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CCNA Wireless 200-355

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DAVID HUCABY, CCIE® No. 4594

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David Hucaby, CCIE No. 4594, is a network engineer for a large university healthcare network based on Cisco wireless 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.

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Jerome Henry, CCIE Wireless No. 24750, is a technical marketing engineer in the Wireless Enterprise Networking Group at Cisco systems. Jerome has close to 17 years of 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 Cisco later acquired to become its 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 No. 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 (*CCNP Wireless IUWMS Quick Reference*, *CCNP Wireless CUWSS Quick Reference*, and so on). Jerome also is an IEEE 802.11 group member and participant of Wi-Fi Alliance working groups. With more than 10,000 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, my two daughters, Lauren and Kara, and my parents, Reid and Doris Hucaby. Their love, encouragement, and support carry me along. I'm so grateful to God, who gives endurance and encouragement (Romans 15:5), who has allowed me to enjoy networking and working on projects like this, and who invented wireless communication. With a higher purpose.

As the sign in front of a church near my home says: "Prayer: The world's greatest wireless connection."

Acknowledgments

It has been my great pleasure to work on another Cisco Press project. I've now been writing Cisco Press titles continuously for more than 15 years. I have physically worn out several laptop keyboards and probably several Cisco Press editors in the process. I am most thankful that Chris Cleveland has never worn out—he has been the development editor for almost every project I have ever worked on. I can't say enough good things about working with him. I am grateful to Mary Beth Ray for inviting me back to revise this book, Tonya Simpson as the project editor, Bill McManus for raising the copy editing bar to an amazing height, and many other Cisco Press folks who have worked hard to make this book happen.

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

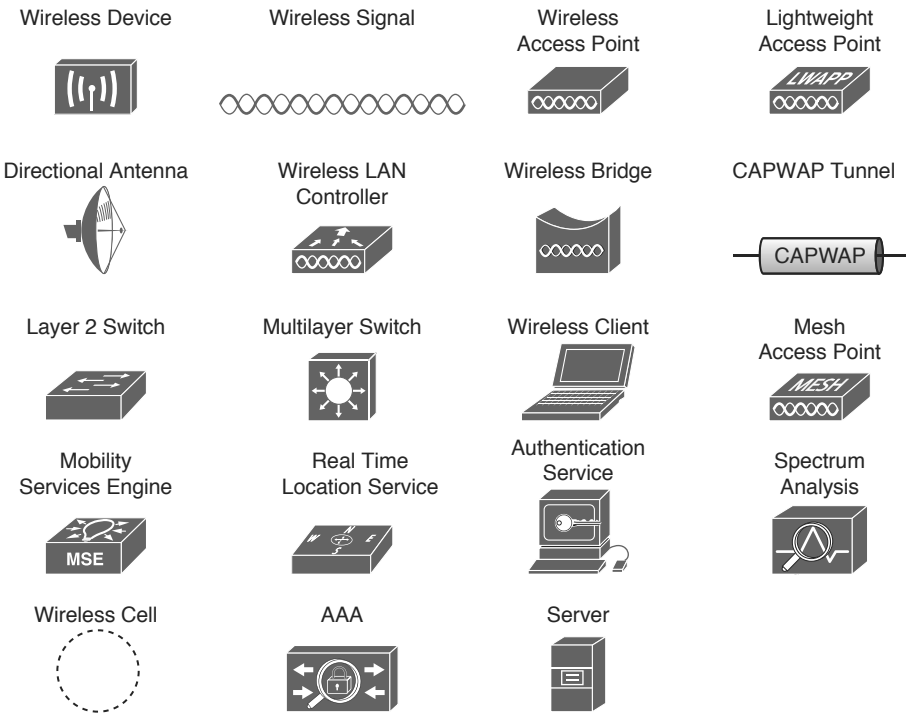
As always, I have enjoyed the good discussions with my dad, Reid Hucaby, a fellow EE and a seasoned RF engineer, that this book has prompted about all things wireless.

Finally, I am indebted to my co-worker and good friend, Rick Herring, who has been saying for years that I should write a wireless book one day. I always thought he was joking until now.

Contents at a Glance

Contents

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 200-355 WIFUND (Implementing Cisco Wireless Networking Fundamentals) certification exam. To achieve the CCNA Wireless specialization, you must first pass the CCENT, CCNA Routing and Switching, or any CCIE certification.

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 21 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. It also explains how coverage can be measured, surveyed, and validated.

- **Chapter 8, "Understanding Cisco Wireless Architectures":** This chapter describes the autonomous, cloud-based, centralized, and converged wireless architectures and how you can leverage their respective strengths to solve some fundamental problems.
- **Chapter 9, "Implementing Autonomous and Cloud Deployments":** 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. It also provides an introduction of Cisco Meraki cloud-based APs.
- **Chapter 10, "Implementing Controller-based Deployments":** 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, "Configuring Client Connectivity":** 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 Cisco Wireless Networks":** This chapter provides an overview of Prime Infrastructure, 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 WLAN Connectivity":** 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, "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.
- **Appendix C, "CCNA Wireless 200-355 Exam Updates"**: This appendix is a living document that provides you with updated information if Cisco makes minor modifications to the exam upon which this book is based. Be sure to check the online version of this appendix at http://www.ciscopress.com/title/9781587144578 for any updates.
- **Appendix D, "Study Planner"**: This spreadsheet is designed as a tool to help you plan and track major study milestones as you prepare for the CCNA Wireless exam.
- **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.

- **DVD-based practice exam:** This book includes a DVD 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.

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 Wireless Networking Fundamentals (WIFUND), exam 200-355. 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.

Tip At the time this book is being published, the WIFUND exam is based on Cisco Wireless LAN Controller software release 8.0 and Cisco Prime Infrastructure release 2.2.

Table I-1 WIFUND Exam 200-355 Topics and Chapter References

WIFUND 200-355 Exam Topic	Chapter(s) in Which Topic Is Covered
1.0 RF Fundamentals	
1.1 Describe the propagation of radio waves	
1.1.a Frequency, amplitude, phase, wavelength (characteristics)	1
1.1.b Absorption, reflection, diffraction, scattering, refraction, fading, free space path loss, multipath	3
1.2 Interpret RF signal measurements	
1.2.a Signal strength (RSSI, Transmit power, receive sensitivity)	1
1.2.b Differentiate interference vs. noise	1, 3, 19
1.2.c Device capabilities (smartphones, laptops, tablets)	17
1.2.d Define SNR	1
1.3 Explain the principles of RF mathematics	
1.3.a Compute dBm, mW, Law of 3s and 10s,	1
1.4 Describe Wi-Fi antenna characteristics	
1.4.a Ability to read a radiation pattern chart	4
1.4.b Antenna types and uses	4

WIFUND 200-355 Exam Topic	Chapter(s) in Which Topic Is Covered
1.4.c dBi, dBd, EIRP	1, 4
2.0 802.11 Technology Fundamentals	
2.1 Describe basic Wi-Fi governance	
2.1.a Describe regional regulatory bodies (such as, FCC / ETSI/ NTT)	2
2.1.b IEEE 802.11	2
2.1.c Wi-Fi Alliance	2
2.2 Describe usable channel and power combination	
2.2.a Regional EIRP limitation examples	2
2.2.b ISM, UNII frequency bands	2
2.2.c Describe RRM fundamental	13
2.3 Describe 802.11 fundamentals	
2.3.a Modulation techniques	1, 2
2.3.b Channel width	2
2.3.c MIMO / MU-MIMO	2
2.3.c (i) MRC	2
2.3.c (ii) Beam forming	2
2.3.c (iii) Spatial streams	2
2.3.d Wireless topologies	5
2.3.d (i) IBSS	5
2.3.d (ii) BSS	5
2.3.d (iii) ESS	5
2.3.e Frame types	6
2.3.e (i) Management	6
2.3.e (ii) Control	6
2.3.e (iii) Data	6
3.0 Implementing a Wireless Network	
3.1 Describe the various Cisco wireless architectures	
3.1.a Cloud	8
3.1.b Autonomous	8
3.1.c Split MAC	8

WIFUND 200-355 Exam Topic	Chapter(s) in Which Topic Is Covered
3.1.c (i) FlexConnect	8
3.1.c (ii) Centralized	8
3.1.c (iii) Converged	8
3.2 Describe physical infrastructure connections	
3.2.a Wired infrastructure (AP, WLC, access/trunk ports, LAG)	10
3.3 Describe AP and WLC management access connections	
3.3.a Management connections (Telnet, SSH, HTTP, HTTPS, console)	9, 10
3.3.b IP addressing: IPv4 / IPv6	9, 10
3.3.c Management via wireless	15
4.0 Operating a Wireless Network	
4.1 Execute initial setup procedures Cisco wireless infrastructures	
4.1.a Cloud	9
4.1.b Converged	10
4.1.c Centralized	10
4.1.d Autonomous	9
4.2 Describe the Cisco implementation of the CAPWAP discovery and join process	
4.2.a DHCP	11
4.2.b DNS	11
4.2.c Master-controller	11
4.2.d Primary-secondary-tertiary	11
4.3 Distinguish different lightweight AP modes	8
4.4 Describe and configure the components of a wireless LAN access for client connectivity using GUI only	15
4.5 Identify wireless network and client management and configuration platform options	
4.5.a Controller GUI and CLI	10
4.5.b Prime infrastructure	18
4.5.c Dashboard	9
4.5.d ISE	18
4.6 Maintain wireless network	

WIFUND 200-355 Exam Topic	Chapter(s) in Which Topic Is Covered
4.6.a Perform controller configuration backups	10
4.6.b Perform code updates on controller, APs, and converged access switches	10
4.6.b (i) AireOS: boot loader (FUS), image	10
4.6.b (ii) IOS-XE: bundle, unbundle	10
4.6.b (iii) Autonomous	9
5.0 Configuration of Client Connectivity	
5.1 Identify authentication mechanisms	
5.1.a LDAP, RADIUS, local authentication, WebAuth, 802.1X, PSK	14, 16
5.2 Configuring WLAN authentication mechanisms on the controller	
5.2.a WebAuth, 802.1X, PSK	14, 16
5.2.b TKIP deprecation	14
5.3 Configure client connectivity in different operating systems	
5.3.a Android, MacOS, iOS, Windows	17
5.4 Describe roaming	
5.4.a Layer 2 and Layer 3	12
5.4.b Intracontroller and intercontroller	12
5.4.c Centralized mobility	12
5.4.d Converged mobility	12
5.5 Describe wireless guest networking	
5.5.a Anchor controller	16
5.5.b Foreign controller	16
6.0 Performing Client Connectivity Troubleshooting	
6.1 Validating WLAN configuration settings at the infrastructure side	
6.1.a Security settings	20
6.1.b SSID settings	20
6.2 Validating AP infrastructure settings	
6.2.a Port level configuration	20
6.2.b Power source	20
6.2.c AP and antenna orientation and position	20

WIFUND 200-355 Exam Topic	Chapter(s) in Which Topic Is Covered
6.3 Validate client settings	
6.3.a SSID	17, 20
6.3.b Security	17, 20
6.3.c Device driver version	17
6.4 Employ appropriate controller tools to assist troubleshooting	
6.4.a GUI logs	20
6.4.b CLI show commands	20
6.4.c Monitor pages	
6.4.c (i) CleanAir (controller GUI)	19
6.5 Identify appropriate third-party tools to assist troubleshooting	
6.5.a OS-based Client utilities	20
6.5.b Wi-Fi scanners	20
6.5.c RF mapping tool	20
7.0 Site Survey Process	
7.1 Describe site survey methodologies and their purpose	
7.1.a Offsite (predictive / plan)	7
7.1.b Onsite	7
7.1.b (i) Predeployment (AP on a stick)	7
7.1.b (ii) Post deployment (validation)	7
7.2 Describe passive and active site surveys	7
7.3 Identify proper application of site survey tools	
7.3.a Spectrum analyzer	19
7.3.b Site surveying software	7
7.4 Describe the requirements of client real-time and non-real-time applications	17

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/9781587144578. 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 WIFUND 200-355 exam is a computer-based exam, with around 60 to 70 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/9781587144578. 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:

- **Configuring 802.11 Support**—This section explains how to configure the data rates in the 2.4- and 5-GHz bands and support for 802.11n high throughput (HT) and 802.11ac very high throughput (VHT) functionality.
- **Understanding RRM**—This section describes the algorithms that can monitor and adjust radio frequency parameters automatically in a wireless network.

This chapter covers the following exam topics:

- 2.2—Describe usable channel and power combination
  - 2.2c—Describe RRM fundamentals

CHAPTER 13

Understanding RRM

In Chapter 7, "Planning Coverage with Wireless APs," you learned how to size access point (AP) cells appropriately by disabling data rates and changing the transmit power levels. You also learned how important a proper channel layout is to promote efficient roaming and minimize co-channel interference. You probably also realized how difficult these tasks are when you have to tune the radio frequency (RF) parameters manually across a large number of APs.

In this chapter, you learn about Cisco Radio Resource Management (RRM), a flexible and automatic mechanism that Cisco Wireless LAN controllers can use to make your life much easier.

"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 13-1 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 13-1 "Do I Know This Already?" Section-to-Question Mapping

Foundation Topics Section	Questions
Configuring 802.11 Support	1–4
Understanding RRM	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 one of the following correctly describes a mandatory data rate?
   a. A data rate that must be used by wireless clients all the time
   b. The highest data rate used by an AP and its clients
   c. A data rate that must be supported by a client before it can associate with an AP
   d. A data rate required by the IEEE 802.11 standards body
2. You can configure only one data rate as mandatory on an AP. True or false?
   a. True
   b. False
3. An AP sends 802.11 broadcast management frames at which one of the following data rates?
   a. The highest mandatory data rate
   b. The lowest mandatory data rate
   c. The lowest supported data rate
   d. All supported data rates
4. Which one of the following is the default state of 802.11n and 802.11ac support and the default channel width on a Cisco wireless LAN controller?
   a. Disabled; 20-MHz channels
   b. Enabled; 20-MHz channels
   c. Enabled; 40-MHz channels
   d. Disabled; 40-MHz channels
   e. Enabled; 80-MHz channels
5. Which one of the following correctly identifies the scope of the RRM algorithms?
   a. All APs joined to one controller
   b. All APs joined to all controllers
   c. All APs joined to controllers in an RF group
   d. All APs of a specific model
6. An RF group is automatically formed by which one of the following?
   a. All APs that share the same channel
   b. All clients that share the same SSID
   c. Any controllers that can overhear neighbor messages with identical RF group names sent between their APs
   d. All controllers that can overhear neighbor messages with identical mobility group names sent between their APs

7. The TPC algorithm is used for which one of the following purposes?
   a. To adjust the transmission control protocol rate
   b. To detect problems in transmission perimeter coverage
   c. To adjust the transmitting primary channel
   d. To adjust the transmit power level
8. If the DCA algorithm detects that an AP is experiencing interference or excessive noise, what might it do to mitigate the problem?
   a. Increase the AP's transmit power level
   b. Decrease the AP's transmit power level
   c. Change the AP's channel number
   d. Direct the client to a different band
9. Which one of the following runs the DCA algorithm?
   a. RF group leader
   b. Master controller
   c. Each controller
   d. NCS or Cisco Prime Infrastructure
10. The 5-GHz radio in one of several APs in a building has failed. Which one of the following algorithms should be able to detect the failure?
    a. CCA
    b. DCA
    c. Dead radio detection
    d. Coverage hole detection

Foundation Topics

Configuring 802.11 Support

Cisco controllers and most APs can support wireless LANs in both the 2.4- and 5-GHz bands. By default, both bands are enabled; however, you can view or change a number of parameters by browsing to the Wireless tab in the controller, shown in Figure 13-1.

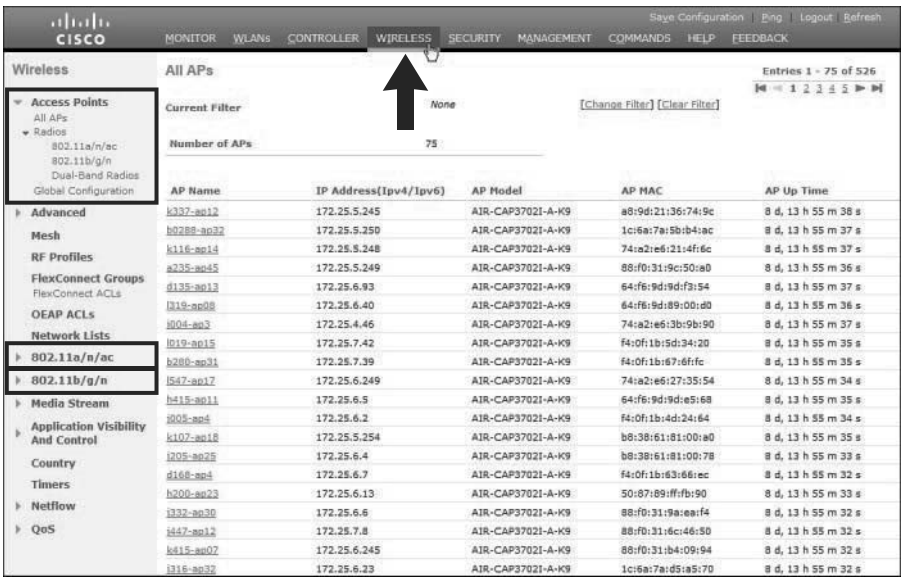


Figure 13-1 *Wireless Tab on a Cisco Controller GUI*

The wireless parameters are organized under a list of links that are found on the left side of the web page. At the CCNA level, you should be familiar with the following links:

- **Access Points**—Used to verify and configure RF things like transmit power level and channel number on individual APs
- **802.11a/n/ac**—Used to configure global parameters for the 5-GHz band
- **802.11b/g/n**—Used to configure global parameters for the 2.4-GHz band

The initial web page displays a list of all APs that are currently joined to the controller, as if you had selected **Wireless > Access Points > All APs**. The remaining configuration is covered in the sections that follow.

Configuring Data Rates

You can enable or disable the 2.4- or 5-GHz bands by selecting **802.11b/g/n** or **802.11a/n/ac**, respectively, and then clicking the **Network** link. Figures 13-2 and 13-3 show the two network configuration pages. Make sure that the **802.11b/g** or **802.11a Network Status** check box is checked to enable the 2.4- or 5-GHz radios on all APs.

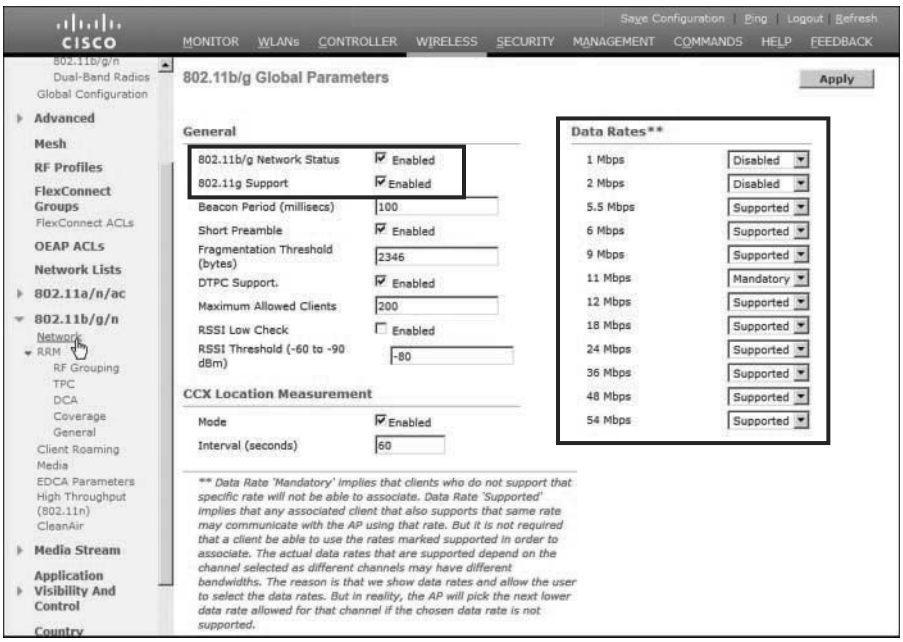


Figure 13-2 *Configuring 2.4-GHz Radios*

On the right side of the network web pages, as shown in Figures 13-2 and 13-3, you can configure the individual data rates (and the corresponding modulation and coding schemes) that are supported on each band. Each data rate can have one of the following states:

Key Topic

- **Mandatory**—A client must be able to use the data rate and Modulation Coding Scheme (MCS) to associate with an AP.
- **Supported**—A client can associate with an AP even if it cannot use the data rate.
- **Disabled**—An AP will not use the data rate with any clients.

By default, all data rates are enabled and supported. In the 2.4-GHz band, the 1-, 2-, 5.5-, and 11-Mbps rates are all marked as mandatory, based on the initial IEEE requirement that all clients be able to support each possible modulation type defined in 802.11b. In the 5-GHz band, the 6-, 12-, and 24-Mbps rates are marked as mandatory.

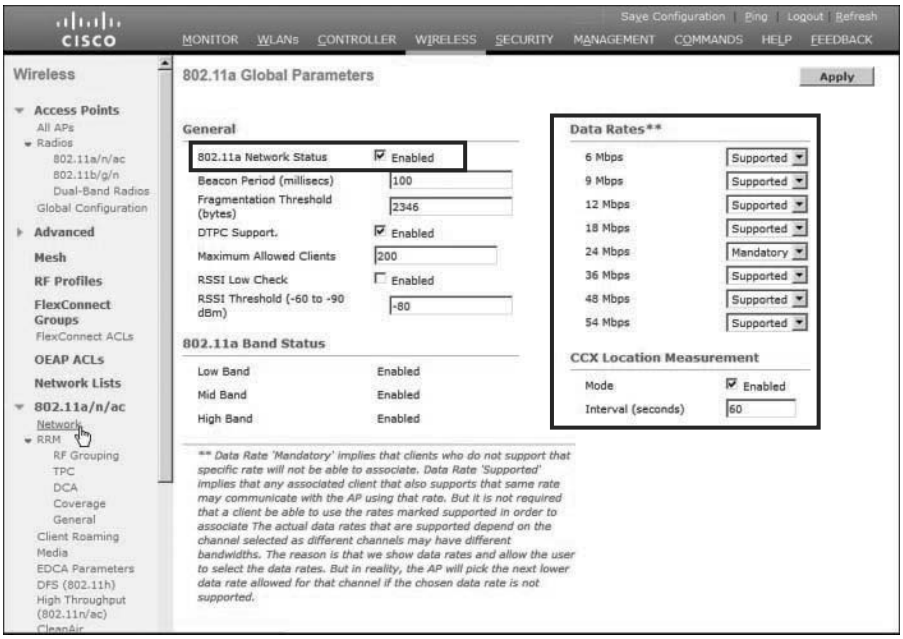


Figure 13-3 *Configuring 5-GHz Radios*

You can change the state of any data rate by selecting a new state from the drop-down menu. Remember that you can disable lower data rates to decrease the AP cell size and make channel use more efficient. Just make sure that your actions do not shrink the cells too much, leaving holes or gaps in the coverage between APs. Also be sure that all of your wireless clients can use the same set of mandatory and supported data rates.

Be sure to click the **Apply** button to make any configuration changes active. Any wireless networks that are already in production on the controller might be disrupted while the new configuration takes effect.

Configuring 802.11n and 802.11ac Support

You might have noticed that you can configure plenty of data rates, but 802.11n and 802.11ac are never mentioned on the wireless network configuration pages. That is because 802.11n and 802.11ac are considered to be rich sets of high-throughput enhancements and must be configured separately.

By default, 802.11n and 802.11ac are enabled. To check or change their state, go to **Wireless > 802.11a/n/ac** or **802.11b/g/n > High Throughput (802.11n/ac)**. Figure 13-4 shows the 5-GHz 802.11n/ac configuration page. Check the **11n Mode** and **11ac Mode** check boxes to enable 802.11n and 802.11ac, respectively. By default, every possible MCS is enabled and supported.

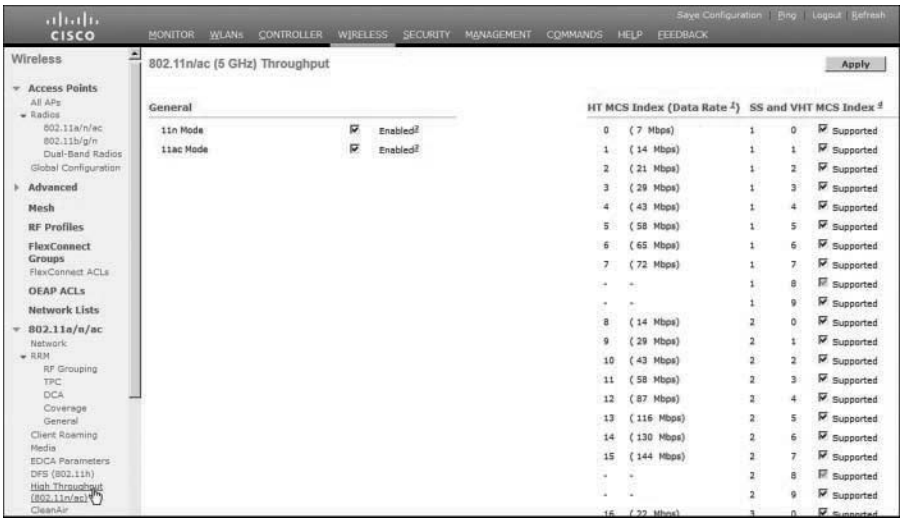


Figure 13-4 *Configuring 802.11n and 802.11ac Support*

Recall that 802.11n can bond one 20-MHz channel to an adjacent 20-MHz channel to effectively double the channel width; 802.11ac can scale even further By default, the controller will use only a single 20-MHz channel on each AP. You can configure channel bonding as a part of the dynamic channel allocation (DCA) configuration for the 5-GHz band only, as covered in the following section.

Understanding RRM

Suppose that you need to provide wireless coverage in a rectangular-shaped building. Using the information you have learned from this book, you decide to use six APs and locate them such that they form a staggered, regular pattern. The pattern shown in Figure 13-5 should create optimum conditions for roaming and channel use. (The building dimensions have not been mentioned, just to keep things simple.)

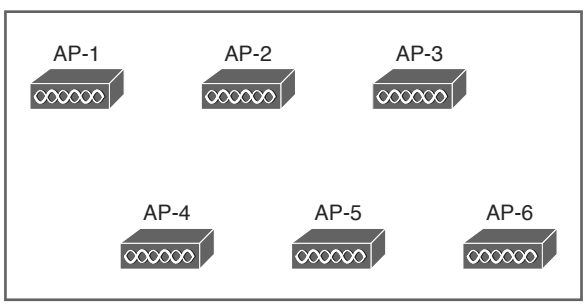


Figure 13-5 *Hypothetical AP Layout*

So far, you have considered the layout pattern and an average cell size, but you still have to tackle the puzzle of selecting the transmit power level and channel number for each AP. The transmit power level will affect the final cell size, and the channel assignment will affect co-channel interference and roaming handoff. At this point, if all the APs are powered up, they might all end up transmitting at maximum power on the same channel. Figure 13-6 shows one possible scenario; each of the AP cells overlaps its neighbors by about 50 percent, and all the APs are fighting to use channel 1!

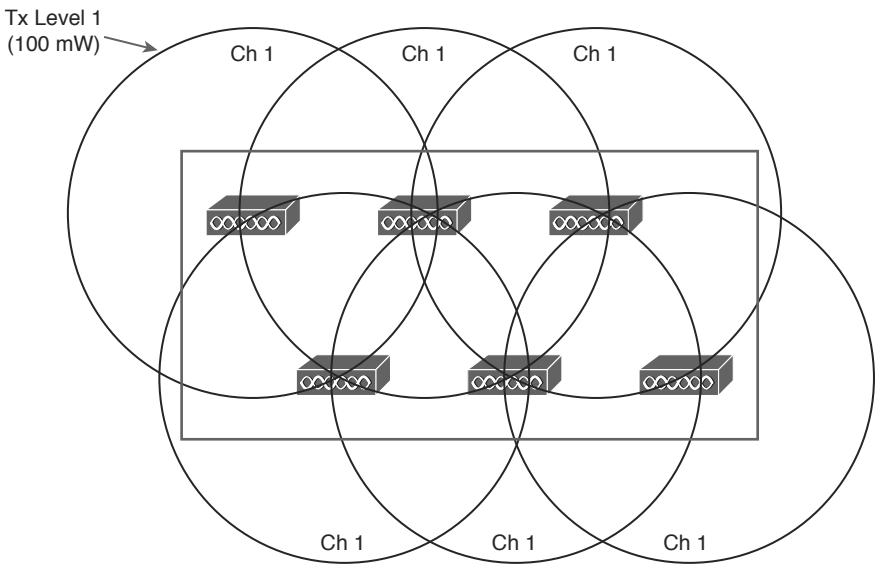


Figure 13-6 *Poorly Configured RF Coverage*

Where do you begin to prevent such mayhem? Because the AP locations are already nailed down, you can figure out the transmit power level that will give the proper cell overlap. Then you can work your way through the AP layout and choose an alternating pattern of channel numbers. With six APs, that might not be a daunting task.

Do not forget to repeat the task for both 2.4- and 5-GHz bands.

Also, if you plan on using 802.11n or 802.11ac with channel widths greater than 20 MHz, do not forget to reserve the extra channels needed for that. Be aware that only the 5-GHz band is capable of supporting wide channels.

If you happen to notice that an AP fails one day, you could always reconfigure its neighboring APs to increase their transmit power level to expand their cells and cover the hole.

If you introduce another AP or two in the future, do not forget to revisit the entire configuration again to make room for cells and channels.

Did your life as the wireless LAN administrator just become depressing and tedious? Cisco Radio Resource Management (RRM) can handle all these tasks regularly and automatically. RRM consists of several algorithms that can look at a large portion of a wireless network and work out an optimum transmit power level and channel number for each AP. If conditions that affect the RF coverage change over time, RRM can detect that and make the appropriate adjustments.

RF Groups

RRM works by monitoring a number of APs and working out optimal RF settings for each one. The APs that are included in the RRM algorithms are contained in a single RF group. An RF group is formed for each band that is supported—one group for 2.4-GHz AP radios and another for 5-GHz AP radios. By default, an RF group contains all the APs that are joined to a single controller.

You can also configure a controller to automatically populate its RF group. In that case, the RF group can expand to include APs from multiple controllers, provided the following two conditions are met:

- The controllers share a common RF group name.
- At least one AP from one controller can be overheard by an AP on another controller.

When an RF group touches more than one controller, the controllers form a type of cluster so that they all participate in any RF adjustments that are needed. Every AP sends a Neighbor Discovery Packet (NDP) at maximum transmit power and at 60-second intervals, by default. If two controllers are close enough in proximity for an AP on one to hear an AP on the other at a received signal strength indicator (RSSI) of –80 dBm or greater, they are close enough to belong to the same RF group. Up to 20 controllers and 1000 APs can join to form a single RF group.

Figure 13-7 shows a simple scenario with four controllers and four APs, resulting in two separate RF groups. AP-1 and AP-2 are both joined to controller WLC-1, so they are members of one RF group by default. AP-3, joined to WLC-2, is located near enough to AP-1 and AP-2 that neighbor advertisements are overheard. As a result, controller WLC-2 joins the RF group with WLC-1. However, AP-4, joined to controller WLC-3, is not close enough to pass the neighbor test. Even though AP-4's cell intersects the cells of AP-2 and AP-3, the APs themselves are not within range. Therefore, controller WLC-3 resides in a different RF group by itself.

Key Topic

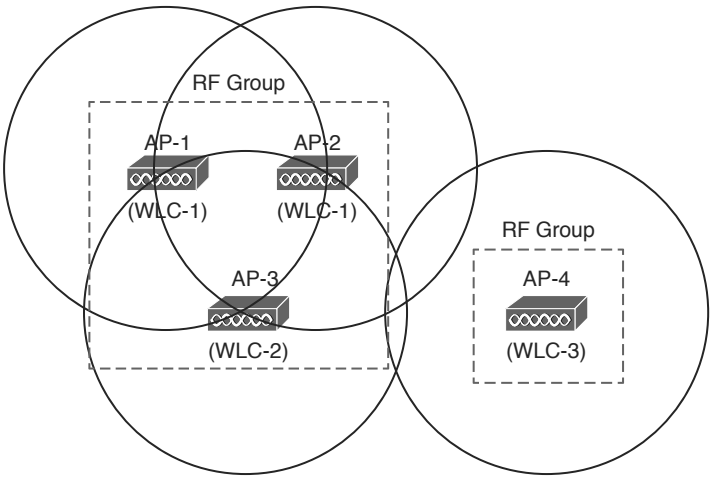


Figure 13-7 *Automatic RF Group Discovery and Formation*

One controller in each group is elected as an RF group leader, although you can override that by configuring one controller as a static leader. The leader collects and analyzes information from all APs in the group about their RF conditions in real time. You can access the RF group leader configuration information by selecting **Wireless > 802.11a/n/ac** or **802.11b/g/n > RRM > RF Grouping**. In Figure 13-8, the controller is in automatic RF group mode and is a member of an RF group along with two other controllers. The RF group leader is controller WLC-1.

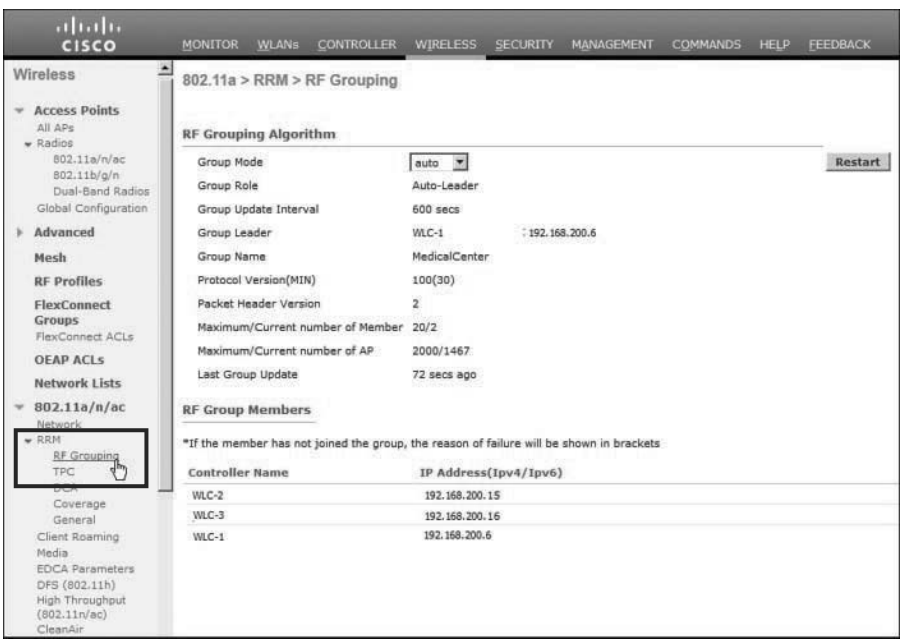


Figure 13-8 *Displaying RF Group Information*

Radio resource monitoring is used to gather and report information from the APs. Each AP is assigned to transmit and receive on a single channel, so it can easily detect noise and interference on that channel, as well as the channel utilization. The AP can also keep a list of clients and other APs that it hears transmitting on that channel.

Each AP can also spend a short bit of time (less than 60 ms) tuning its receiver to all of the other channels that are available. By scanning channels other than the one normally used, an AP can measure noise and interference all across the band from its own vantage point. The AP can also detect unexpected transmissions coming from rogue clients and APs, or devices that are not formally joined to the Cisco wireless network.

Based on the radio resource monitoring data, RRM can make the following decisions about APs in an RF group:

- **Transmit power control (TPC)**—RRM can set the transmit power level of each AP.
- **Dynamic channel allocation (DCA)**—RRM can select the channel number for each AP.
- **Coverage hole detection mitigation (CHDM)**—Based on information gathered from client associations, RRM can detect an area with weak RF coverage and increase an AP's transmit power level to compensate.

The RRM algorithms are designed to keep the entire wireless network as stable and efficient as possible. The TPC and DCA algorithms run independently because they perform very different functions. By default, the algorithms are run every 600 seconds (10 minutes). If conditions in the RF environment change, such as interference or the addition or failure of an AP, RRM can discover and react to the changes at the next interval. The RRM algorithms are discussed in more detail in the following sections.

TPC

The TPC algorithm focuses on one goal: setting each AP's transmit power level to an appropriate value so that it offers good coverage for clients while avoiding interference with neighboring APs that are using the same channel. Figure 13-9 illustrates this process. APs that were once transmitting too strongly and overlapping each other's cells are adjusted for proper coverage, reducing the cell size more appropriately to support clients.

Key Topic

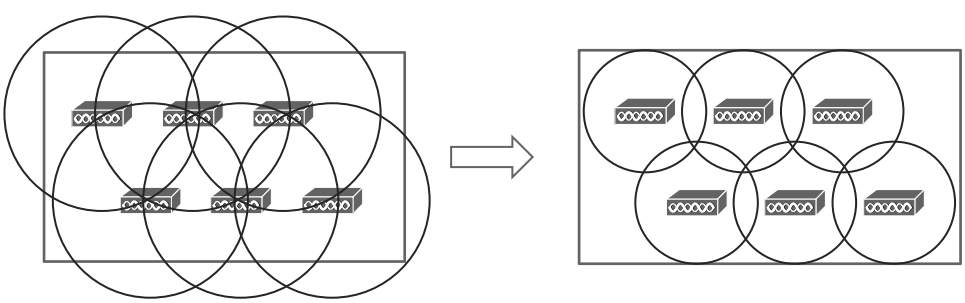


Figure 13-9 *Basic Concept of the TPC Algorithm*

Controllers have no knowledge of the physical location of each AP. By looking at Figure 13-9, you can see that the APs are arranged in a nice, evenly spaced pattern,

but the controller cannot see that. When an AP joins a controller, only the AP's MAC address, IP address, and some basic information are advertised to the controller. If the locations of neighboring APs cannot be known, each AP must resort to using the RSSI of its neighbors as a measure of how closely their cells touch or overlap its own.

During the time each AP scans the channels to listen for RF conditions and other APs, it forms a list of its neighbors and their RSSI values. Each of those lists is sent to the local controller and on to the RF group leader where they are used by the TPC algorithm.

TPC works on one band at a time, making adjustments to APs as needed. If an AP has been heard with an RSSI above a threshold (–70 dBm by default) by at least three of its neighbors, TPC considers the AP's cell to be overlapping the cells of its three neighbors too much. The AP's transmit power level will be decreased by 3 dB, and then its RSSI will be evaluated again. This process is repeated for all APs at regular intervals until the neighbor that is measuring the third-strongest RSSI value for the AP no longer measures the RSSI greater than the threshold.

Although you probably will not have to make any configuration changes for the TPC algorithm, it is still useful to understand its settings. **TPC** runs on the 2.4- and 5-GHz bands independently. You can see the settings by selecting **Wireless > 802.11a/n/ac** or **802.11b/g/n > RRM > TPC**. Figure 13-10 shows the TPC configuration for the 5-GHz band.

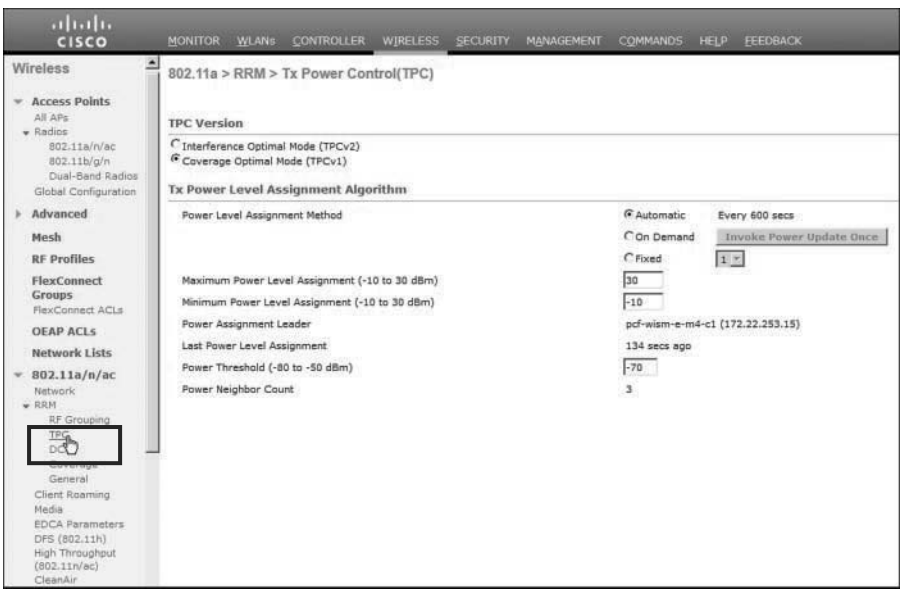


Figure 13-10 *Adjusting the RRM TPC Algorithm Parameters*

Actually, there are two different TPC algorithms as you can see in the figure. TPCv1 (the default), also known as Coverage Optimal Mode, works toward making adjustments that give the best RF coverage, while keeping signals sufficient and stable. TPCv2, also known as Interference Optimal Mode, focuses on avoiding negative impacts that TPCv1 might have had, where the power among AP cells ends up being imbalanced, causing some cells to interfere with others. TPCv2 requires proper tuning of RF parameters in order to work

properly. While TPCv2 might sound superior, it should only be enabled in specific cases that are outside the scope of the CCNA Wireless exam or when directed by Cisco TAC.

By default, TPC runs automatically every 10 minutes. This is the recommended mode because any changes in the RF environment can be detected and compensated for without any intervention. As an alternative, you can select **On Demand** to run the algorithm immediately; then the resulting transmit power levels will be frozen until TPC is manually triggered again. If you would rather have the controller set the transmit power level on all APs to one fixed value, you can select **Fixed** and choose the power level from the drop-down menu.

Cisco controllers determine the transmit power level according to an index from 1 to 8, rather than discrete dBm or mW values. A value of 1 corresponds to the maximum power level that is allowed in the AP's regulatory domain. Each increment in the power level number reduces the transmit power by 3 dBm. You might remember from Chapter 1 that reducing by 3 dBm also means that the power in mW is cut in half. As an example, Table 13-2 lists the power levels used in the 2.4-GHz and 5-GHz bands on a Cisco 3700 AP in the Americas or European domains.

Key Topic

Table 13-2 AP Transmit Power Level Numbers, dBm, and mW Values in the 2.4-GHz Band

Power Level	dBm (2.4 GHz)	dBm (5 GHz)	mW
1	23	23	200
2	20	20	100
3	17	17	50
4	14	14	25
5	11	11	12.5
6	8	8	6.25
7	5	Unused	3.125
8	2	Unused	1.56

With every iteration, the TPC algorithm can continue adjusting the transmit power levels until no further changes are needed. As a result, some APs might end up higher or lower than you might want. For example, it is usually best to match the AP transmit power level with that of the clients. Suppose that some of the clients have a fixed power level of 25 mW; if TPC ends up reducing some APs to 10 mW, the AP and client power levels will be mismatched.

To prevent such a condition, you can set minimum and maximum power level boundaries for the TPC algorithm. By default, the minimum level is set to –10 dBm and the maximum to 30 dBm, as shown in Figure 13-10.

Whenever you change the TPC parameters in a controller configuration, remember to make the same changes to all controllers that might be members of the same RF group. No matter which controller might become the RF group leader, the parameters should be identical.

Tip What transmit power level does an AP use when it first powers up? A new AP right out of the box will power up at its maximum power level. After the TPC algorithm has run and adjusted an AP's power level, that level is remembered the next time the AP is power cycled.

DCA

Recall from Chapter 7, "Planning Coverage with Wireless APs," and Chapter 12, "Understanding Roaming," that a proper channel assignment is vital for efficient use of air time and for client mobility. When neighboring APs use the same channel, they can interfere with each other. Ideally, adjacent APs should use different, non-overlapping channels. Working out a channel layout for many APs can be a difficult puzzle, but the DCA algorithm can work out optimum solutions automatically for all APs in an RF group.

When a new AP first powers up, it uses the first non-overlapping channel in each band—channel 1 for 2.4 GHz and channel 36 for 5 GHz. Consider a simplistic scenario where all APs are new and powered up for the first time. You would end up with a building full of overlapping cells competing for the use of 2.4-GHz channel 1, as shown in simplified form in Figure 13-11. The DCA algorithm works to correct this situation by finding a channel that each AP in the RF group can use without overlapping or interfering with other APs. Like TPC, DCA works out one channel layout in the 2.4-GHz band and another layout in the 5-GHz band.

Key Topic

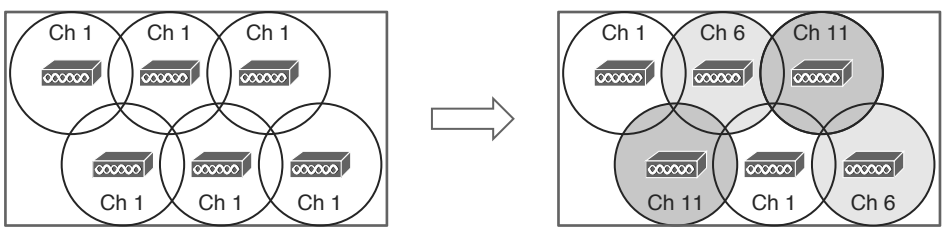


Figure 13-11 *Basic Concept of the DCA Algorithm*

DCA does not just solve the channel layout puzzle once for all APs. The algorithm runs every 10 minutes by default, so that it can detect any conditions that might require an AP's channel to change. APs in the RF group are monitored for the metrics listed in Table 13-3 that can influence the channel reassignment decision.

Table 13-3 Metrics Affecting DCA Decisions

Metric	Default State	Description
RSSI of neighboring APs	Always enabled	If DCA detects co-channel interference, it may move an AP to a different channel.
802.11 interference	Enabled	If transmissions from APs and devices that are not part of the wireless network are detected, DCA may choose to move an AP to a different channel.

Metric	Default State	Description
Non-802.11 noise	Enabled	If excessive noise is present on a channel, DCA may choose to avoid using it.
AP traffic load	Disabled	If an AP is heavily used, DCA may not change its channel to keep client disruption to a minimum.
Persistent interference	Disabled	If an interference source with a high duty cycle is detected on a channel, DCA may choose to avoid using it.

The DCA algorithm tends to look at each AP individually to find the ones with the worst RF conditions. Changing the channel of even one AP can affect many other APs if there are not other alternative channels available. Channel layout is a puzzle that may require several iterations to solve. For this reason, the controller that is the RF group leader will undergo an RRM startup mode after it is elected. The startup mode consists of ten DCA iterations at 10-minute intervals, or a total of 100 minutes before the channel layout reaches a steady state.

The end result of DCA is a channel layout that takes a variety of conditions into account. The channel layout is not just limited to the two dimensions of a single floor space in a building; it also extends to three-dimensional space because the RF signals from one floor can bleed through to another. As long as the APs on different floors belong to the same RF group, co-channel interference between them should be minimized.

You can display and configure the DCA parameters of either the 2.4- or 5-GHz band by selecting **Wireless > 802.11a/n/ac** or **802.11b/g/n > RRM > DCA**. Figure 13-12 shows the 802.11a/n/ac configuration.

By default, the DCA algorithm runs automatically at 10-minute intervals. You can change the interval time, select **Freeze** to run DCA manually on demand, or turn it **Off** completely. You can also select the conditions to avoid, which will trigger a channel change on an AP.

The DCA parameters also include the 802.11n channel width. By default, 20-MHz channels will be used. If you have enabled 802.11n in the 5-GHz band and want to enable 40-MHz channels, be sure to select **40 MHz** as the channel width. If you have 802.11ac enabled, you can choose between 20-, 40-, and 80-MHz channel width. The DCA algorithm will solve the channel assignment puzzle automatically, even with wide channels.

Tip You might be wondering why 802.11ac can support 80- and 160-MHz channel widths, but 160 MHz is not an option on the controller depicted in Figure 13-12. The reason is twofold: (1) Full 160-MHz channel width is not supported until 802.11ac Wave 2; and (2) the CCNA Wireless 200-355 exam uses AireOS 8.0, which supports only Wave 1. In addition, the available spectrum does not currently support more than two 160-MHz channels. Both reasons will be solved over time, as new hardware is developed and as new spectrum is reclaimed and set aside in the 5-GHz band.

The bottom portion of the web page contains a list of channels that DCA can use as it assigns channels to APs in the respective band. This list is populated with channel numbers by default, but you can edit the list as needed. You can also enable or disable individual channel use by using the list of **Select** check boxes.

The DCA algorithm normally runs on an automatic schedule or manually on demand. Event-Driven RRM (ED-RRM) takes this a step further; DCA can be triggered based on RF events that occur in real time. The CleanAir feature, covered in more detail in Chapter 19, "Dealing with Wireless Interference," provides the triggers for ED-RRM. By default, ED-RRM is disabled. You can enable it with the **EDRRM** check box at the very bottom of the web page.

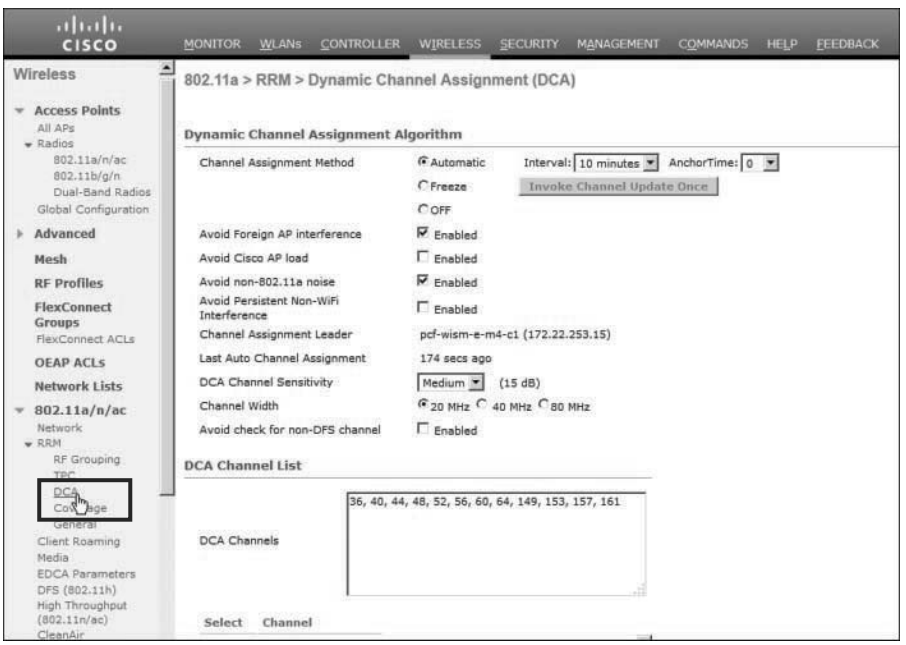


Figure 13-12 *Adjusting the RRM DCA Algorithm Parameters*

Coverage Hole Detection Mitigation

The TPC algorithm normally reduces AP transmit power levels to make cell sizes appropriate. Sometimes you might find that your best intentions at providing RF coverage with a good AP layout still come up short. For example, you might discover that signals are weak in some small area of a building due to the building construction or surrounding obstacles. You might also have an AP radio that happens to fail, causing a larger coverage hole. How would you discover such a condition? You could make a habit of surveying the RF coverage often. More likely, your wireless users will discover a weakness or hole in the coverage and complain to you about it.

A Cisco controller-based wireless network offers an additional RRM algorithm that can detect coverage holes and take action to address them. Coverage hole detection mitigation (CHDM) can alert you to a hole that it has discovered and it can increase an AP's transmit power level to compensate for the hole.

CHDM is useful in two cases:

- Extending coverage in a weak area
- Rapidly healing a coverage hole caused by an AP or radio failure, sooner than the TPC algorithm can detect and correct

The algorithm does not run at regular intervals like TPC and DCA do. Instead, it monitors the RF conditions of wireless clients and decides when to take action. In effect, the algorithm leverages your wireless users who are out in the field and tries to notice a problem before they do.

Every controller maintains a database of associated clients and their RSSI and signal-to-noise ratio (SNR) values. It might seem logical to think that a low RSSI or SNR would mean a client is experiencing a hole in coverage. Assuming the client and its AP are using the same transmit power levels, if the AP is receiving the client at a low level, the client must also be receiving the AP at a low level. This might not be true at all; the client might just be exiting the building and getting too far away from the AP. The client might also have a "sticky" roaming behavior, where it maintains an association with one AP until the RSSI falls to a very low level before reassociating elsewhere.

CHDM tries to rule out conditions that are experienced by small numbers of clients and signal conditions due to client roaming behavior. A valid coverage hole is detected when some number of clients, all associated to the same AP, have RSSI values that fall below a threshold. In addition, the coverage hole condition must exist longer than a threshold of time without the client roaming to a different AP.

Key Topic

By default, the following conditions must all be met for a coverage hole to be detected:

- Client RSSI at the AP is at or below –80 dBm.
- The low RSSI condition must last at least 60 seconds over the past 180 seconds.
- The condition must affect at least three clients or more than 25 percent of the clients on a single AP.

Be aware that CHDM runs on a per-band basis. Unlike TPC and DCA, which operate on the entire RF group of controllers, CHDM runs on each controller independently, on a per-AP radio basis.

You can display and configure the CHDM thresholds by selecting **Wireless > 802.11a/n/ac** or **802.11b/g/n > RRM > Coverage**. Figure 13-13 shows the threshold parameters for the 5-GHz 802.11a band.

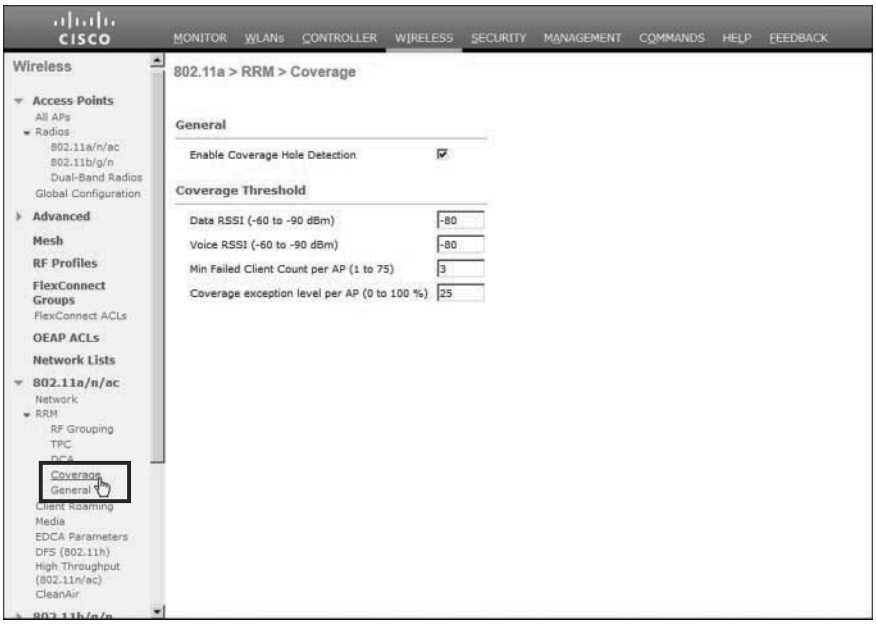


Figure 13-13 *Displaying Coverage Threshold Parameters for the 5-GHz 802.11a Band*

Manual RF Configuration

You might sometimes want to keep RRM from changing the RF conditions in parts of your wireless network. For instance, you might have client devices that operate at a fixed transmit power level. Ideally, the AP and client power levels should be identical or matched. If RRM raises or lowers AP power levels at a later time, then asymmetric power levels would result.

You can override RRM on a per-AP basis by selecting **Wireless > Access Points > Radios > 802.11a/n/ac** or **802.11b/g/n**. From the list of APs displayed, choose a specific AP and select the drop-down menu at the far-right side of the list. From this menu, select **Configure**, as shown in Figure 13-14.

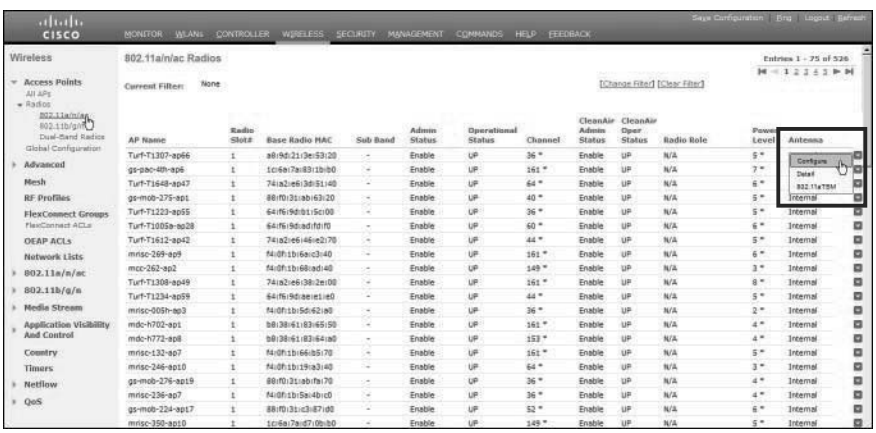


Figure 13-14 *Selecting an AP for Manual Configuration*

On the AP configuration page, as shown in Figure 13-15, you can set the channel under RF Channel Assignment or the transmit power under Tx Power Level Assignment. By default, the **Global** radio button is selected for each, which allows the value to be determined globally within the RF group. You can set a specific channel or power level by selecting the **Custom** radio button and then choosing a value from the drop-down list. In the figure, the AP's transmit power level has been manually set to 3.

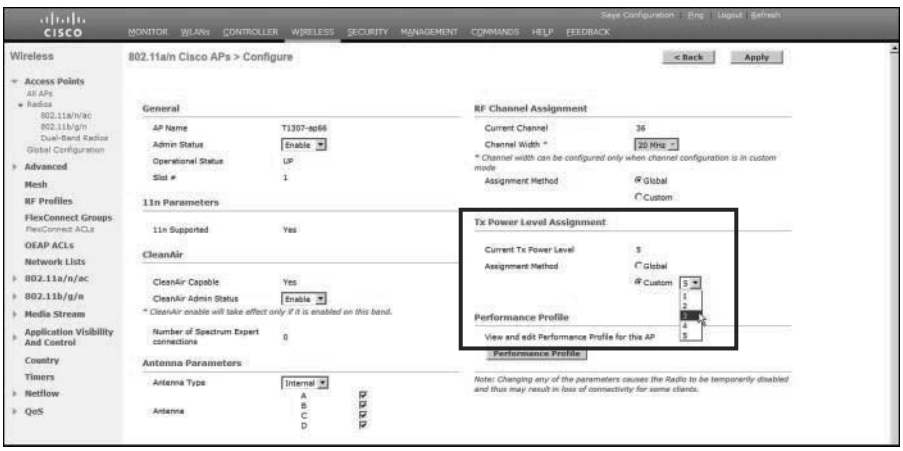


Figure 13-15 *Manually Setting the Transmit Power Level of an AP*

Tip You should let RRM automatically adjust both channels and transmit power levels whenever possible.

Verifying RRM Results

The RRM algorithms can either run at regular intervals or on demand. You can display the channel number and transmit power level that are being used on every AP by selecting **Wireless > Access Points > Radios > 802.11a/n/ac** or **802.11b/g/n**, as shown in Figure 13-15. The controller displays an asterisk next to values that have been set through RRM. Otherwise, if no asterisk appears, the value has been set manually.

To get a much better feel for the RRM results, you can use the Cisco Prime Infrastructure management system (covered in Chapter 18, "Managing Cisco Wireless Networks") to view APs on a graphical representation of an area. The map in Figure 13-16 displays each AP's location on a building floor plan, along with its channel number and transmit power level for the 2.4-GHz band. Figure 13-17 shows the same map for the 5-GHz band. Seeing the physical arrangement of APs and their cells can help you get a much better idea how the channels are assigned and reused.

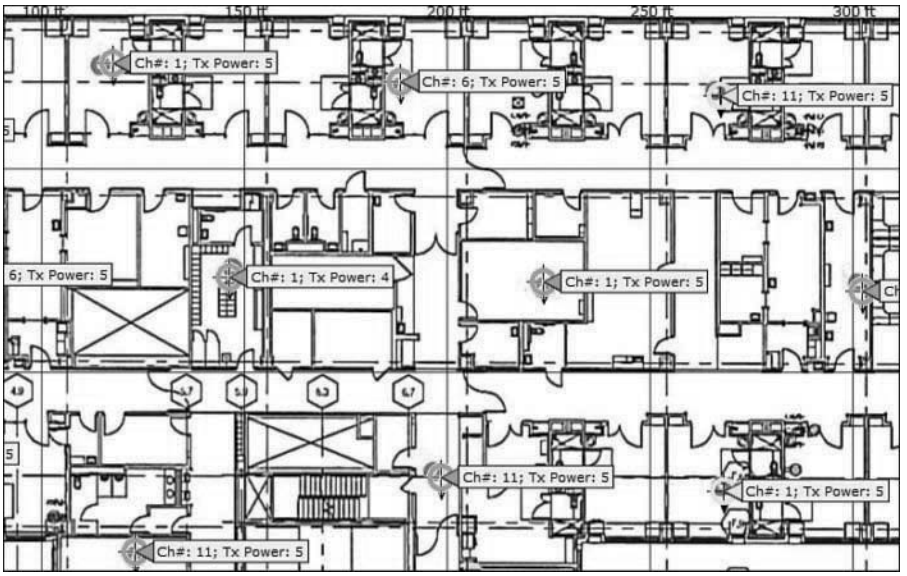


Figure 13-16 *Displaying 2.4-GHz RRM Results in Cisco Prime Infrastructure Maps*

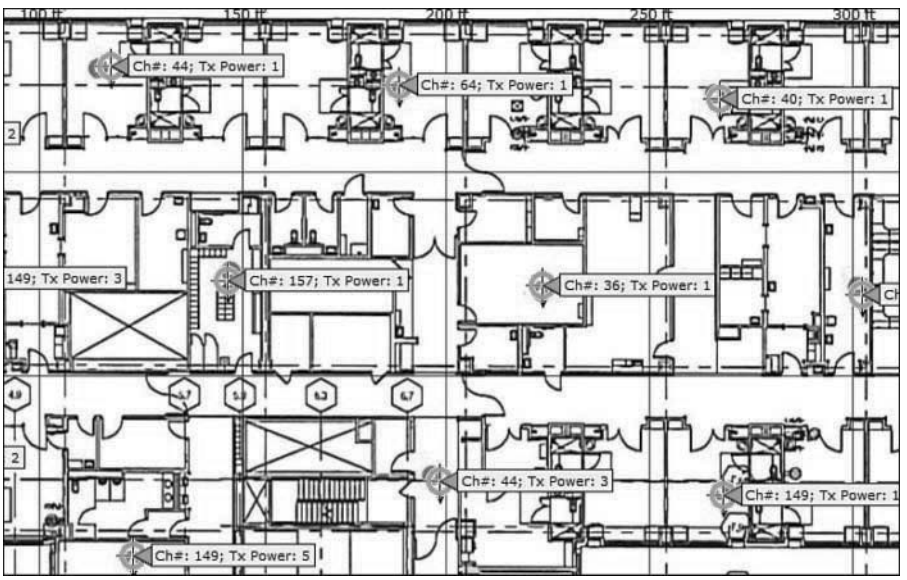


Figure 13-17 *Displaying 5-GHz RRM Results in Cisco Prime Infrastructure Maps*

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 21, "Final Review," and the exam simulation questions on the DVD.

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 13-4 lists a reference of these key topics and the page numbers on which each is found.

Key Topic

Table 13-4 Key Topics for Chapter 13

Key Topic Element	Description	Page Number
List	Data rate states	309
Figure 13-7	RF group formation	314
Figure 13-9	TPC operation	315
Table 13-2	AP transmit power level numbers	317
Figure 13-11	DCA operation	318
List	Coverage hole detection criteria	321

Define Key Terms

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

coverage hole, dynamic channel allocation (DCA), mandatory data rate, Radio Resource Management (RRM), RF group, RF group leader, supported data rate, transmit power control (TPC)

Index

Symbols

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X – Z