Printed in the United States of America
Second Printing January 2015
Library of Congress Control Number: 2014931706

Warning and Disclaimer

This book is designed to provide information about preparing for the CCNA Wireless 640-722 exam. Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied.

The information is provided on an “as is” basis. The author, Cisco Press, and Cisco Systems, Inc., shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book or from the use of the discs or programs that may accompany it.

The opinions expressed in this book belong to the author and are not necessarily those of Cisco Systems, Inc.

Trademark Acknowledgments

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Cisco Press or Cisco Systems, Inc. cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.
Special Sales

For information about buying this title in bulk quantities, or for special sales opportunities (which may include electronic versions; custom cover designs; and content particular to your business, training goals, marketing focus, or branding interests), please contact our corporate sales department at corporalsales@pearsoned.com or (800) 382-3419.

For government sales inquiries, please contact governmentsales@pearsoned.com.

For questions about sales outside the U.S., please contact international@pearsoned.com.

Feedback Information

At Cisco Press, our goal is to create in-depth technical books of the highest quality and value. Each book is crafted with care and precision, undergoing rigorous development that involves the unique expertise of members from the professional technical community.

Readers’ feedback is a natural continuation of this process. If you have any comments regarding how we could improve the quality of this book, or otherwise alter it to better suit your needs, you can contact us through e-mail at feedback@ciscopress.com. Please make sure to include the book title and ISBN in your message.

We greatly appreciate your assistance.

Publisher: Paul Boger
Associate Publisher: Dave Dusthimer
Executive Editor: Mary Beth Ray
Managing Editor: Sandra Schroeder
Project Editor: Seth Kerney
Editorial Assistant: Vanessa Evans
Cover Designer: Mark Shirar
Composition: Jake McFarland

Business Operation Manager, Cisco Press: Jan Cornelissen
Manager Global Certification: Sean Donovan
Senior Development Editor: Christopher Cleveland
Copy Editor: Keith Cline
Technical Editor: Jerome Henry
Proofreader: Jess DeGabriele
Indexer: Tim Wright
About the Author

David Hucaby, CCIE No. 4594, is a network architect for the University of Kentucky, where he works with academic and healthcare networks based on the Cisco Unified Wireless Network products. David has bachelor’s and master’s degrees in electrical engineering from the University of Kentucky. He is the author of several Cisco Press titles, including CCNP SWITCH Exam Certification Guide; Cisco LAN Switching Video Mentor; CCNP Security FIREWALL Exam Certification Guide; Cisco ASA, PIX, and FWSM Firewall Handbook, Second Edition; and Cisco Firewall Video Mentor.

David lives in Kentucky with his wife, Marci, and two daughters.
About the Technical Reviewer

Jerome Henry, CCIE Wireless No. 24750, is technical marketing engineer in the Wireless Enterprise Networking Group at Cisco systems. Jerome has close to 15 years experience teaching technical Cisco courses in more than 15 different countries and 4 different languages, to audiences ranging from bachelor degree students to networking professionals and Cisco internal system engineers.

Focusing on his wireless experience, Jerome joined Cisco in 2012. Before that time, he was consulting and teaching Heterogeneous Networks and Wireless Integration with the European Airespace team, which was later acquired by Cisco to become their main wireless solution. He then spent several years with a Cisco Learning partner, developing wireless courses, and working on training material for new wireless technologies. In addition to his CCIE Wireless certification, Jerome is a certified wireless networking expert (CWNE #45) and has developed several Cisco courses focusing on wireless topics (IUWNE, IUWMS, IUWVN, CUWSS, IAUWS, LBS, CWMN lab guide, and so on) and authored several Wireless books (IUWMS, CUWSS Quick Reference, and so on). Jerome is also an IEEE 802.11 group member and participant of Wi-Fi Alliance working groups. With more than 10000 hours in the classroom, Jerome was awarded the IT Training Award best Instructor silver medal in 2009. He is based in the Research Triangle Park in North Carolina.
Dedications

As always, this book is dedicated to the most important people in my life: my wife, Marci, and my two daughters, Lauren and Kara. Their love, encouragement, and support carry me along. I'm so grateful to God, who gives endurance and encouragement (Romans 15:5), and who has allowed me to enjoy networking and work on projects like this.

I would also like to dedicate this book to the memory of my father-in-law, Ermel Wilson. He helped me appreciate the simpler things in life—the outdoors, hikes in the woods, and snow.
Acknowledgments

It has been my great pleasure to work on another Cisco Press project. I enjoy the networking field very much, and technical writing even more. And more than that, I'm thankful for the joy and inner peace that Jesus Christ gives, making everything more abundant and worthwhile. As much as I enjoy learning about wireless networking (there's no end to it!), I realize that God created the original wireless connection that has no distance limits, unlimited capacity for clients (there's always room for one more), is trustworthy, always available everywhere, and connects directly to the Source: prayer!

I've now been writing Cisco Press titles continuously for what will soon be 15 years. I have physically worn out several laptop keyboards and probably several Cisco Press editors in the process. It has been a great pleasure to work with Chris Cleveland and Mary Beth Ray. I should have a certification in schedule slipping by now. Keith Cline and Seth Kerney have been great to work with and have made the whole review process smooth and efficient. One important part of the book I never get to see is the index. I'm grateful that Tim Wright worked on this one.

I am very grateful for the insight, knowledge, and helpful comments that Jerome Henry has provided. He is a great resource for wireless networking expertise and training. Jerome's input has made this a more well-rounded book and me a more educated author.

Finally, I have enjoyed the good discussions with my dad, Reid Hucaby, a fellow EE and a seasoned RF engineer, that this book has prompted about all things wireless.
Contents at a Glance

Introduction xix

Chapter 1 RF Signals and Modulation 3
Chapter 2 RF Standards 37
Chapter 3 RF Signals in the Real World 67
Chapter 4 Understanding Antennas 85
Chapter 5 Wireless LAN Topologies 105
Chapter 6 Understanding 802.11 Frame Types 123
Chapter 7 Planning Coverage with Wireless APs 147
Chapter 8 Using Autonomous APs 163
Chapter 9 Understanding the CUWN Architecture 181
Chapter 10 Initial Controller Configuration 201
Chapter 11 Understanding Controller Discovery 221
Chapter 12 Understanding Roaming 239
Chapter 13 Understanding RRM 259
Chapter 14 Wireless Security Fundamentals 281
Chapter 15 Configuring a WLAN 307
Chapter 16 Implementing a Wireless Guest Network 323
Chapter 17 Understanding Wireless Clients 335
Chapter 18 Managing Wireless Networks with WCS 359
Chapter 19 Dealing with Wireless Interference 383
Chapter 20 Troubleshooting WLAN Connectivity 401
Chapter 21 Maintaining Controllers 427
Chapter 22 Final Review 447

Appendix A Answers to “Do I Know This Already?” Quizzes 457
Appendix B Modulation and Coding Schemes 473
Key Terms Glossary 481
Index 494
Contents

Introduction  xix

Chapter 1  RF Signals and Modulation  3
“Do I Know This Already?” Quiz  3
Foundation Topics  7
Comparing Wired and Wireless Networks  7
Understanding Basic Wireless Theory  8
  Understanding Frequency  10
  Understanding Phase  14
  Measuring Wavelength  14
  Understanding RF Power and dB  15
Important dB Facts to Remember  17
Comparing Power Against a Reference: dBm  19
Measuring Power Changes Along the Signal Path  20
Understanding Power Levels at the Receiver  23
Carrying Data Over an RF Signal  24
  FHSS  26
  DSSS  27
  1-Mbps Data Rate  28
  2-Mbps Data Rate  29
  5.5-Mbps Data Rate  30
  11-Mbps Data Rate  30
  OFDM  31
  Modulation Summary  32
Exam Preparation Tasks  34
  Review All Key Topics  34
  Key Terms  34

Chapter 2  RF Standards  37
“Do I Know This Already?” Quiz  37
Foundation Topics  41
Regulatory Bodies  41
  ITU-R  41
  FCC  42
  ETSI  44
Other Regulatory Bodies  45
IEEE Standards Body  45
802.11 Channel Use  47
  Channels in the 2.4-GHz ISM Band  47
  Channels in the 5-GHz U-NII Bands  49
IEEE 802.11 Standards  51
  802.11-1997  52
  802.11b  52
  802.11g  52
  802.11a  54
  802.11n  55
Channel Aggregation  57
Spatial Multiplexing  58
MAC Layer Efficiency  59
Transmit Beam Forming (TxBF)  60
Maximal-Ratio Combining  61
802.11n Modulation and Coding Schemes  61
Beyond 802.11n  62
Wi-Fi Alliance  63
Exam Preparation Tasks  64
  Review All Key Topics  64
  Define Key Terms  64

Chapter 3  RF Signals in the Real World  67
“Do I Know This Already?” Quiz  67
Foundation Topics  70
Interference  70
  Co-Channel Interference  70
  Neighboring Channel Interference  71
  Non-802.11 Interference  72
Free Space Path Loss  72
  Mitigating the Effects of Free Space Path Loss  74
Effects of Physical Objects  76
  Reflection  76
  Absorption  78
  Scattering  78
  Refraction  79
  Diffraction  80
  Fresnel Zones  80
Exam Preparation Tasks  83
  Review All Key Topics  83
  Define Key Terms  83

Chapter 4  Understanding Antennas  85
“Do I Know This Already?” Quiz  85
Foundation Topics  88
Antenna Characteristics 88
  Radiation Patterns 88
  Gain 91
  Beamwidth 92
  Polarization 92
Antenna Types 93
  Omnidirectional Antennas 94
  Directional Antennas 97
  Antenna Summary 101
Adding Antenna Accessories 101
Exam Preparation Tasks 103
  Review All Key Topics 103
  Define Key Terms 103

Chapter 5  Wireless LAN Topologies 105
“Do I Know This Already?” Quiz 105
Foundation Topics 108
  Types of Wireless Networks 108
  Wireless LAN Topologies 109
    Basic Service Set 110
    Distribution System 112
    Extended Service Set 114
    Independent Basic Service Set 115
  Other Wireless Topologies 116
    Repeater 116
    Workgroup Bridge 117
    Outdoor Bridge 118
    Mesh Network 119
Exam Preparation Tasks 120
  Review All Key Topics 120
  Define Key Terms 120

Chapter 6  Understanding 802.11 Frame Types 123
“Do I Know This Already?” Quiz 123
  802.11 Frame Format 126
  802.11 Frame Addressing 128
  Accessing the Wireless Medium 130
    Carrier Sense 131
    Collision Avoidance 132
  802.11 Frame Types 134
    Management Frames 134
Control Frames 135
Data Frames 136
Client Housekeeping 136
   A Client Scans for APs 137
   A Client Joins a BSS 138
   A Client Leaves a BSS 139
   A Client Moves Between BSSs 140
   A Client Saves Power 142
Exam Preparation Tasks 145
   Review All Key Topics 145
   Define Key Terms 145

Chapter 7  Planning Coverage with Wireless APs 147
“Do I Know This Already?” Quiz 147
AP Cell Size 150
   Tuning Cell Size with Transmit Power 150
   Tuning Cell Size with Data Rates 152
Adding APs to an ESS 153
   The Roaming Process 155
   WLAN Channel Layout 157
Exam Preparation Tasks 161
   Review All Key Topics 161
   Define Key Terms 161

Chapter 8  Using Autonomous APs 163
“Do I Know This Already?” Quiz 163
Foundation Topics 166
   Autonomous Architecture 166
Configuring an Autonomous AP 167
   Connecting the AP 167
   Configuring the AP 170
Converting an Autonomous AP 174
   Using the Autonomous to Lightweight Mode Upgrade Tool 174
   Converting an Autonomous AP Manually 176
Exam Preparation Tasks 178
   Review All Key Topics 178
   Define Key Terms 178

Chapter 9  Understanding the CUWN Architecture 181
“Do I Know This Already?” Quiz 181
Foundation Topics 184
   A Distributed Architecture 184
Chapter 10  Initial Controller Configuration  201
“Do I Know This Already?” Quiz  201
Foundation Topics  204
Connecting the Controller  204
  Using Controller Ports  204
  Using Controller Interfaces  206
Running the Initial Setup Wizard  208
  Initial Setup with the Web Interface  208
  Initial Setup with the CLI  216
Exam Preparation Tasks  218
  Review All Key Topics  218
  Define Key Terms  218

Chapter 11  Understanding Controller Discovery  221
“Do I Know This Already?” Quiz  221
Foundation Topics  224
Discovering a Controller  224
  AP States  224
  Discovering a WLC  226
  Selecting a WLC  227
Designing High Availability  228
  Detecting a Controller Failure  230
  Building Redundancy  231
  \textit{N+1 Redundancy}  231
  \textit{N+N Redundancy}  232
  \textit{N+N+1 Redundancy}  232
  \textit{AP SSO Redundancy}  233
Exam Preparation Tasks  235
  Review All Key Topics  235
  Define Key Terms  236
Chapter 12 Understanding Roaming  239
“Do I Know This Already?” Quiz  239
Foundation Topics  242
Roaming with Autonomous APs  242
Intracontroller Roaming  244
Intercontroller Roaming  246
  Layer 2 Roaming  247
  Layer 3 Roaming  248
  Using Mobility Groups  252
Exam Preparation Tasks  256
  Review All Key Topics  256
  Define Key Terms  256

Chapter 13 Understanding RRM  259
“Do I Know This Already?” Quiz  259
Foundation Topics  262
  Configuring 802.11 Support  262
    Configuring Data Rates  263
    Configuring 802.11n Support  264
Understanding RRM  265
  RF Groups  267
  TPC  269
  DCA  272
  Coverage Hole Detection  274
  Manual RF Configuration  276
  Verifying RRM Results  278
Exam Preparation Tasks  279
  Review All Key Topics  279
  Define Key Terms  279

Chapter 14 Wireless Security Fundamentals  281
“Do I Know This Already?” Quiz  282
Foundation Topics  285
Anatomy of a Secure Connection  285
  Authentication  286
  Message Privacy  287
  Message Integrity  288
  Intrusion Protection  289
Wireless Client Authentication Methods  290
  Open Authentication  290
  WEP  291
Chapter 15 Configuring a WLAN 307

“Do I Know This Already?” Quiz 307

Foundation Topics 309

WLAN Overview 309

Configuring a WLAN 310

Configuring a RADIUS Server 310

Creating a Dynamic Interface 312

Creating a New WLAN 313

Configuring WLAN Security 315

Configuring WLAN QoS 317

Configuring Advanced WLAN Settings 318

Finalizing WLAN Configuration 319

Exam Preparation Tasks 320

Review All Key Topics 320

Chapter 16 Implementing a Wireless Guest Network 323

“Do I Know This Already?” Quiz 323

Foundation Topics 325

Guest Network Overview 325

Configuring a Guest Network 326

Scaling the Guest Network 329

Exam Preparation Tasks 332

Review All Key Topics 332

Define Key Terms 332
Chapter 17  Understanding Wireless Clients  335
“Do I Know This Already?” Quiz  335
Foundation Topics  338
Configuring Common Wireless Clients  338
  Windows 7 and 8  338
  Intel PROSet  341
  Android  345
  Apple OS X  346
  Cisco AnyConnect  348
Cisco Compatible Extensions  352
Exam Preparation Tasks  356
  Review All Key Topics  356
  Define Key Terms  356

Chapter 18  Managing Wireless Networks with WCS  359
“Do I Know This Already?” Quiz  359
Foundation Topics  362
WCS Overview  362
  Alarm Summary Dashboard  364
  Main Navigation Area  366
  WCS Home Area  366
Using WCS to Configure Devices  368
Using WCS Maps  370
  Displaying Maps  370
  Manipulating APs on Maps  373
  Viewing Information on Maps  375
Generating Reports  377
Exam Preparation Tasks  381
  Review All Key Topics  381

Chapter 19  Dealing with Wireless Interference  383
“Do I Know This Already?” Quiz  383
Understanding Types of Interference  386
Bluetooth  386
  ZigBee  387
Cordless Phones  388
Microwave Ovens  388
WiMAX  388
Other Devices  389
Icons Used in This Book

Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a `show` command).
- **Italic** indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.
Introduction

Welcome to the world of Cisco Certified Network Associate (CCNA) Wireless! As technology continues to evolve, wireless technologies are finding their way to the forefront. This clearly indicates the progression from a fixed wired type of connectivity to a more fluid, mobile workforce that can work when, where, and how they want. Regardless of your background, one of the primary goals of the CCNA Wireless certification is to introduce you to the Cisco Unified Wireless Network (CUWN).

This book is designed to help you prepare for the Cisco CCNA Wireless 640-722 IUWNE (Implementing Cisco Unified Wireless Networking Essentials) certification exam. To achieve the CCNA Wireless specialization, you must first pass the ICND1, ICND2, or the CCNA Composite exam.
Who Should Read This Book

Wireless networking is a complex business. The CCNA Wireless specialization was developed to introduce wireless LANs, the CUWN, and Cisco’s wireless product line. The certification tests for proficiency in designing, installing, configuring, monitoring, and troubleshooting wireless networks in an enterprise setting.

How to Use This Book

The book consists of 22 chapters. Each chapter tends to build upon the chapter that precedes it. The chapters of the book cover the following topics:

- **Chapter 1, “RF Signals and Modulation”:** This chapter covers the basic theory behind radio frequency (RF) signals and the methods used to carry data wirelessly.
- **Chapter 2, “RF Standards”:** This chapter covers the agencies that regulate, standardize, and validate the correct use of wireless LAN devices.
- **Chapter 3, “RF Signals in the Real World”:** This chapter explores many of the conditions that can affect wireless signal propagation.
- **Chapter 4, “Understanding Antennas”:** This chapter explains some basic antenna theory, in addition to various types of antennas and their application.
- **Chapter 5, “Wireless LAN Topologies”:** This chapter explains the topologies that can be used to control access to the wireless medium and provide data exchange between devices.
- **Chapter 6, “Understanding 802.11 Frame Types”:** This chapter covers the frame format and frame types that APs and clients must use to communicate successfully. It also discusses the choreography that occurs between an AP and its clients.
- **Chapter 7, “Planning Coverage with Wireless APs”:** This chapter explains how wireless coverage can be adjusted to meet a need and how it can be grown to scale over a greater area and a greater number of clients.
- **Chapter 8, “Using Autonomous APs”:** This chapter discusses basic operation of an autonomous AP and how you can connect to it and convert it to lightweight mode, to become a part of a larger, more integrated wireless network.
- **Chapter 9, “Understanding the CUWN Architecture”:** This chapter describes the centralized or unified wireless architecture and how you can leverage its strengths to solve some fundamental problems.
- **Chapter 10, “Initial Controller Configuration”:** This chapter covers the wireless controller’s role in linking wired and wireless networks. It also covers the minimal initial configuration needed to get a controller up on the network where you can manage it more fully.
- **Chapter 11, “Understanding Controller Discovery”:** This chapter explains the process that each lightweight AP must go through to discover and bind itself with a controller before wireless clients can be supported.
Chapter 12, “Understanding Roaming”: This chapter discusses client mobility from the AP and controller perspectives so that you can design and configure your wireless network properly as it grows over time.

Chapter 13, “Understanding RRM”: This chapter covers Radio Resource Management (RRM), a flexible and automatic mechanism that Cisco wireless LAN controllers can use to make wireless network operation more efficient.

Chapter 14, “Wireless Security Fundamentals”: This chapter covers many of the methods you can use to secure a wireless network.

Chapter 15, “Configuring a WLAN”: This chapter explains how to define and tune a wireless LAN to support wireless clients and connectivity with a wired infrastructure.

Chapter 16, “Implementing a Wireless Guest Network”: This chapter discusses the steps you can take to configure a guest network as an extension to your wireless infrastructure.

Chapter 17, “Understanding Wireless Clients”: This chapter introduces some of the most common types of wireless clients and how to configure them to join a wireless LAN.

Chapter 18, “Managing Wireless Networks with WCS”: This chapter provides a brief overview of WCS, how you can configure controllers and APs with it, and how you can use it to monitor a variety of things in your network.

Chapter 19, “Dealing with Wireless Interference”: This chapter covers some common types of devices that can cause interference and the Cisco CleanAir features that can detect and react to the interference sources.

Chapter 20, “Troubleshooting WLANs”: This chapter helps you get some perspective about wireless problems, develop a troubleshooting strategy, and become comfortable using the tools at your disposal.

Chapter 21, “Maintaining Controllers”: This chapter explains how you can interface with controllers and APs so that you can upload and download files needed for their operation.

Chapter 22, “Final Review”: This short chapter lists the exam preparation tools useful at this point in the study process. It also provides a suggested study plan now that you have completed all of the earlier chapters in this book.

Appendix A, “Answers to the ‘Do I Know This Already?’ Quizzes”: This appendix provides the correct answers to the “Do I Know This Already?” quizzes that you will find at the beginning of each chapter. Brief explanations for the correct answers will also help you complete your understanding of topics covered.

Appendix B, “Modulation and Coding Schemes”: This appendix outlines the direct sequence spread spectrum (DSSS) and orthogonal frequency-division multiplexing (OFDM) data rates used for 802.11b/g and 802.11a; the modulation and coding schemes and data rates used for 802.11n; and the modulation, coding schemes, and data rates used for 802.11ac.
Key Terms Glossary: The glossary defines all WLAN-related terms that you were asked to define at the end of each chapter.

Each chapter follows the same format and incorporates the following tools to assist you by assessing your current knowledge and emphasizing specific areas of interest within the chapter:

- Do I Already Know This Quiz?: Each chapter begins with a quiz to help you assess your current knowledge of the subject. The quiz is divided into specific areas of emphasis that enable you to best determine where to focus your efforts when working through the chapter.

- Foundation Topics: The foundation topics are the core sections of each chapter. They focus on the specific protocols, concepts, or skills that you must master to successfully prepare for the examination.

- Exam Preparation: Near the end of each chapter, this section highlights the key topics from the chapter and the pages where you can find them for quick review. This section also provides a list of key terms that you should be able to define in preparation for the exam. It is unlikely that you will be able to successfully complete the certification exam by just studying the key topics and key terms, although they are a good tool for last-minute preparation just before taking the exam.

- CD-ROM-based practice exam: This book includes a CD-ROM containing several interactive practice exams. It is recommended that you continue to test your knowledge and test-taking skills by using these exams. You will find that your test-taking skills will improve by continued exposure to the test format. Remember that the potential range of exam questions is limitless. Therefore, your goal should not be to “know” every possible answer but to have a sufficient understanding of the subject matter so that you can figure out the correct answer with the information provided.

Pearson IT Certification Practice Test Engine and Questions on the CD-ROM

The CD-ROM in the back of the book includes the Pearson IT Certification Practice Test engine—software that displays and grades a set of exam-realistic multiple-choice questions. Using the Pearson IT Certification Practice Test engine, you can either study by going through the questions in Study Mode, or take a simulated exam that mimics real exam conditions. You can also serve up questions in a Flash Card Mode, which will display just the question and no answers, challenging you to state the answer in your own words before checking the actual answers to verify your work.

The installation process requires two major steps: installing the software and then activating the exam. The CD in the back of this book has a recent copy of the Pearson IT Certification Practice Test engine. The practice exam (the database of exam questions) is not on the CD.
Install the Software from the CD

The Pearson IT Certification Practice Test is a Windows-only desktop application. You can run it on a Mac using a Windows virtual machine, but it was built specifically for the PC platform. The minimum system requirements are as follows:

- Windows XP (SP3), Windows Vista (SP2), Windows 7, or Windows 8
- Microsoft .NET Framework 4.0 Client
- Pentium-class 1GHz processor (or equivalent)
- 512MB RAM
- 650MB disk space plus 50MB for each downloaded practice exam
- Access to the Internet to register and download exam databases

The software installation process is routine as compared with other software installation processes. If you have already installed the Pearson IT Certification Practice Test software from another Pearson product, there is no need for you to reinstall the software. Simply launch the software on your desktop and proceed to activate the practice exam from this book by using the activation code included in the CD sleeve.

The following steps outline the installation process:

1. Insert the CD into your PC.
2. The media interface that automatically runs allows you to access and use all CD-based features, including the exam engine and sample content from other Cisco self-study products. From the main menu, click the Install the Exam Engine option.
3. Respond to windows prompts as with any typical software installation process.

The installation process will give you the option to activate your exam with the activation code supplied on the paper in the CD sleeve. This process requires that you establish a Pearson website login. You need this login to activate the exam, so please do register when prompted. If you already have a Pearson website login, there is no need to register again. Just use your existing login.
Activate and Download the Practice Exam

Once the exam engine is installed, you should then activate the exam associated with this book (if you did not do so during the installation process) as follows:

1. Start the Pearson IT Certification Practice Test software from the Windows Start menu or from your desktop shortcut icon.

2. To activate and download the exam associated with this book, from the My Products or Tools tab, click the Activate Exam button.

3. At the next screen, enter the activation key from paper inside the cardboard CD holder in the back of the book. Once entered, click the Activate button.

4. The activation process will download the practice exam. Click Next, and then click Finish.

When the activation process completes, the My Products tab should list your new exam. If you do not see the exam, make sure that you have selected the My Products tab on the menu. At this point, the software and practice exam are ready to use. Simply select the exam and click the Open Exam button.

To update a particular exam you have already activated and downloaded, display the Tools tab and click the Update Products button. Updating your exams will ensure that you have the latest changes and updates to the exam data.

If you want to check for updates to the Pearson Cert Practice Test exam engine software, display the Tools tab and click the Update Application button. You can then ensure that you are running the latest version of the software engine.

Activating Other Exams

The exam software installation process, and the registration process, only has to happen once. Then, for each new exam, only a few steps are required. For instance, if you buy another Pearson IT Certification Cert Guide, extract the activation code from the CD sleeve in the back of that book; you do not even need the CD at this point. From there, all you have to do is start the exam engine (if not still up and running) and perform Steps 2 through 4 from the previous list.

Certification Exam Topics and This Book

The questions for each certification exam are a closely guarded secret. However, we do know which topics you must know to successfully complete this exam. Cisco publishes them as an exam blueprint for Implementing Cisco Unified Wireless Networking Essentials (IUWNE), exam 640-722. Table I-1 lists each exam topic listed in the blueprint along with a reference to the book chapter that covers the topic. These are the same topics you should be proficient in when working with Cisco wireless LANs in the real world.
<table>
<thead>
<tr>
<th>Exam Topic</th>
<th>Chapter Where Topic is Covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe WLAN Fundamentals</td>
<td></td>
</tr>
<tr>
<td>Describe basics of spread spectrum technology</td>
<td>Chapter 1</td>
</tr>
<tr>
<td>Describe the impact of various wireless technologies (Bluetooth, WiMAX,</td>
<td>Chapter 19</td>
</tr>
<tr>
<td>ZigBee, and cordless phone)</td>
<td></td>
</tr>
<tr>
<td>Describe wireless regulatory bodies, standards and certifications (FCC,</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>ETSI, 802.11a/b/g/n, and WiFi Alliance)</td>
<td></td>
</tr>
<tr>
<td>Describe Wireless LAN (WLAN) RF principles (antenna types, RF gain/loss,</td>
<td>Chapters 3-4</td>
</tr>
<tr>
<td>Effective Isotropic Radiated Power (EIRP), refraction, reflection, and so</td>
<td></td>
</tr>
<tr>
<td>on)</td>
<td></td>
</tr>
<tr>
<td>Describe networking technologies used in wireless (SSID to WLAN_ID to</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>Interface to VLAN, 802.1q trunking)</td>
<td></td>
</tr>
<tr>
<td>Describe wireless topologies, such as Independent Basic Service Set (IBSS),</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>Basic Service Set (BSS), Extended Service Set (ESS), Point-to-Point,</td>
<td></td>
</tr>
<tr>
<td>Point-to-Multipoint, Mesh, and bridging)</td>
<td></td>
</tr>
<tr>
<td>Describe 802.11 authentication and encryption methods (Open, Shared, 802.</td>
<td>Chapter 14</td>
</tr>
<tr>
<td>1X, EAP, TKIP, and AES)</td>
<td></td>
</tr>
<tr>
<td>Describe frame types (associated and unassociated, management, control,</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>and data)</td>
<td></td>
</tr>
<tr>
<td>Describe basic RF deployment considerations related to site survey</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>design of data or VoWLAN applications, common RF interference sources</td>
<td></td>
</tr>
<tr>
<td>such as devices, building material, AP location, and basic RF site</td>
<td></td>
</tr>
<tr>
<td>survey design related to channel reuse, signal strength, and cell overlap</td>
<td></td>
</tr>
<tr>
<td>Install a Basic Cisco Wireless LAN</td>
<td></td>
</tr>
<tr>
<td>Identify the components of the Cisco Unified Wireless Network architecture</td>
<td>Chapter 9</td>
</tr>
<tr>
<td>(Split MAC, LWAPP, stand-alone AP vs controller-based AP, specific</td>
<td></td>
</tr>
<tr>
<td>hardware examples)</td>
<td></td>
</tr>
<tr>
<td>Install and configure autonomous access points in the small business</td>
<td>Chapter 8</td>
</tr>
<tr>
<td>environment</td>
<td></td>
</tr>
<tr>
<td>Describe the modes of controller-based AP deployment (local, monitor,</td>
<td>Chapter 9</td>
</tr>
<tr>
<td>HREAP, sniffer, rogue detector, bridge, OEAP, and SE-Connect)</td>
<td></td>
</tr>
<tr>
<td>Describe controller-based AP discovery and association (DHCP, DNS,</td>
<td>Chapter 11</td>
</tr>
<tr>
<td>Master-Controller, Primary-Secondary-Tertiary, and n+1 redundancy)</td>
<td></td>
</tr>
<tr>
<td>Describe roaming (Layer 2 and Layer 3, intra-controller and inter-</td>
<td>Chapter 12</td>
</tr>
<tr>
<td>controller, and mobility list)</td>
<td></td>
</tr>
<tr>
<td>Exam Topic</td>
<td>Chapter Where Topic is Covered</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Configure a WLAN controller and access points WLC: ports, interfaces, WLANs, NTP, CLI and Web UI, CLI wizard, and link aggregation group (LAG) AP: Channel and Power</td>
<td>Chapter 10, 15</td>
</tr>
<tr>
<td>Describe Radio Resource Management (RRM) fundamentals including ED-RRM.</td>
<td>Chapter 13</td>
</tr>
<tr>
<td>Verify basic wireless network operation</td>
<td>Chapter 20</td>
</tr>
<tr>
<td><strong>Install Wireless Clients</strong></td>
<td></td>
</tr>
<tr>
<td>Describe client WLAN configuration requirements, such as Service Set Identifier (SSID), security selection, and authentication</td>
<td>Chapter 17</td>
</tr>
<tr>
<td>Identify basic configuration of common wireless supplicants (Macintosh, Intel Wireless Pro, Windows, iOS, and Android)</td>
<td>Chapter 17</td>
</tr>
<tr>
<td>Describe basic AnyConnect 3.0 or above wireless configuration parameters</td>
<td>Chapter 17</td>
</tr>
<tr>
<td>Identify capabilities available in CCX versions 1 through 5</td>
<td>Chapter 17</td>
</tr>
<tr>
<td><strong>Implement Basic WLAN Security</strong></td>
<td></td>
</tr>
<tr>
<td>Describe the general framework of wireless security and security components (authentication, encryption, MFP, IPS)</td>
<td>Chapter 14</td>
</tr>
<tr>
<td>Describe and configure authentication methods (Guest, PSK, 802.1X, WPA/WPA2 with EAP-TLS, EAP-FAST, PEAP, LEAP)</td>
<td>Chapters 14, 16</td>
</tr>
<tr>
<td>Describe and configure encryption methods (WPA/WPA2 with TKIP, AES)</td>
<td>Chapter 14</td>
</tr>
<tr>
<td>Describe and configure the different sources of authentication (PSK, EAP-local or -external, Radius)</td>
<td>Chapter 14</td>
</tr>
<tr>
<td><strong>Operate Basic WCS</strong></td>
<td></td>
</tr>
<tr>
<td>Identify key functions of Cisco Wireless Control System (WCS) and Navigator (versions and licensing)</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Navigate WCS interface</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Configure controllers and access points (APs) (using the Configuration tab not templates)</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Use preconfigured maps in the WCS (adding/relocating/removing access points, turn on/off heat maps, view client location, and view CleanAir zones of influence)</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Use the WCS monitor tab and alarm summary to verify the WLAN operations</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Generate standard WCS reports (inventory, CleanAir, client-related, AP-related, and utilization)</td>
<td>Chapter 18</td>
</tr>
<tr>
<td>Exam Topic</td>
<td>Chapter Where Topic is Covered</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Conduct Basic WLAN Maintenance and Troubleshooting</td>
<td></td>
</tr>
<tr>
<td>Identify and use basic WLAN troubleshooting tools (WLC show debug and logging) for client to AP connectivity, AP to controller connectivity</td>
<td>Chapter 20</td>
</tr>
<tr>
<td>Use the WCS client troubleshooting tool</td>
<td>Chapter 20</td>
</tr>
<tr>
<td>Transfer logs, configuration files, and O/S images to and from the WLC via the GUI</td>
<td>Chapter 21</td>
</tr>
<tr>
<td>Differentiate and use WLC and AP (autonomous and LAP) management access methods (console port, CLI, telnet, ssh, http, https, and wired vs wireless management)</td>
<td>Chapter 21</td>
</tr>
</tbody>
</table>

Notice that not all the chapters map to a specific exam topic. Each version of the exam can have topics that emphasize different functions or features, and some topics can be rather broad and generalized. The goal of this book is to provide the most comprehensive coverage to ensure that you are well prepared for the exam. Although some chapters might not address specific exam topics, they provide a foundation that is necessary for a clear understanding of important topics. Your short-term goal might be to pass this exam, but your long-term goal should be to become a qualified wireless networking professional.

It is also important to understand that this book is a “static” reference, whereas the exam topics are dynamic. Cisco can and does change the topics covered on certification exams often.

This exam guide should not be your only reference when preparing for the certification exam. You can find a wealth of information available at Cisco.com that covers each topic in great detail. If you think that you need more detailed information on a specific topic, read the Cisco documentation that focuses on that topic.

Note that as wireless technologies continue to develop, Cisco reserves the right to change the exam topics without notice. Although you can refer to the list of exam topics in Table I-1, always check Cisco.com to verify the actual list of topics to ensure that you are prepared before taking the exam. You can view the current exam topics on any current Cisco certification exam by visiting the Cisco.com website, hovering over Training & Events, and selecting from the Certifications list. Note also that, if needed, Cisco Press might post additional preparatory content on the web page associated with this book at http://www.ciscopress.com/title/9781587205620. It’s a good idea to check the website a couple of weeks before taking your exam to be sure that you have up-to-date content.
Taking the CCNA Wireless Certification Exam

As with any Cisco certification exam, you should strive to be thoroughly prepared before taking the exam. There is no way to determine exactly what questions are on the exam, so the best way to prepare is to have a good working knowledge of all subjects covered on the exam. Schedule yourself for the exam and be sure to be rested and ready to focus when taking the exam.

The best place to find out the latest available Cisco training and certifications is under the Training & Events section at Cisco.com.

Tracking Your Status

You can track your certification progress by checking http://www.cisco.com/go/certifications/login. You must create an account the first time you log in to the site.

How to Prepare for an Exam

The best way to prepare for any certification exam is to use a combination of the preparation resources, labs, and practice tests. This guide has integrated some practice questions and example scenarios to help you better prepare. If possible, get some hands-on experience with CUWN equipment. There is no substitute for real-world experience; it is much easier to understand the designs, configurations, and concepts when you can actually work with a live wireless network.

Cisco.com provides a wealth of information about wireless LAN controllers, access points (APs), and wireless management products, and wireless LAN technologies and features.

Assessing Exam Readiness

Exam candidates never really know whether they are adequately prepared for the exam until they have completed about 30 percent of the questions. At that point, if you are not prepared, it is too late. The best way to determine your readiness is to work through the “Do I Know This Already?” quizzes at the beginning of each chapter and review the foundation and key topics presented in each chapter. It is best to work your way through the entire book unless you can complete each subject without having to do any research or look up any answers.

Cisco Wireless Certifications in the Real World

Cisco has one of the most recognized names on the Internet. Cisco Certified wireless specialists can bring quite a bit of knowledge to the table because of their deep understanding of wireless technologies, standards, and networking devices. This is why the
Cisco certification carries such high respect in the marketplace. Cisco certifications demonstrate to potential employers and contract holders a certain professionalism, expertise, and dedication required to complete a difficult goal. If Cisco certifications were easy to obtain, everyone would have them.

**Exam Registration**

The CCNA Wireless IUWNE 640-722 exam is a computer-based exam, with around 75 to 85 multiple-choice, fill-in-the-blank, list-in-order, and simulation-based questions. You can take the exam at any Pearson VUE (http://www.pearsonvue.com) testing center. According to Cisco, the exam should last about 90 minutes. Be aware that when you register for the exam, you might be told to allow a certain amount of time to take the exam that is longer than the testing time indicated by the testing software when you begin. This discrepancy is because the testing center will want you to allow for some time to get settled and take the tutorial about the test engine.

**Book Content Updates**

Because Cisco occasionally updates exam topics without notice, Cisco Press might post additional preparatory content on the web page associated with this book at http://www.ciscopress.com/title/9781587205620. It is a good idea to check the website a couple of weeks before taking your exam, to review any updated content that might be posted online. We also recommend that you periodically check back to this page on the Cisco Press website to view any errata or supporting book files that may be available.
This chapter covers the following topics:

- **AP Cell Size**—This section discusses how the size of a wireless cell affects things like coverage area, performance, and efficiency.

- **Adding APs to an ESS**—This section covers the process of growing an extended service set, with an emphasis on client roaming and proper layout of wireless channels over an area.

This chapter covers the following exam topics:

- Describe basic RF deployment considerations related to site survey design of data or VoWLAN applications; common RF interference sources such as devices, building material, AP location; and basic RF site survey design related to channel reuse, signal strength, and cell overlap.
Chapters 1 through 6 covered wireless communication with a focus on a single access point (AP) exchanging data with one or more clients. A single AP may be sufficient for home or small office use, but most wireless LANs involve a greater geographic area and require more APs. This chapter explains how wireless coverage can be adjusted to meet a need and how it can be grown to scale over a greater area and a greater number of clients. As you work through this chapter, remember that two things are important: the size of the BSA or AP cell and the location of cells in relation to each other.

“Do I Know This Already?” Quiz

The “Do I Know This Already?” quiz allows you to assess whether you should read this entire chapter thoroughly or jump to the “Exam Preparation Tasks” section. If you are in doubt about your answers to these questions or your own assessment of your knowledge of the topics, read the entire chapter. Table 7-1 lists the major headings in this chapter and their corresponding “Do I Know This Already?” quiz questions. You can find the answers in Appendix A, “Answers to the ‘Do I Know This Already?’ Quizzes.”

<table>
<thead>
<tr>
<th>Foundation Topics Section</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Cell Size</td>
<td>1–4</td>
</tr>
<tr>
<td>Adding APs to an ESS</td>
<td>5–10</td>
</tr>
</tbody>
</table>

Caution  The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark that question as wrong for purposes of the self-assessment. Giving yourself credit for an answer you correctly guess skews your self-assessment results and might provide you with a false sense of security.
1. Which of the following parameters can be adjusted on an AP to change the size of its cell or BSA? (Choose all that apply.)
   a. Channel number within a band
   b. Transmit power
   c. Supported modulation and coding schemes
   d. Supported data rates

2. An AP has been configured to use channel 1 with a transmit power of 20 dBm. With the AP located in the center of the lobby, you have determined that its signal will reach all locations in the lobby area. However, some users with small battery-operated devices report connectivity problems when they move toward the outer walls of the lobby. Which one of the following approaches will probably fix the problem?
   a. Increase the AP's transmit power to increase its range
   b. Increase the client device's transmit power
   c. Adjust the client device’s roaming algorithm
   d. Enable some lower data rates on the AP

3. Suppose that an AP is configured to offer the following data rates: 2-, 5.5-, 6-, 9-, 11-, 12-, 18-, 24-, 36-, and 48-Mbps data rates to its clients. Which one of the following strategies should be used to reduce the AP's cell size?
   a. Enable the 1-Mbps data rate
   b. Enable the 54-Mbps data rate
   c. Disable the 36- and 48-Mbps data rates
   d. Disable the 2-Mbps data rate

4. All the APs on the second floor of a building are part of a single ESS. Each AP has been configured with a transmit power level of 14 dBm. In addition, each AP has been configured to use a non-overlapping channel that is different from its adjacent neighbors. All APs have been configured to offer only the 24-, 36-, 48-, and 54-Mbps data rates; all other rates are disabled. One day, one of the APs fails and someone replaces it. Afterward, users begin to call and complain about poor performance and roaming. You discover that the problems are not occurring in the area covered by the failed AP; instead, they are occurring about two APs away from it. Which one of the following could be causing the problem?
   a. The replacement AP has its radios disabled.
   b. The replacement AP is using a transmit level of 1 dBm.
   c. The replacement AP is using the 1- and 2-Mbps data rates.
   d. The replacement AP is new and cannot be causing the problem.

5. Which one of the following determines when a wireless client will roam from one AP to another?
   a. The current AP detects a weak signal coming from the client and forces the client to roam.
b. The next AP overhears the client’s signal and asks it to roam.
c. The client’s roaming algorithm reaches a threshold in signal quality.
d. The client loses its IP address.

6. Which one of the following 802.11 frames is used to trigger a roam from one AP to another?
a. Association request
b. Disassociation request
c. Probe
d. Reassociation request

7. Which one of the following statements is true about roaming?
a. All wireless clients use the same algorithms to trigger a roaming condition.
b. Wireless clients can scan available channels to look for a new AP when roaming.
c. Wireless clients must roam from one AP to another on the same channel.
d. The 802.11 standard defines a set of roaming algorithms for clients.

8. Which one of the following statements is true about a good wireless LAN design?
a. Neighboring APs should use the same channel to promote good roaming.
b. APs should be positioned so that their cells overlap.
c. APs should be positioned so that their cells do not overlap at all.
d. APs should use channels that overlap each other.

9. When you are designing the AP channel layout for an area, which one of the following is the most important consideration?
a. The number of channels is conserved.
b. APs in different areas use different channels.
c. Adjacent APs use non-overlapping channels.
d. Clients are grouped into common channels.

10. An AP is located in the main office on the third floor of a building. The AP is configured to use channel 6 in the 2.4-GHz band. Which of the following conditions might hinder clients as they move around on the third floor and need to roam? (Choose all that apply.)
a. Two other APs in the third floor main office area use channel 6.
b. None of the fourth floor APs directly above the main office use channel 6.
c. One of the second floor APs directly below the main office use channel 6.
d. All of these answers are correct.
AP Cell Size

The basic service area (BSA) or cell that is provided by an AP can vary, depending on several factors. Obviously, the cell size determines the geographic area where wireless service will be offered. AP cell size can also affect the performance of the APs as clients move around or gather in one place.

Remember that a wireless LAN is a shared medium. Within a single AP cell, all of the clients associated with that AP must share the bandwidth and contend for access. If the cell is large, a large number of clients could potentially gather and use that AP. If the cell size is reduced, the number of simultaneous clients can also be reduced.

The signal from an AP does not simply stop at the boundary of its cell. Instead, the signal continues to expand ad infinitum, growing exponentially weaker. Devices inside the cell boundary can communicate with the AP. Devices outside the boundary cannot because the signal strength of either the client or the AP is too weak for the pair to find any usable modulation that can be used to exchange information. You can control the size of a cell by changing the parameters that are described in the following sections.

Tuning Cell Size with Transmit Power

To use a wireless LAN, devices must be located within the range of an AP’s signal and have an active association with the AP. This area is known as the BSA or cell. Consider the scenario shown in Figure 7-1. PCs 1 through 4 are within the cell’s perimeter and are associated with the AP. PC-5, however, is outside the cell and cannot form an association or participate in the basic service set (BSS).

![Figure 7-1 An Example Cell That Includes All but One Client.](image-url)
If the area outside a cell is a legitimate location where wireless devices might be present, the coverage area should probably be extended there. How can that be accomplished? The most straightforward approach is to increase the transmit power or signal strength leaving the AP's antenna. A greater signal strength will overcome some of the free space path loss so that the usable signal reaches farther away from the AP.

Figure 7-2 shows the effect of changing the AP's transmit power level. The original cell from Figure 7-1 is shown as the second concentric circle, where the transmit power level was set to 17 dBm. If the level is increased to 20 dBm, the cell grows into the area shown by the outermost circle. Notice that PC-5 now falls within the cell boundary. If the transmit power level is decreased to 10 dBm, the cell shrinks and includes only clients PC-2 and PC-3. Why would you ever want to decrease a cell's size? That question will be answered later in this section.

How should you decide on a transmit power level value? Cisco APs offer eight different values for their 2.4-GHz radios and seven values for their 5-GHz radios. Most 802.11 scenarios fall within government regulations which limit the effective isotropic radiated power (EIRP) to a maximum transmit power level of 20 dBm (100 mW). You could just configure an AP to run wide open at maximum power, but that is not always appropriate or beneficial.

One thing to consider is the two-way nature of wireless communications. By increasing the AP's transmit power, the AP might reach a distant client, but can the client's own signal reach the AP? Notice client PC-5 in Figure 7-3. If the AP transmit power level is increased to 20 dBm (the outermost circle), PC-5 is included in the cell. However, PC-5's wireless transmitter has a lesser power level; in its current location, PC-5 has a coverage area that falls short of including the AP. This scenario is known as the asymmetric power problem, where the two communicating devices have differing transmit power levels that might not reach each other.
Tuning Cell Size with Data Rates

Setting the transmit power level is a simplistic approach to defining the cell size, but that is not the only variable involved. The cell size of an AP is actually a compromise between its transmit power and the data rates that it offers.

Recall from Chapters 1 and 3 that the higher data rates or more complex modulation and coding schemes (MCS) offer the greatest throughput but require the best signal conditions—usually closer to the AP. The less complex schemes can work further away from an AP, but offer slower data rates. Therefore, at the perimeter of a cell, a client is likely to be using the least complex MCS and the lowest data rate. Figure 7-4 shows a simplified representation of the range of each data rate with concentric circles. At the outer edge of the cell, a client will probably resort to a 1-Mbps data rate.

To design a wireless LAN for best performance, you would most likely need to disable some of the lower data rates. For example, you could disable the 1-, 2-, and 5.5-Mbps rates to force clients to use higher rates and better modulation and coding schemes. That would improve throughput for individual clients and would also benefit the BSS as a whole by eliminating the slower rates that use more time on a channel.

As you disable lower data rates, the respective concentric circles in Figure 7-4 become irrelevant. This effectively reduces the usable size of the AP’s cell, even though the radio frequency (RF) footprint remains the same. After all, you haven’t reduced the transmit power level which would reduce the extent of the RF energy. Be aware that as smaller usable cells are placed closer together, their available data rates are higher. At the same time, their RF footprints can remain large and overlap each other, resulting in a higher noise floor.
To provide robust wireless coverage to an ever-increasing area, you should use the following two-pronged approach:

- Tune the cell size based on data rates and performance.
- Add additional APs to build an ESS that covers more area.

Adding APs requires careful consideration for client mobility and the use of wireless channels. These topics are covered in the next section.

**Adding APs to an ESS**

If a client is associated with an AP, it can maintain the association as long as it stays within range of the AP. Consider the cell shown in Figure 7-5. As long as the client stays within points A and B, three conditions are met:

- The client is able to receive the AP's signal at an acceptable level.
- The AP is able to receive the client's signal.
- One of the acceptable modulations can be successfully used between the client and the AP.
As soon as the client goes outside the cell range at point C, one or more of the conditions fails and the client loses the association. In the figure, the AP’s signal has fallen below an acceptable threshold.

Other APs can be added so that the client can move within a larger area; however, the APs must be carefully deployed to allow the client to roam from AP to AP. Roaming is the process of moving an association from one AP to the next, so that the wireless connection is maintained as the client moves.

In Figure 7-6, a new AP has been added alongside AP-1, each using the same channel. It might seem intuitive to build a larger coverage area by using a single channel. Usually this turns out to be a bad idea because the client may experience an excessive amount of frame collisions in the area between the two cells.

Remember that the signal from an AP does not actually stop at the edge of the cell; rather, it continues to propagate as it eventually dies off. This is shown by the signal strength graph of each AP. The client is able to form an association with AP-1 at point A. Even at that location, some portion of AP-2’s signal can be received, albeit at a lower level. Because AP-2 is using the same channel as AP-1, the two APs (and any clients within range) can essentially interfere with each other through co-channel interference.
Ideally, when the client in Figure 7-6 moves to location B, it should begin to anticipate the need to roam or transfer its association from AP-1 to AP-2. Notice that AP-1 and AP-2 are spaced appropriately for roaming, where their cells have some overlap. The two APs are out of range of each other, so they are not aware of each other’s transmissions on the same channel. Each AP will coordinate the use of the channel with devices that are inside its own cell, but not with the other AP and devices in the other cell. As a result, the client around location B will probably experience so many collisions that it may never be able to roam cleanly.

**The Roaming Process**

What enables a client to roam in the first place? First, adjacent APs should be configured to use different non-overlapping channels. For example, an AP using channel 1 must not be adjacent to other APs also using channel 1. Instead, a neighboring AP should use channel 6 or higher to avoid any frequency overlap with channel 1. This ensures that clients will be able to receive signals from a nearby AP without interference from other APs. As you learned in Chapter 2, “RF Standards,” the 5-GHz band is much more flexible in this regard because it has many more non-overlapping channels available.
The roaming process is driven entirely by the wireless client driver—not by the AP. Wireless clients decide that it is time to roam based on a variety of conditions. The 802.11 standard does not address this at all, so roaming algorithms are vendor specific. In addition, the roaming algorithms are usually “secret recipes,” so the exact thresholds and conditions are hidden from view.

Some of the ingredients in the roaming algorithm are the received signal strength indicator (RSSI), signal-to-noise ratio (SNR), a count of missed AP beacons, errors due to collisions or interference, and so on. These are usually logical choices because they indicate an inferior connection.

Because different clients use different thresholds, some will try to roam earlier than others at a given location within a cell. Some clients will tend to “latch on” to an existing association until the AP can hardly be heard, whereas others will attempt to roam whenever a better AP is discovered.

Figure 7-7 depicts a clean roam between two APs that have been correctly configured with non-overlapping channels 1 and 6. The two AP signal strengths are also shown as a graph corresponding to the client’s location. At location A, the client has a clear signal from AP-1, so it maintains an association with that AP.

**Figure 7-7**  A Client Roaming Correctly Between Two APs.
As the client moves toward location B, it decides that AP-1’s signal is no longer optimal. Somewhere along the way, the client begins to gather more information about any neighboring AP cells. The client can passively scan by tuning its radio to another channel and listening for beacons transmitted from other APs. During the time that the radio is tuned away from the associated channel, the client might lose packets that have been sent to it. A client might use active scanning instead, where it sends probe requests to seek out a better AP where it can move its association. The client does not know what channel is used on the next AP it encounters, so it must send the probes over every possible channel. Again, the client must take time to tune its radio away from the current AP’s channel so it can scan other channels and send probes.

You might think of this as someone watching television. As the current program gets boring or nears its end, the viewer begins to “channel surf” and scans other channels for a better program. One thing to keep in mind: While the viewer is scanning channels, he cannot keep watching the original program. Some of that program will be missed. This is also true of wireless clients. While a radio is scanning other channels, packets arriving on the original channel will be dropped because they cannot be received. Therefore, there is a trade-off between staying available on a single channel and attempting to roam to other APs.

After the client is satisfied with all of the beacons or probe responses it receives, it evaluates them to see which AP offers the most potential for a new association. Returning to Figure 7-7, when the client nears location B, it receives a probe response from AP-2 on channel 6. At location C, the client sends a reassociation frame to AP-2 and moves its association to that BSS.

How much should cells overlap each other to promote good roaming? Cisco recommends 15 percent to 20 percent overlap for most applications. The idea is to give a client device some continued coverage even after the RSSI of its associated AP falls below a threshold and a roam might be triggered. The client can probe and reassociate with the next AP before it completely loses contact with the previous AP. Seamless roaming is especially important for time critical applications like voice traffic.

**WLAN Channel Layout**

The previous section laid the foundation for roaming by describing movement between two AP cells. Most scenarios require more than two APs to cover the appropriate area within a building. Therefore, you need to consider the layout and configuration of more and more APs to scale the design to fit your wireless environment.

For example, to cover the entire area of a warehouse or one floor of a building, APs must be placed at regular intervals throughout that space. A site survey is a vital step toward deciding on AP placement, as actual live measurements are taken with an AP staged at various points in the actual space. This method also takes any factors like free space loss and absorption into account, as the signal strength is measured within the actual environment where clients are located.

To minimize channel overlap and interference, APs should be designed so that adjacent APs use different channels. For simplicity and a convenient design constraint, the
examples in this section use the three non-overlapping 2.4-GHz channels. The cells could be laid out in a regular, alternating pattern, as shown in Figure 7-8.

![Diagram of channel reuse](image)

**Figure 7-8**  Holes in an Alternating Channel Pattern.

However, notice what is happening in the center where the cells meet; there is a small hole in RF coverage. If a client roams through that hole, his wireless signal could drop completely. In addition, if the cells were brought closer together to close this hole, the two cells using channel 1 would overlap and begin interfering with each other.

Instead, you should lay the cells out in a “honeycomb” fashion, as shown in Figure 7-9. This pattern is seamless, leaving no holes in coverage. In addition, notice how the two cells using channel 1 are well separated, providing isolation from interference. As far as ordering channels in the pattern, there are several different variations using combinations of the three channels, but the result is basically the same.

Notice that as the client shown in the channel 1 cell moves around, it will roam into adjacent cells on different channels. For roaming to work properly, a client must be able to move from one channel into a completely different channel.

Alternating channels to avoid overlap is commonly called *channel reuse*. The basic pattern shown in Figure 7-9 can be repeated to expand over a larger area, as shown in Figure 7-10. Naturally, this ideal layout uses perfect circles that are positioned regularly across the building. In practice, cells can take on different shapes and the AP locations may end up being irregularly spaced.
So far, only the channel layout of a two-dimensional area has been discussed. For example, Figure 7-10 might represent only one floor of a building. What happens when you need to design a wireless LAN for multiple floors in the same building?

Recall that an RF signal propagating from an antenna actually takes on a three-dimensional shape. With an omnidirectional antenna, the pattern is somewhat like a donut shape with the antenna at the center. The signal extends outward, giving the cell a circular shape along the floor. The signal also extends upward and downward to a lesser extent—affecting AP cells on adjacent floors as well.

Consider the building with three floors shown in Figure 7-11. The same two-dimensional channel layout from Figure 7-10 is being used on the first floor. The floors in the figure are shown greatly separated, so that you can see the channel patterns and numbers. In reality, the cells on adjacent floors would touch or overlap, just as adjacent cells on the same floor do.
Figure 7-10  Channel Reuse Over a Large Area.

Figure 7-11  Channel Layout in Three Dimensions.
The pattern of alternating channels exists within the plane of a floor and between floors. Channel 1 on the first floor should not overlap with channel 1 directly above it on the second floor or below it in the basement.

When you consider each of the tasks involved in designing and maintaining a wireless LAN, it can really become a puzzle to solve. The cell size, transmit power, and channel assignment all have to be coordinated for each and every AP. Roaming also becomes an issue on a large scale, if mobile clients can move throughout an entire campus wireless network.

The good news is that Chapter 13, “Understanding RRM,” explains how to solve many of these puzzles automatically.

### Exam Preparation Tasks

As mentioned in the section, “How to Use This Book,” in the Introduction, you have a couple of choices for exam preparation: the exercises here, Chapter 22, “Final Review,” and the exam simulation questions on the CD-ROM.

### Review All Key Topics

Review the most important topics in this chapter, noted with the Key Topic icon in the outer margin of the page. Table 7-2 lists a reference of these key topics and the page numbers on which each is found.

<table>
<thead>
<tr>
<th>Key Topic Element</th>
<th>Description</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 7-2</td>
<td>The effects of transmit power on cell size</td>
<td>151</td>
</tr>
<tr>
<td>Figure 7-4</td>
<td>The effects of data rate on cell size</td>
<td>153</td>
</tr>
<tr>
<td>Figure 7-7</td>
<td>Roaming between BSSs</td>
<td>156</td>
</tr>
<tr>
<td>Figure 7-9</td>
<td>Optimizing channel layout for roaming</td>
<td>159</td>
</tr>
</tbody>
</table>

### Define Key Terms

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

asymmetric power problem, channel reuse
This page intentionally left blank
Symbols & Numerics
λ (lambda), 14
1-Mbps data rate, 28-29
2.4 GHz ISM band, 47-49
2-Mbps data rate (DSSS), 29
5.5-Mbps data rate (DSSS), 30
5-GHz frequency bands, 12
5-GHz U-NII bands, 49-51
11-Mbps data rate (DSSS), 30
802.11-1997 standard, 52
802.11a standard, 54-55
802.11ac amendment, 62
802.11b standard, 52-53
802.11g standard, 52-54
802.11n standard, 55-56
channel aggregation, 57-58
Cisco controller support, configuring, 264
MAC layer efficiency, 59-60
MRC, 61
spatial multiplexing, 58-59
TxBF, 60-61
802.11x standard, 292-293

accessing
AP management interface, 432-433
wireless media, 130-134
WLC management interface, 430-432
accessories, adding to antennas, 101-102
ACK frames, 136
active scans, 137
adding
APs to ESS, 153-161
roaming process, 155-157
controllers to WCS configuration, 368-369
addressing, 802.11 frames, 128-130
advanced settings, configuring on WLANs, 318-319
AES (Advanced Encryption Standard), 296
Alarm Summary dashboard (WCS), 364-365
alternating channel pattern, 159-160
amendments (IEEE), 47
802.11ac, 62
amplifiers, 101
amplitude, 15
Android wireless clients, configuring, 345
answers to self-assessment quizzes
chapter 1, 456-458
chapter 2, 458

A

absolute power measurement, 16
absorption, 78
chapter 3, 459
chapter 4, 459-460
chapter 5, 460-461
chapter 6, 461
chapter 7, 461-462
chapter 8, 462-463
chapter 9, 463-464
chapter 10, 464
chapter 11, 464-465
chapter 12, 465-466
chapter 13, 466
chapter 14, 467
chapter 15, 467-468
chapter 16, 468
chapter 17, 468-469
chapter 18, 469
chapter 19, 469-470
chapter 20, 470
chapter 21, 471

antennas, 20-21
adding accessories, 101-102
amplifiers, 101
attenuators, 102
beamwidth, 92
dipole, 22
directional antennas, 96-100
dish antennas, 99-100
patch antennas, 96-98
Yagi-Uda antennas, 98-99
EIRP, measuring, 21-22
gain, 91
lightning arrestors, 102
omnidirectional antennas, 94-96
dipole antennas, 94
integrated omnidirectional antennas, 96
monopole antennas, 94
polarization, 92-93
radiation patterns, 88-91
AP SSO redundancy, 233-235
Apple OS X wireless clients, configuring, 345
APs (access points), 110-111
adding to an ESS, 153-161
roaming process, 155-157
authentication, 287
autonomous APs
centralized architecture, 186-187
configuring, 167-173
converting to lightweight mode, 174-177
distributed architecture, 184-186
management functions, 187
real-time processes, 187
roaming, 242-244
BSS, join process, 137-140
CAPWAP, 188-190
cell size, tuning, 150-153
  with data rates, 152-153
  with transmit power, 150-151
connectivity, troubleshooting, 420-424
  AP-to-network connectivity, verifying, 422-423
  AP-to-WLC connectivity, verifying, 420-421
data rates, 136
IP address, identifying, 168-170
LAPs, 187
  image downloads, 225-226
  split-MAC architecture, 188-190
  state machine, 224
  WLC, discovering, 226-227
  WLC, selecting, 227-228
management interface, accessing, 432-433
manipulating on maps, 373-374
multiple SSID support, 113-114
placement of, 157-161
ports, 167-168
repeater mode, 116
roaming process, intercontroller roaming, 246-255
rogue APs, 290, 386
RRM
  CHDM, 274-275
  DCA, 272
  ED-RRM, 272
  manual RF configuration, 276-278
  RF groups, 267-269
  TPC, 269-271
AQI (air quality index), displaying, 394-395
association request frames, 135
associations, 111, 405-406
attenuators, 102
authentication, 286-287
  802.1x, 292-293
  EAP, 292-293
  EAP-FAST, 294
  EAP-TLS, 295
enterprise mode authentication (WPA/WPA2), configuring, 300-302
LEAP, 294
local EAP, configuring, 302-305
open authentication, 290-291
PEAP, 294-295
personal mode authentication (WPA), 297
personal mode authentication (WPA), configuring, 299-300
supported schemes in CCX versions, 355-354
WEP, 291-292
autonomous APs, 166-167
  centralized architecture, 186-187
  configuring, 167-173, 170-173
  converting to lightweight mode, 174-177
  Autonomous to Lightweight Mode Upgrade tool, 174-176
  manual conversion, 176-177
distributed architecture, 184-186
management functions, 187
real-time processes, 187
roaming, 242-244
Autonomous to Lightweight Mode Upgrade tool, 174-176
azimuth plane, 90
bands of frequency, 11
channels, 12-13
licensed bands, 42
2.4 GHz ISM band, 47-49
U-NII, 42
unlicensed bands, 42
bandwidth, 12
base-10 logarithm function, 17
beacons, 134
beamwidth, 92
benefits of Cisco WCS, 362
bidirectional communication, 109
Block ACK frames, 136
Bluetooth as source of interference, 386-387
BPSK (binary phase shift keying), 32
BSA (basic service area), 111
BSS (basic service set), 110-111
DS, 112-114
multiple SSID support on APs, 113-114
join process, 137-140
leaving, 139-140
moving between, 140-142
BSSID (basic service set identifier), 111
building blocks of CUWN, 192-194
Cisco LAPs, 194-196
Cisco WLC, 192-194
BVI (bridged-virtual interface),
displaying P address, 169-170

calculating free space path loss, 73-74
Canopy as source of interference, 389

CAPWAP (Control and Provisioning of Wireless Access Points), 188-190
RFC 5415, 224
carrier sense, 131
carrier signals, 24
CCA (clear channel assessment), 131
CCK (Complementary Code Keying), 27, 30
CCKM (Cisco Centralized Key Management), 246
CCMP (Counter/CBC-MAC Protocol), 296
CCX (Cisco Compatible Extensions), 352-354
feature support, 352-353
goals of, 352
supported authentication schemes, 355-354
CCX Lite, 354
cells
layout, 157-161
size of, tuning
with data rates, 152-153
with transmit power, 150-151
centralized architecture, 186-187
channel aggregation, 57-58
channel separation, 12
channels, 12-13
in 2.4 GHz ISM band, 47-49
alternating pattern, 159-160
AP placement, 157-161
DCA, 272
non-overlapping, 49
subchannels, 31
CHDM (coverage hole detection mechanism), 269, 274-275
Cisco Aironet Antennas and Accessories Reference Guide, 93
Cisco AnyConnect Secure Mobility Client, configuring, 348-350
Cisco Certification Exam Tutorial, 446-452
Cisco CleanAir, 392-396. See also AQI, 394-395
                        ED-RRM, 396
                        enabling, 392
Cisco LAPs (lightweight access points), 194-196
Cisco WLC (Wireless LAN Controller), 192-194
CLI
                        initial WLC configuration, 216-217
                        LAP management interface, accessing, 432-433
                        WLC management interface, accessing, 430-432
client MFP, 298
co-channel interference, 70-71
code images
                        displaying, 434
                        downloading, 434-436
coding, 27
collisions, 131, 132-134
                        DCF, 134
                        interframe space periods, 132-133
commands, show run-config, 439
comparing
                        802.3 and 802.11 frames, 126-128
                        power levels, 17-19
                        wired and wireless networks, 7
configuration files
                        displaying, 439
                        saving, 437-438
                        uploading to PC, 438
configuring
                        autonomous APs, 167-173, 170-173
                        IP address, identifying, 168-170
controllers
                        802.11n support, 264
                        data rates, 263-264
                        with WCS, 368-370
wireless clients
                        Android, 345
                        Apple OS X, 345
                        Cisco AnyConnect Secure Mobility Client, 348-350
                        Intel PROSet, 341-344
                        Windows 7/8, 338-340
WLANs, 310-312, 315-319
                        advanced settings, 318-319
                        dynamic interface, 312
                        QoS, 317
                        RADIUS server, 310
                        security, 315-317
WLC
                        with CLI, 216-217
                        with web browser, 208-216
WPA/WPA2
                        enterprise mode authentication, 300-302
                        personal mode authentication, 299-300
connecting WLC to switched network
                        using controller interfaces, 205-208
                        using controller ports, 204-206
connectivity
                        AP connectivity, 420-424
                        AP-to-network connectivity, verifying, 422-423
                        AP-to-WLC connectivity, verifying, 420-421
wireless clients, troubleshooting, 405-419
associations, 405-406
from controller, 41-410
link tests, performing, 411
from WCS/NCS, 44-45
conserving power on wireless devices, 142-144
control plane, 185
controllers
802.11n support, configuring, 264
adding to WCS configuration, 368-369
AQL, displaying, 394-395
code images
displaying, 434
downloading, 434-436
configuration files
displaying, 439
saving, 437-438
uploading to PC, 438
configuring
with CLI, 216-217
with WCS, 368-370
with web browser, 208-216
connecting WLC to switched network
using controller interfaces, 205-208
using controller ports, 204-206
data rates, configuring, 263-264
discovering, 228-229
failure, detecting, 230
high availability
AP SSO redundancy, 233-235
N+1 redundancy, 231
N+N redundancy, 232
N+N+1 redundancy, 232-233
redundancy, 231
hot standby controller, 234
intercontroller roaming, 246-255
Layer 2 roaming, 247
mobility groups, 252-255
intracontroller roaming, 244-246
rebooting, 436-437
trap logs, 439-443
sending to trap receivers, 440-443
viewing, 440
wireless client connectivity, troubleshooting, 41-410
WLC, discovering, 226-227
converting autonomous APs to lightweight mode, 174-177
Autonomous to Lightweight Mode
Upgrade tool, 174-176
manual conversion, 176-177
CORDLESS PHONES AS SOURCE OF INTERFERENCE, 388
creating
guest networks, 326-328
WCS reports, 377-380
WLANs, 313-315
CSMA (carrier sense multiple access), 131
CUWN (Cisco Unified Wireless Network), 180
building blocks, 192-194
Cisco LAPs, 194-196
Cisco WLC, 192-194
LAPs, 187
split-MAC architecture, 188-190
managing, 197
traffic patterns, 190-191
cycles, 10
data frames, 136
data plane, 185
data rates
802.11-1997 standard, 52
802.11a standard, 54
802.11b standard, 52-53
802.11g standard, 53
for APs, 136
for controllers, configuring, 263-264
effect on AP cell size, 152-153
dB (decibel), 17-19
dBm (decibel-milliwatt), 22
DBPSK (differential binary phase shift keying), 28-29
DCA (dynamic channel allocation), 269, 272
DCF (distributed coordination function), 130, 134
designing
AP cells, 157-161
high availability, 228-235
  AP SSO redundancy, 233-235
  controller failure, detecting, 230
  N+N redundancy, 232
  N+N+1 redundancy, 232-233
  redundancy, 231
detecting
controller failure, 230
  sources of interference, 390-391
diffraction, 80
DIFS (distributed interframe space), 132
dipole antennas, 22, 94
directional antennas, 96-100
dish antennas, 99-100
  patch antennas, 96-98
  Yagi-Uda antennas, 98-99
disabled data rates, 136
discovering
  controllers, 228-229
  WLC, 226-227
dish antennas, 99-100
displaying
  alarm details (WCS), 364-365
  AQI, 394-395
  configuration files, 439
  maps (WCS), 370-372
  RRM results in NCS maps, 278
dissociation frames, 135
distributed architecture, 184-186
DMZ (demilitarized zone), 325
"Do I Know This Already?" quizzes.
  See self-assessment quizzes
downloading controller code images, 434-436
DQPSK (differential quadrature phase shift keying), 29
DRS (dynamic rate shifting), 75
DS (distribution system), 112-114
  multiple SSID support, 113-114
DSSS (direct-sequence spread spectrum), 26, 27-28
  11-Mbps data rate, 30
  1-Mbps data rate, 28-29
  2-Mbps data rate, 29
  5.5-Mbps data rate, 30
DTIM (delivery traffic indication message), 143
duration field, 802.11 frames, 131
dynamic interface, configuring for WLANs, 312
### E

EAP (Extensible Authentication Protocol), 292-293

EAP-FAST (EAP Flexible Authentication by Secure Tunneling), 294

EAP-TLS (EAP Transport Layer Security), 295

ED-RRM (Event-Driven RRM), 272

using with Cisco CleanAir, 396

EIFS (extended interframe space), 132

EIRP (effective isotropic radiated power)

FCC requirements, 43-44

measuring, 21-22

electromagnetic waves in wireless networks, 9

elevation plane, 90

enabling Cisco CleanAir, 392

encoding, Barker 11 code, 28

encryption, AES, 296

enterprise mode authentication (WPA/WPA2), configuring, 300-302

ERP (Extended Rate PHY), 53

ESS (extended service set), 114-115

APs, adding, 153-161

ETSI (European Telecommunication Standards Institute), 44-45

Express Setup configuration, autonomous APs, 170-173

### F

FCC (Federal Communications Commission), 42-44

EIRP, 43-44

transmitter requirements, 44

U-NII, 5-GHz bands, 49-51

feature support for CCX program, 352-353

FHSS (frequency-hopping spread spectrum), 26-27

finalizing WLAN configuration, 319

frames (802.11), 126-130

addressing, 128-130

collision avoidance, 132-134

comparing with 802.3 frames, 126-128

data frames, 136

duration field, 131

management frames, 134-135

  securing with MFP, 298

NAV timer, 131-132

free space path loss, 72-76

calculating, 73-74

mitigating, 74-76

frequency, 10-13

  5-GHz frequency bands, 12

amplitude, 15

bands, 11

bands of frequency

  channels, 12-13

  U-NII, 42

cycles, 10

Hz, 10

microwave frequency, 11

phase, 14

RF, 11-13

  absolute power measurement, 16

  signal strength, 15-17

signal bandwidth, 12

watts, 15

wavelength, measuring, 14-15

Fresnel zones, 80-82
G

gain, 20-21, 91
generating WCS reports, 377-380
goals of CCX program, 352
GTC (Generic Token Card), 295
guest networks, 325
  configuring, 326-328
  scaling, 329-331

H

H plane, 90
half-duplex transmission, 110
heatmaps (WCS), 370-372
high availability, 228-235
  AP SSO redundancy, 233-235
  controller failure, detecting, 230
  N+1 redundancy, 231
  N+N redundancy, 232
  N+N+1 redundancy, 232-233
  redundancy, 231
history of CUWN management products, 197
home area (WCS), 366-367
home page (WCS), 363
  Alarm Summary dashboard, 364-365
  home area, 366-367
  main navigation area, 366
hot standby controller, 234
Hz (hertz), 10

I

IBSS (independent basic service set), 115-116
identifying
  IP address of APs, 168-170
  sources of interference, 390-391
IEEE (Institute of Electric and Electronic Engineers), 45-47
  amendments, 47
  study groups, 47
  task groups, 47
  working groups, 46
IEEE 802.11 standard, 47-62
  2.4 GHz ISM band, 47-49
  5-GHz U-NII bands, 49-51
  802.11-1997 standard, 52
  802.11a standard, 54-55
  802.11ac amendment, 62
  802.11b standard, 52-53
  802.11g standard, 52-54
  802.11n standard, 55-56
    channel aggregation, 57-58
    MAC layer efficiency, 59-60
    modulation, 61
    MRC, 61
    spatial multiplexing, 58-59
    TxBF, 60-61
CSMA, 131
frames, 126-130
  addressing, 128-130
  collision avoidance, 132-134
  comparing with 802.3 frames, 126-128
  data frames, 136
  duration field, 131
  management frames, 134-135
  NAV timer, 131-132
interframe space periods, 132-133
IEEE 802.3 standard, 7
image downloads for LAP, 225-226
infrastructure MFP, 298
initial WLC configuration
  using CLI, 216-217
  using web browser, 208-216
integrated omnidirectional antennas, 96
integrity
  MIC, 288-289
  TKIP, 295-296
Intel PROSet wireless client, configuring, 341-344
intercontroller roaming, 246-255
  Layer 2 roaming, 247
  Layer 3 roaming, 248-252
  mobility groups, 252-255
interfaces, connecting WLC to switched network, 205-208
interference, 386-389
  co-channel interference, 70-71
  neighboring channel interference, 71-72
  non-802.11 interference, 72
  rogue APs, 386
  sources of, 389
    Bluetooth, 386-387
cordless phones, 388
detecting, 390-391
microwave ovens, 388
WiMAX, 388-389
ZigBee, 387
interframe space periods, 132-133
interleaving, 27
intracontroller roaming, 244-246
intrusion protection, 289-290
IP address of APs, identifying, 168-170
ISM (industrial, scientific, and medical applications), 2.4 GHz band, 47-49
isotropic antennas
  EIRP, measuring, 21-22
  radiation patterns, 88-91
ITU-R (International Telecommunication Union Radiocommunication Sector), 41-42
IV (Initialization Vector), 296

J-K
jammers as source of interference, 389
join process (BSS), 137-140
keepalives, detecting controller failure, 230
key exchanges during roams, 246

L
LAPs (lightweight access points), 187
  Cisco LAPs, 194-196
  image downloads, 225-226
  management interface, accessing, 432-433
  split-MAC architecture, 188-190
  state machine, 224
  WLC
    discovering, 226-227
    selecting, 227-228
Layer 2 roaming, 247
Layer 3 roaming, 248-252
leader configuration (RF groups), 268
LEAP (Lightweight EAP), 294
leaving a BSS, 139-140
licensed bands, 42
  2.4 GHz ISM band, 47-49
licensing, WCS, 363
lightning arrestors, 102
lightweight mode
conversion from autonomous APs, 174-177

lightweight mode, conversion from autonomous APs
Autonomous to Lightweight Mode Upgrade tool, 174-176
manual conversion, 176-177

limitations
of 802.11g, 54
of wired networks, 7
line-of-sight transmission, Fresnel zones, 80-82
link budget, 22
link tests, performing, 411
local EAP, configuring, 302-305
locating sources of interference, 390-391
log files, 439
logarithms, 16
login screen, WCS, 363
loss in signal strength, measuring, 19-20

M
MAC layer efficiency, 59-60
magnetic waves in wireless networks, 8
main navigation area (WCS), 366
management frames (802.11), 134-135
securing with MFP, 298
management functions of autonomous APs, 187
management interface
for APs, accessing, 432-433
for WLC, accessing, 430-432
managing CUWN, 197
mandatory data rates, 136
manipulating APs on maps, 373-374
manual RF configuration (RRM), 276-278
maps (WCS), 370
APs, manipulating, 373-374
displaying, 370-372
viewing information, 375-376
MCS (modulation and coding scheme), 136
measuring
EIRP, 21-22
loss in signal strength, 19-20
power
absolute power measurement, 16-17
dB, 17-19
QAM, 32
wavelength, 14-15
media, accessing wireless media, 130-134
mesh networks, 119
message privacy, 287-288
MFP (Management Frame Protection), 298
MIC (message integrity check), 288-289
microwave frequency, 11
microwave ovens as source of interference, 388
MIMO (multiple-input, multiple-output) systems, 56
mitigating free space path loss, 74-76
mobility anchors, creating for guest networks, 330-331
mobility groups, 252-255
modulation, 25-26,
802.11n standard, 61
DBPSK, 28-29
DQPSK, 29
monopole antennas, 94
moving between a BSS (clients), 140-142
MRC (maximal-ratio combining), 61
MSCHAPv2 (Microsoft Challenge Authentication Protocol), 295
multi-floor buildings, cell layout, 159-161

N

N+1 redundancy, 231
N+N redundancy, 232
N+N+1 redundancy, 232-233
narrowband transmissions, 26
NAV (network allocation vector) timer, 131-132
NCS (Cisco Prime Network Control System), 197
displaying RRM results, 278
wireless client connectivity, troubleshooting, 44-45
neighboring channel interference, 71-72
net loss in signal strength, measuring, 19-20
noise, 386
non-802.11 interference, 72
non-overlapping channels, 49
DCA, 272

O

OFDM (orthogonal frequency-division multiplexing), 26, 31-32
omnidirectional antennas, 94-96
dipole antennas, 94
integrated omnidirectional antennas, 96
monopole antennas, 94
open authentication, 290-291
outdoor bridges, 118
overlapping channels, DCA, 272

P

PAC (protected access credential), 294
parabolic dish antennas, 99-100
passive scans, 137
patch antennas, 96-98
PEAP (Protected EAP), 294-295
performing link tests, 411
personal mode authentication (WPA), 297
configuring, 299-300
phase, 14
physical carrier sense, 131
ping tests, performing, 411
PKC (proactive key caching), 246
polarization, 92-93
ports
on APs, 167-168
connecting WLC to switched network, 204-206
power
absolute power measurement, 16
dB, 17-19
link budget, 22
at receiving end, 23-24
TPC, 269-271
power conservation on wireless clients, 142-144
preparing for exam, 453-454
Cisco Certification Exam Tutorial, 446-452
time management, 452-453
privacy
CCMP, 296
message privacy, 287-288
WEP, 291-292
probes, 135
Project 802, 46
protected mode transmission (802.11g), 53-54
protecting message privacy, 287-288
PS-Poll frames, 136

Q
QAM (quadrature amplitude modulation), 32
QoS (Quality of Service), configuring on WLANs, 317
QPSK (quadrature phase shift keying), 32

R
radiation patterns, 88-91
radio chains, 56
RADIUS server, configuring for WLANs, 310
RC4 cipher algorithm, 291
real-time processes of autonomous APs, 187
reassociation frames, 135
rebooting controllers, 436-437
receivers
loss of signal strength, measuring, 19-20
power levels, 23-24
redundancy
AP SSO redundancy, 233-235
N+1 redundancy, 231
N+N redundancy, 232
N+N+1 redundancy, 232-233
reflection, 76-77
refraction, 79
regions in ITU-R, 41
regulatory bodies, 41-45
ETSI, 44-45
FCC, 42-44
EIRP, 43-44
transmitter requirements, 44
ITU-R, 41-42
repeater mode, 116
reports (WCS), generating, 377-380
RF (radio frequency), 11-13
absolute power measurement, 16
absorption, 78
amplitude, 15
antennas, 20-21
EIRP, measuring, 21-22
bands of frequency, 2.4 GHz ISM band, 47-49
carrier signals, 24
channel aggregation, 57-58
diffraction, 80
free space path loss, 72-76
calculating, 73-74
mitigating, 74-76
Fresnel zones, 80-82
interference, 386-389
Bluetooth as source of, 386-387
cordless phones as source of, 388
microwave ovens as source of, 388
rogue APs, 386
WiMAX as source of, 388-389
ZigBee as source of, 387
MAC layer efficiency, 59-60
modulation, 25-26
  DBPSK, 28-29
  DQPSK, 29
narrowband transmissions, 26
non-overlapping channels, 49
phase, 14
receiver power levels, 23-24
reflection, 76-77
refraction, 79
scattering, 78-79
signal strength, 15-17
spatial multiplexing, 58-59
spread spectrum
  DSSS, 27-28
  FHSS, 26-27
  watts, 15
RF groups, 267-269
RFC 5415, 224
RIFS (reduced interframe space), 132
roaming process, 155-157
  with autonomous APs, 242-244
  intercontroller roaming, 246-255
    Layer 2 roaming, 247
    Layer 3 roaming, 248-252
  mobility groups, 252-255
intracontroller roaming, 244-246
key exchanges, 246
rogue APs, 290, 386
rogue clients, 290
rope analogy of wireless networks, 8
RP-TNC (reverse-polarity threaded Neill-Concelman) connectors, 43
RRM (Radio Resource Management), 265-278
  CHDM, 274-275
  DCA, 272
  ED-RRM, 272
  manual RF configuration, 276-278
  results, displaying in NCS maps, 278
  RF groups, 267-269
  TPC, 269-271
RSSI (received signal strength indicator) scale, 23-24
RTS/CTS frames, 136

S

saving controller configuration files, 437-438
scanning for APs, 137
scattering, 78-79
scrambling, 27
security
  authentication, 286-287
    802.1x, 292-293
    EAP, 292-293
    EAP-FAST, 294
    EAP-TLS, 295
    LEAP, 294
  open authentication, 290-291
  PEAP, 294-295
  personal mode authentication (WPA), 297
  supported schemes in CCX versions, 354-355
    WEP, 291-292
CCMP, 296
integrity
  MIC, 288-289
  TKIP, 295-296
intrusion protection, 289-290
message privacy, 287-288
MFP, 298
MIC, 288-289
shared-key security, 292
WLAN, configuring, 315-317
WPA, 297
  enterprise mode authentication, configuring, 300-302
  personal mode authentication, configuring, 299-300
WPA2, 297
  enterprise mode authentication, configuring, 300-302
  personal mode authentication, configuring, 299-300
selecting WLC, 227-228
self-assessment quizzes
  answers
    chapter 1, 456-458
    chapter 2, 458
    chapter 3, 459
    chapter 4, 459-460
    chapter 5, 460-461
    chapter 6, 461
    chapter 7, 461-462
    chapter 8, 462-463
    chapter 9, 463-464
    chapter 10, 464
    chapter 11, 464-465
    chapter 12, 465-466
    chapter 13, 466
    chapter 14, 467
    chapter 15, 467-468
    chapter 16, 468
    chapter 17, 468-469
    chapter 18, 469
    chapter 19, 469-470
    chapter 20, 470
    chapter 21, 471
chapter 1, 2-6
chapter 2, 36-40
chapter 3, 66-69
chapter 4, 84-87
chapter 5, 104-107
chapter 6, 122-125
chapter 7, 146-149
chapter 8, 162-165
chapter 9, 180-183
chapter 10, 200-203
chapter 11, 220-223
chapter 12, 238-242
chapter 13, 258-261
chapter 14, 282-284
chapter 15, 306-308
chapter 16, 322-324
chapter 17, 334-337
chapter 18, 358-361
chapter 19, 382-385
chapter 20, 400-404
chapter 21, 426-429
sending messages to trap receivers, 440-443
shared-key security, 292
show run-config command, 439
SIFS (short interframe space), 132
signal bandwidth, 12
signal strength (RF), 15-17
  free space path loss, 72-76
    calculating, 73-74
    mitigating, 74-76
link budget, 22
loss in, measuring, 19-20
RSSI, 23-24
watts, 15
SISO (single-in, single-out) systems, 56
SNMP, sending messages to trap receivers, 440-443
SNR (signal-to-noise ratio), 75
sources of interference, 389
  Bluetooth, 386-387
cordless phones, 388
microwave ovens, 388
WiMAX, 388-389
spatial multiplexing, 58-59
spectral mask, 13
split-MAC architecture, 188-190
spread spectrum, 26
  DSSS, 27-28
  11-Mbps data rate, 30
  1-Mbps data rate, 28-29
  2-Mbps data rate, 29
  5.5-Mbps data rate, 30
FHSS, 26-27
OFDM, 31-32
SSID (service set identifier), 111
  bridging to VLANs, 166-167
state machine, 224
STP (Spanning Tree Protocol), 186
study groups, 47
subchannels, 31
SuperAG as source of interference, 389
supplicants, 293
supported data rates (APs), 136
time management, preparing for exam, 452-453
timing schemes, 132-133
TKIP (Temporal Key Integrity Protocol), 295-296
TLS (Transport Layer Security), 294
EAP-TLS, 295
TNC (threaded Neill-Concelman) connectors, 43
topologies for wireless networks, 109-119
  BSS, 110-111
  DS, 112-114
  ESS, 114-115
  IBSS, 115-116
  mesh network, 119
  outdoor bridge, 118
  repeater mode, 116
  WGB, 117-118
TPC (transmit power control), 269-271
traffic patterns in CUWN, 190-191
translational bridging, 112
transmitters
  absolute power measurement, 16-17
  antennas, 20-21
    adding accessories, 101-102
    amplifiers, 101
    attenuators, 102
    beamwidth, 92
directional antennas, 96-100
  EIRP, measuring, 21-22
  gain, 91
  lightning arrestors, 102
  omnidirectional, 94-96
  polarization, 92-93
  radiation patterns, 88-91
ETSI requirements, 45

T

task groups, 47
telecommunications regulatory bodies, 41
three-dimensional channel layout, 159-161
TIM (traffic indication map), 143
FCC requirements, 44
interference
  co-channel interference, 70-71
  neighboring channel interference, 71-72
  non-802.11 interference, 72
loss in signal strength, measuring, 19-20
narrowband transmissions, 26
power level, effect on AP cell size, 150-151
trap logs, 439-443
  sending to trap receivers, 440-443
  viewing, 440
troubleshooting
  AP connectivity, 420-424
    AP-to-network connectivity,
    verifying, 422-423
    AP-to-WLC connectivity,
    verifying, 420-421
wireless client connectivity, 405-419
  associations, 405-406
  from controller, 41-410
  link tests, performing, 411
  from WCS/NCS, 44-45
tuning cell size of APs, 150-153
  with data rates, 152-153
  with transmit power, 150-151
two-dimensional channel layout, 157-160
TxBF (transmit beam forming), 60-61

U

U-APSD (unscheduled automatic power delivery), 144
unidirectional communication, 109
U-NII (Unlicensed National Information Infrastructure), 42
5-GHz bands, 49-51
unlicensed bands, 42
uploading configuration files to PC, 438
uWGB (universal workgroup bridge), 118

V

verifying
  AP-to-network connectivity, 422-423
  AP-to-WLC connectivity, 420-421
video cameras as source of interference, 389
viewing
  map information, 375-376
  trap logs, 440
virtual carrier sense, 131
VLANs, bridging to SSIDs, 166-167

W

W (watts), 15
wave propagation, 8-9
  cycles, 10
  frequency, 10-13
    benefits of, 362
wavelength, measuring, 14-15
WCS (Wireless Control System), 197.
  See also NCS (Cisco Prime Network Control System)
controllers
  adding, 368-369
  configuring, 368-370
home page, 363
  Alarm Summary dashboard, 364-365
  home area, 366-367
main navigation area, 366
licensing, 363
login screen, 363
maps, 370
APs, manipulating, 373-374
displaying, 370-372
viewing information, 375-376
reports, generating, 377-380
wireless client connectivity, troubleshooting, 44-45
web browser, initial WLC configuration, 208-216
websites
ETSI, 44
FCC, 42
IEEE, 45
ITU-R, 41
Wi-Fi Alliance, 63
WEP (Wired Equivalent Privacy), 135, 291-292
WGB (workgroup bridge), 117-118
Wi-Fi Alliance, WPA, 297
WiGig (Wireless Gigabit Alliance), 62
WiMAX as source of interference, 388-389
Windows 8, wireless client configuration, 338-340
wIPS (wireless intrusion protection system), 289-290
wired networks
comparing with wireless, 7
DS, 112-114
limitations of, 7
wireless clients
Android, configuring, 345
Apple OS X, configuring, 345
authentication, 286-287
open authentication, 290-291
WEP, 291-292
CCX, 352-354
feature support, 352-353
goals of, 352
CCX Lite, 354
Cisco AnyConnect Secure Mobility Client, configuring, 348-350
connectivity
associations, 405-406
troubleshooting, 405-419
conserving power, 142-144
debugging, 44-415
Intel PROSet, configuring, 341-344
joining a BSS, 139-140
leaving a BSS, 139-140
moving between a BSS, 140-142
rogue clients, 290
scanning for APs, 137
Windows 7/8, configuring, 338-340
wireless networks
APs, repeater mode, 116
collision avoidance, 132-134
comparing with wired, 7
distributed architecture, 184-186
electromagnetic waves, 9
frequency, 10-13
5-GHz frequency bands, 12
bands of frequency, 11
channels, 12-13
Hz, 10
phase, 14
RF, 11-13
signal bandwidth, 12
rope analogy, 8
topologies, 109-119
BSS, 110-111
ESS, 114-115
IBSS, 115-116
mesh network, 119
outdoor bridge, 118
WGB, 117-118
wave propagation, 8-9
cycles, 10
wireless LANs, 108
WLANs, 108
WMANs, 108
WPANs, 108
WWANs, 109
WiSM2 (Wireless Service Module 2), 192
WLANs (wireless local-area networks), 108, 309-310
advanced settings, configuring, 318-319
channel layout, 157-161
configuring, 310-312, 315-319
creating, 313-315
dynamic interface, configuring, 312
QoS, configuring, 317
RADIUS server, configuring, 310
security, configuring, 315-317
WLC (wireless LAN controller), 190
configuration files
displaying, 439
saving, 437-438
uploading to PC, 438
configuring
with CLI, 216-217
with web browser, 208-216
connecting to switched network, 204-217
using controller interfaces,

205-208
using controller ports, 204-206
as CUWN building block, 192-194
discovering, 226-227
management interface, accessing, 430-432
selecting, 227-228
trap logs, 439-443

WMANs (wireless metropolitan-area networks), 108
WMM (Wireless Multimedia), 144
working groups, 46
WPA (Wi-Fi Protected Access), 297
personal mode authentication, configuring, 299-300
WPA2 (Wi-Fi Protected Access version 2), 297
local EAP, configuring, 302-305
personal mode authentication, configuring, 299-300
WPANs (wireless personal-area networks), 108
WWANs (wireless wide-area networks), 109

X-Y-Z

Xbox as source of interference, 389
Yagi-Uda antennas, 98-99
zero gain antennas, 91
ZigBee as source of interference, 387