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CCNA Wireless 640-722

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DAVID HUCABY, CCIE® No. 4594

CCNA Wireless 640-722 Official Cert Guide

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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

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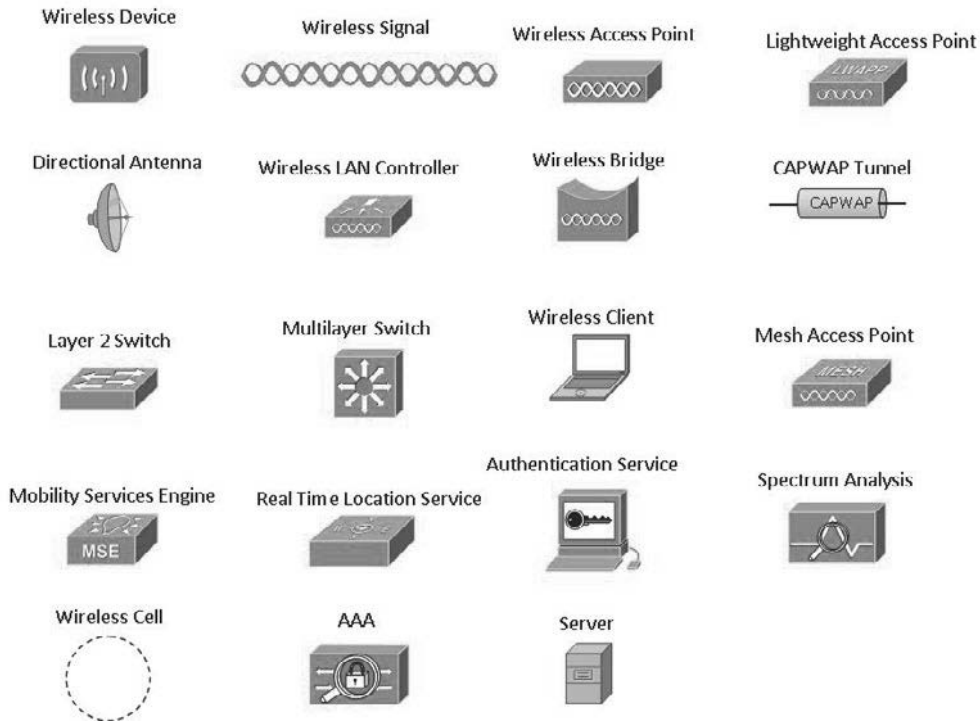

Command Syntax Conventions

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.

Note The cardboard CD case in the back of this book includes the CD and a piece of paper. The paper lists the activation code for the practice exam associated with this book. Do not lose the activation code. On the opposite side of the paper from the activation code is a unique, one-time-use coupon code for the purchase of the Premium Edition eBook and Practice Test.

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 I-1 *IUWNE Exam 640-722 Topics and Chapter References*

Exam Topic	Chapter Where Topic is Covered
Describe WLAN Fundamentals	
Describe basics of spread spectrum technology	Chapter 1
Describe the impact of various wireless technologies (Bluetooth, WiMAX, ZigBee, and cordless phone)	Chapter 19
Describe wireless regulatory bodies, standards and certifications (FCC, ETSI, 802.11a/b/g/n, and WiFi Alliance)	Chapter 2
Describe Wireless LAN (WLAN) RF principles (antenna types, RF gain/loss, Effective Isotropic Radiated Power (EIRP), refraction, reflection, and so on)	Chapters 3-4
Describe networking technologies used in wireless (SSID to WLAN_ ID to Interface to VLAN, 802.1q trunking)	Chapter 5
Describe wireless topologies, such as Independent Basic Service Set (IBSS), Basic Service Set (BSS), Extended Service Set (ESS), Point-to-Point, Point-to-Multipoint, Mesh, and bridging)	Chapter 5
Describe 802.11 authentication and encryption methods (Open, Shared, 802.1X, EAP, TKIP, and AES)	Chapter 14
Describe frame types (associated and unassociated, management, control, and data)	Chapter 6
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	Chapter 7
Install a Basic Cisco Wireless LAN	
Identify the components of the Cisco Unified Wireless Network architecture (Split MAC, LWAPP, stand-alone AP vs controller-based AP, specific hardware examples)	Chapter 9
Install and configure autonomous access points in the small business environment	Chapter 8
Describe the modes of controller-based AP deployment (local, monitor, HREAP, sniffer, rogue detector, bridge, OEAP, and SE-Connect)	Chapter 9
Describe controller-based AP discovery and association (DHCP, DNS, Master-Controller, Primary-Secondary-Tertiary, and n+1 redundancy)	Chapter 11
Describe roaming (Layer 2 and Layer 3, intra-controller and inter-controller, and mobility list)	Chapter 12

Exam Topic	Chapter Where Topic is Covered
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	Chapter 10, 15
Describe Radio Resource Management (RRM) fundamentals including ED-RRM.	Chapter 13
Verify basic wireless network operation	Chapter 20
Install Wireless Clients	
Describe client WLAN configuration requirements, such as Service Set Identifier (SSID), security selection, and authentication	Chapter 17
Identify basic configuration of common wireless supplicants (Macintosh, Intel Wireless Pro, Windows, iOS, and Android)	Chapter 17
Describe basic AnyConnect 3.0 or above wireless configuration parameters	Chapter 17
Identify capabilities available in CCX versions 1 through 5	Chapter 17
Implement Basic WLAN Security	
Describe the general framework of wireless security and security components (authentication, encryption, MFP, IPS)	Chapter 14
Describe and configure authentication methods (Guest, PSK, 802.1X, WPA/WPA2 with EAP- TLS, EAP-FAST, PEAP, LEAP)	Chapters 14, 16
Describe and configure encryption methods (WPA/WPA2 with TKIP, AES)	Chapter 14
Describe and configure the different sources of authentication (PSK, EAP-local or -external, Radius)	Chapter 14
Operate Basic WCS	
Identify key functions of Cisco Wireless Control System (WCS) and Navigator (versions and licensing)	Chapter 18
Navigate WCS interface	Chapter 18
Configure controllers and access points (APs) (using the Configuration tab not templates)	Chapter 18
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)	Chapter 18
Use the WCS monitor tab and alarm summary to verify the WLAN operations	Chapter 18
Generate standard WCS reports (inventory, CleanAir, client-related, AP-related, and utilization)	Chapter 18

Exam Topic	Chapter Where Topic is Covered
Conduct Basic WLAN Maintenance and Troubleshooting	
Identify and use basic WLAN troubleshooting tools (WLC show debug and logging) for client to AP connectivity, AP to controller connectivity	Chapter 20
Use the WCS client troubleshooting tool	Chapter 20
Transfer logs, configuration files, and O/S images to and from the WLC via the GUI	Chapter 21
Differentiate and use WLC and AP (autonomous and LAP) management access methods (console port, CLI, telnet, ssh, http, https, and wired vs wireless management)	Chapter 21

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.

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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

CHAPTER 7

Planning Coverage with Wireless APs

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 7-1 *"Do I Know This Already?" Section-to-Question Mapping*

Foundation Topics Section	Questions
AP Cell Size	1–4
Adding APs to an ESS	5–10

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).

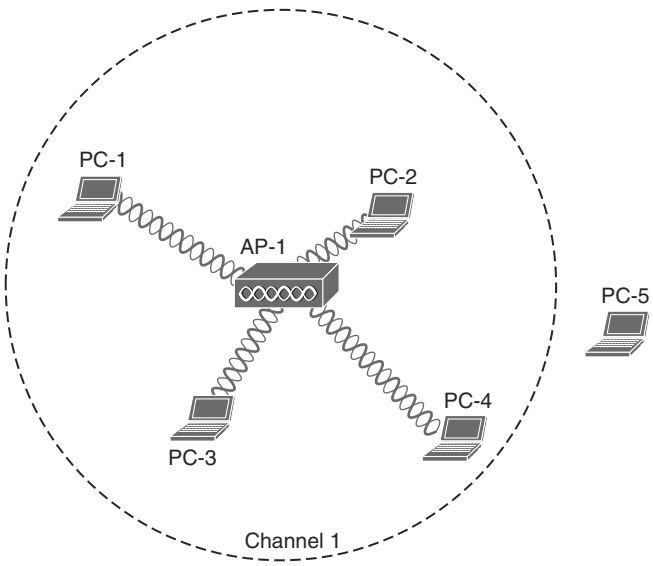
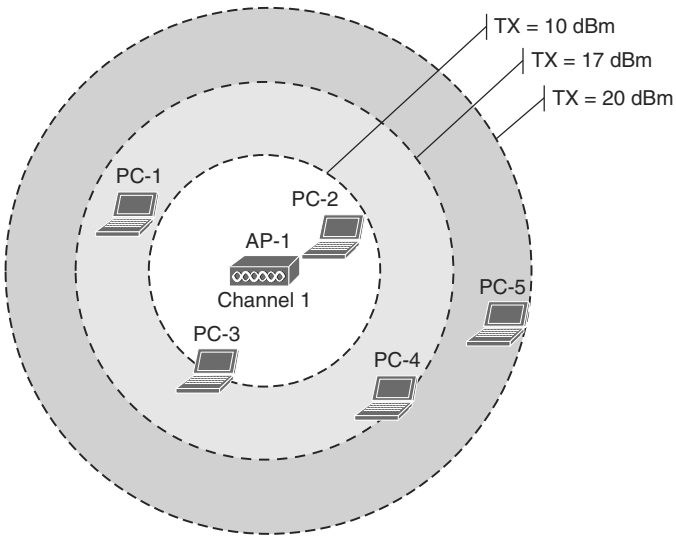


Figure 7-1 *An Example Cell That Includes All but One Client.*

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.



Key Topic

Figure 7-2 *The Effects of the Transmit Power Level on Cell Size.*

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.

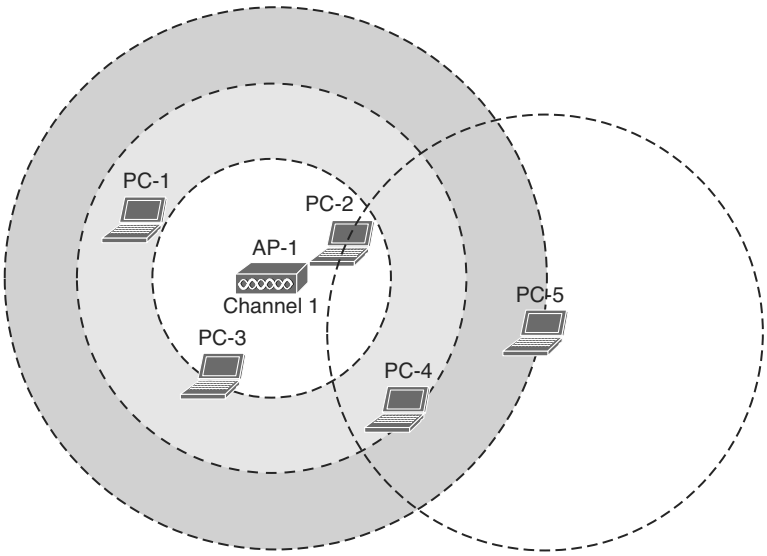


Figure 7-3 *The Asymmetric Power Problem.*

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.

Key Topic

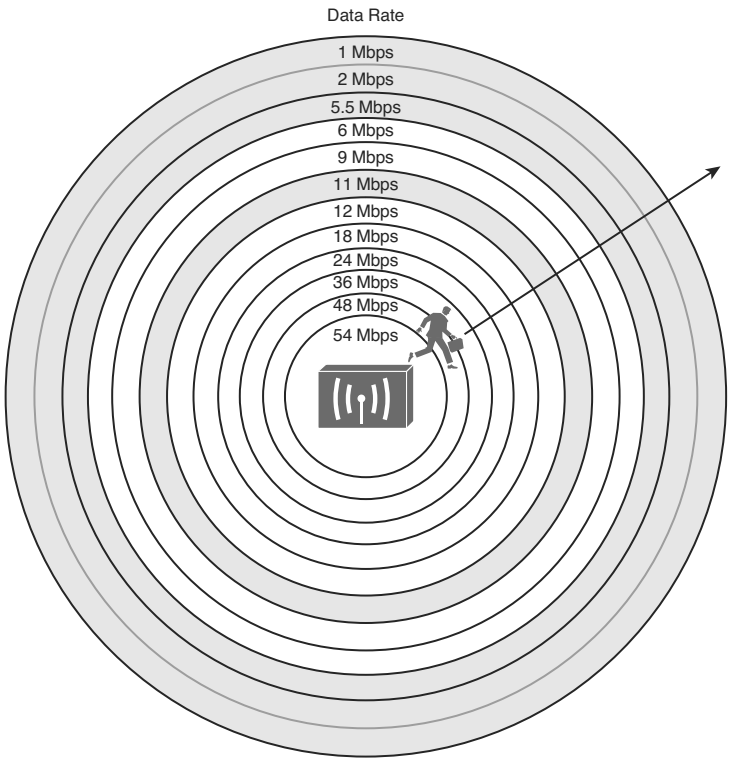


Figure 7-4 *The Relationship of Data Rates and Cell Range.*

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.

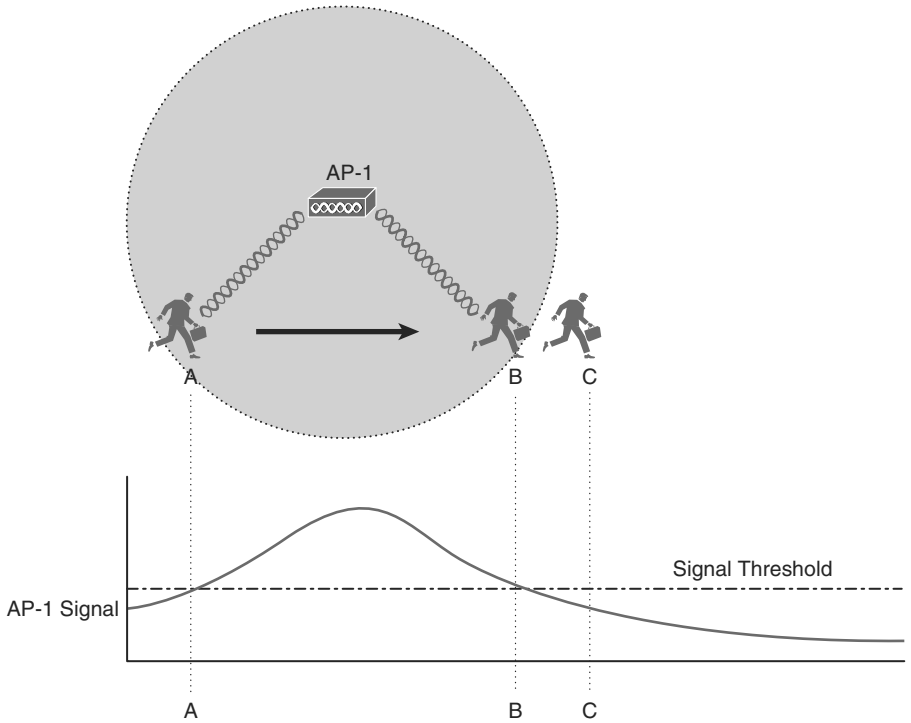


Figure 7-5 *A Mobile Client Moves Within an AP Cell.*

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.

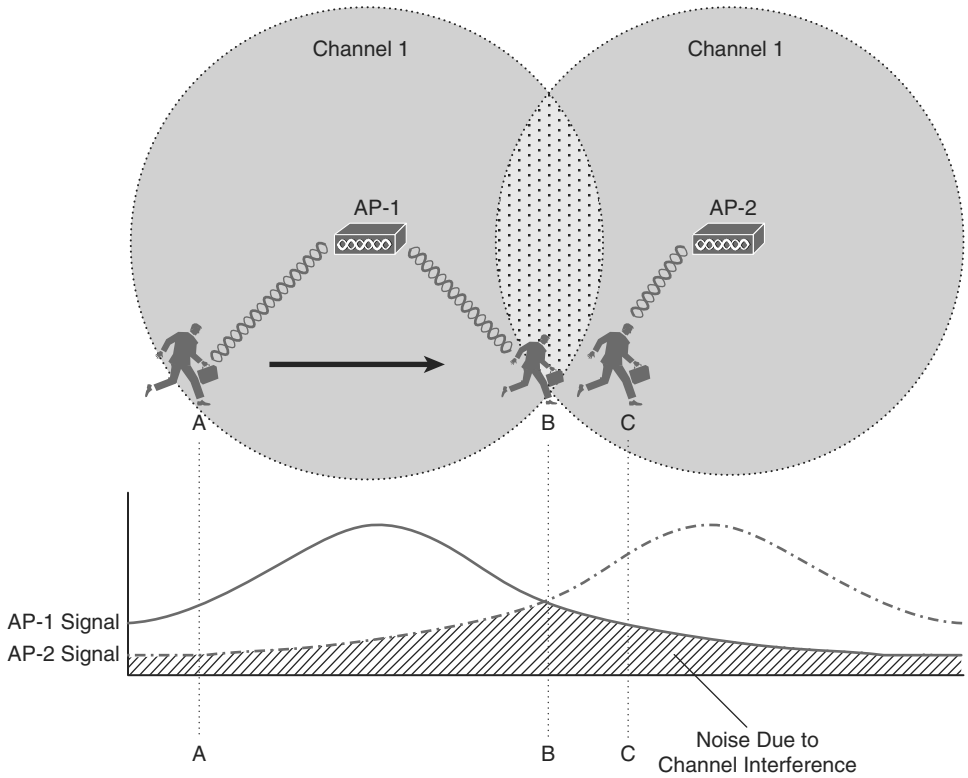


Figure 7-6 *Pitfalls of Reusing Channels in Adjacent Aps.*

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.

Key Topic

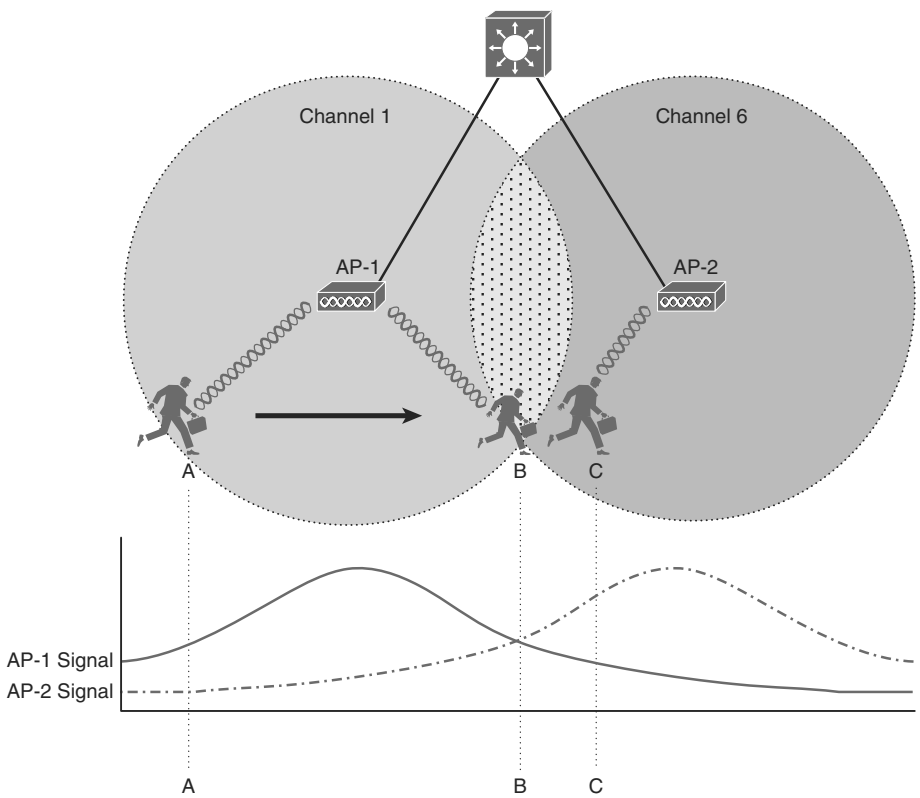


Figure 7-7 *A Client Roaming Correctly Between Two APs.*

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 cells 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.

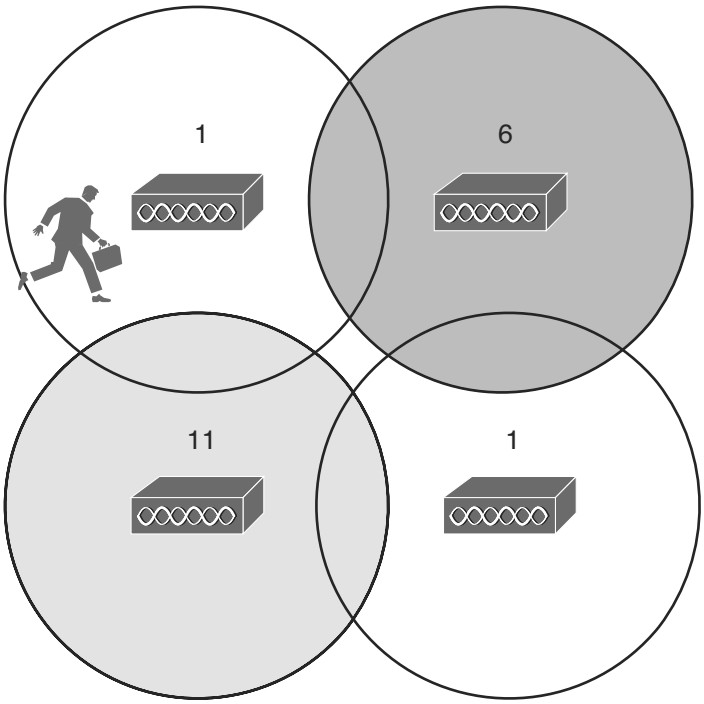


Figure 7-8 *Holes in an Alternating Channel Pattern.*

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.

Key Topic

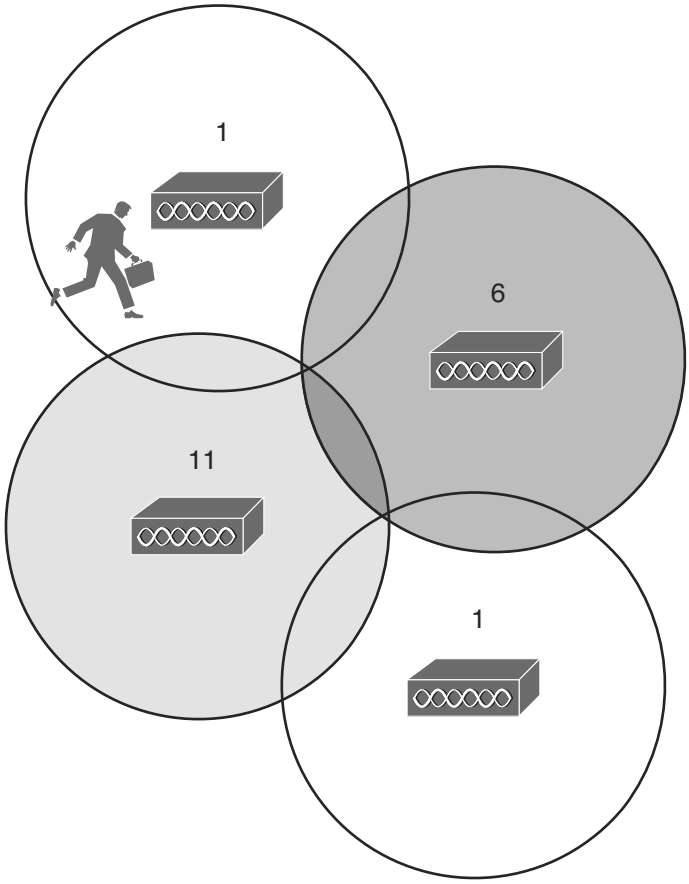


Figure 7-9 *A Better Alternating Channel Pattern.*

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.

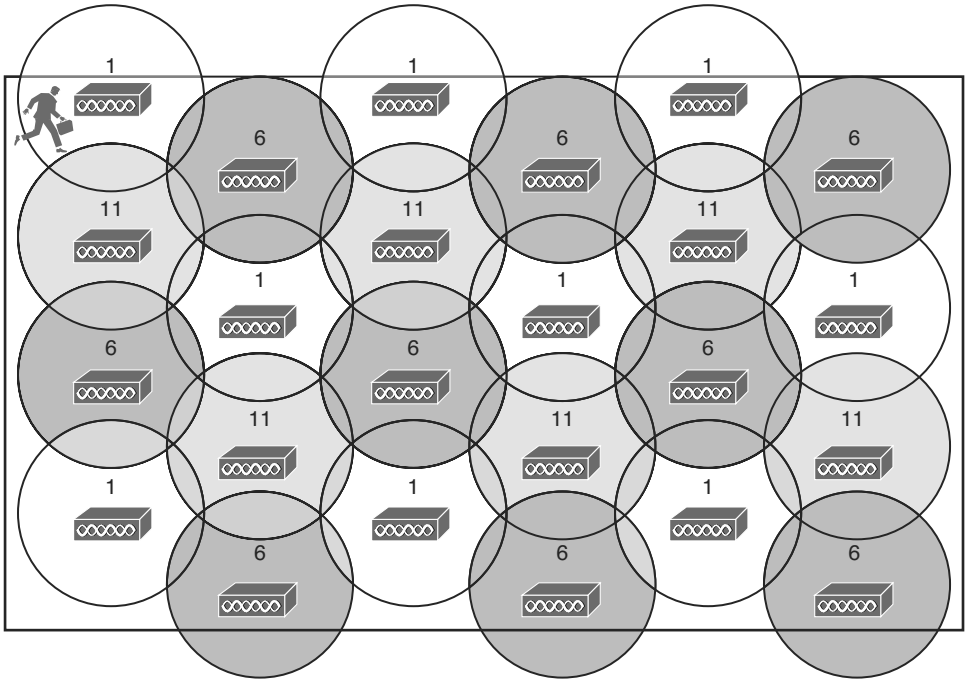


Figure 7-10 *Channel Reuse Over a Large Area.*

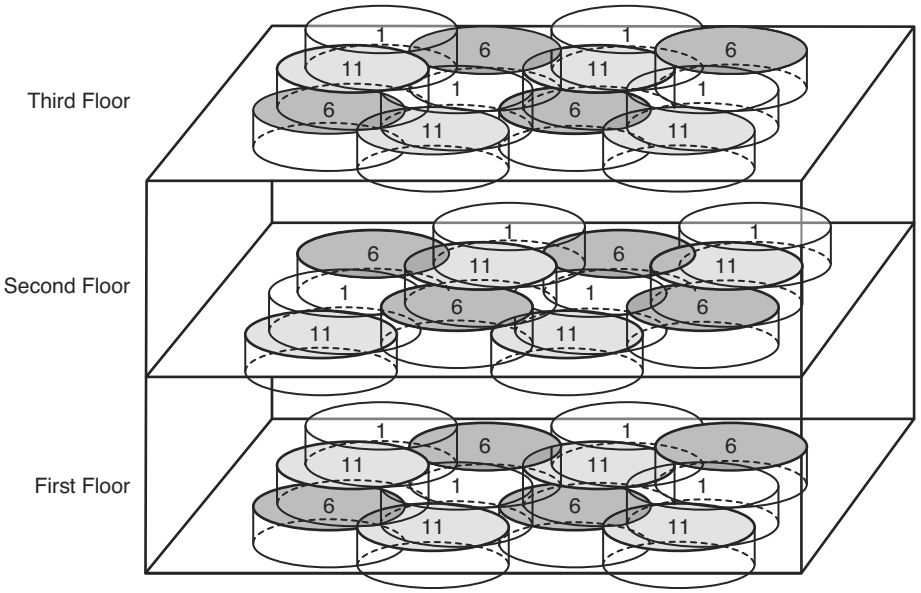


Figure 7-11 *Channel Layout in Three Dimensions.*

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 7-2 *Key Topics for Chapter 7*

Key Topic Element	Description	Page Number
Figure 7-2	The effects of transmit power on cell size	151
Figure 7-4	The effects of data rate on cell size	153
Figure 7-7	Roaming between BSSs	156
Figure 7-9	Optimizing channel layout for roaming	159

Define Key Terms

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

asymmetric power problem, channel reuse

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