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Wendell Odom

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Wendell Odom, CCIE No. 1624 (Emeritus), has been in the networking industry since 1981. He has worked as a network engineer, consultant, systems engineer, instructor, and course developer; he currently works writing and creating certification study tools. This book is his 27th edition of some product for Pearson, and he is the author of all editions of the CCNA R&S and CCENT Cert Guides from Cisco Press. He has written books about topics from networking basics, certification guides throughout the years for CCENT, CCNA R&S, CCNA DC, CCNP ROUTE, CCNP QoS, and CCIE R&S. He helped develop the popular Pearson Network Simulator. He maintains study tools, links to his blogs, and other resources at www.certskills.com.

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Dedications

For Hannah Grace Odom, my wonderful daughter:

Tomato softball, equiangular equilateral quadrilaterals, being Jesus's hands and feet, wasabi, smart brain and a bigger heart, movies while other kids are at school, Underdog stories, math homework—hooray!, singing scat. Love you, precious girl.

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As for technical editors, ho hum, Elan Beer did his usual amazing job. It is truly abnormal to find one person who can do all aspects of technical editing in the same pass, with excellence. From finding small technical errors, to noticing phrasing that might mislead, to suggesting where an extra thought or two rounds out a topic, Elan does it all. Fantastic job as usual; thanks, Elan.

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Welcome and thanks to a new team member, Lisa Matthews, new at least in terms of someone I interact with during the writing process. Lisa handled all the practice app development: taking various appendixes, learning some subnetting (fun, huh Lisa?), and building apps to make the practice experience more interactive. Thanks for guiding us through the process, Lisa!

I love the magic wand that is production. Presto, word docs with gobs of queries and comments feed into the machine, and out pops these beautiful books. Thanks to Sandra Schroeder, Tonya Simpson, Mandie Frank, for jumping into the fray to keep the schedule moving, and all the production team for making the magic happen. From fixing all my grammar, crummy word choices, passive-voice sentences, and then pulling the design and layout together, they do it all; thanks for putting it all together and making it look easy. And Tonya, once again getting the "opportunity" to manage two books with many elements at the same timeline, once again, the juggling act continues, and done well. Thanks for managing the whole production process again.

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and lots of mind reading of what Wendell really wanted versus what I drew poorly on my Wacom tablet. Mike came through again with some beautiful finished products. And a thanks goes out to Laura Robbins for working on helping make sure all the figures follow our color standards—standards she helped develop over several other editions of other books.

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Thanks to my wonderful wife, Kris, who helps make this sometimes challenging work lifestyle a breeze. I love walking this journey with you, doll. Thanks to my daughter Hannah (see dedication). And thanks to Jesus Christ, Lord of everything in my life.

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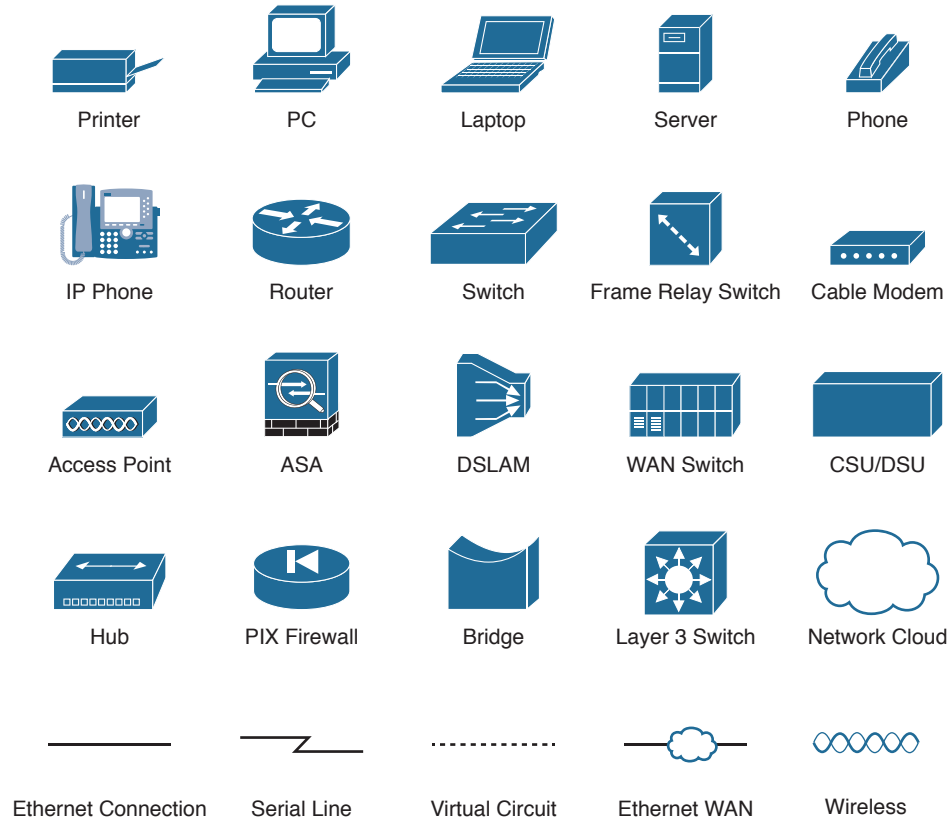

Command Syntax Conventions

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

About the Exams

Congratulations! If you're reading far enough to look at this book's Introduction, you've probably already decided to go for your Cisco certification. If you want to succeed as a technical person in the networking industry at all, you need to know Cisco. Cisco has a ridiculously high market share in the router and switch marketplace, with more than 80 percent market share in some markets. In many geographies and markets around the world, networking equals Cisco. If you want to be taken seriously as a network engineer, Cisco certification makes perfect sense.

The Exams to Achieve CCENT and CCNA R&S

Cisco announced changes to the CCENT and CCNA Routing and Switching certifications, and the related 100-105 ICND1, 200-105 ICND2, and 200-125 CCNA exams, early in the year 2016. Most everyone new to Cisco certifications begins with either CCENT or CCNA Routing and Switching (CCNA R&S). However, the paths to certification are not quite obvious at first.

The CCENT certification requires a single step: pass the ICND1 exam. Simple enough.

Cisco gives you two options to achieve CCNA R&S certification, as shown in Figure I-1: pass both the ICND1 and ICND2 exams, or just pass the CCNA exam. Both paths cover the same exam topics, but the two-exam path does so spread over two exams rather than one. You also pick up the CCENT certification by going through the two-exam path, but you do not when working through the single-exam option.

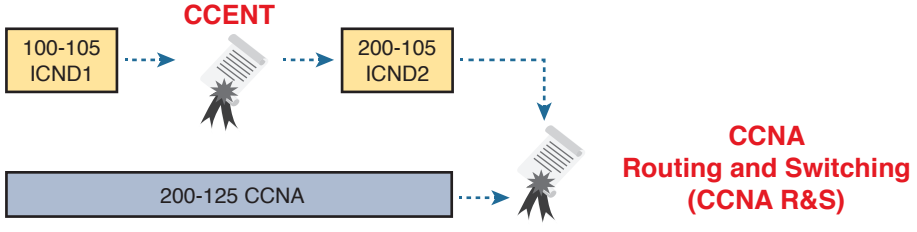

Figure I-1 *Cisco Entry-Level Certifications and Exams*

Note that Cisco has begun referencing some exams with a version number on some of their web pages. If that form holds true, the exams in Figure I-1 will likely be called version 3 (or v3 for short). Historically, the 200-125 CCNA R&S exam is the seventh separate version of the exam (which warrants a different exam number), dating back to 1998. To make sure you reference the correct exam, when looking for information, using forums, and registering for the test, just make sure to use the correct exam number as shown in the figure.

Types of Questions on the Exams

The ICND1, ICND2, and CCNA exams all follow the same general format. At the testing center, you sit in a quiet room with a PC. Before the exam timer begins, you have a chance to do a few other tasks on the PC; for instance, you can take a sample quiz just to get accustomed to the PC and the testing engine. Anyone who has user-level skills in

getting around a PC should have no problems with the testing environment. The question types are

- Multiple-choice, single-answer
- Multiple-choice, multiple-answer
- Testlet (one scenario with multiple multi-choice questions)
- Drag-and-drop
- Simulated lab (sim)
- Simlet

Before taking the test, learn the exam user interface by using the Cisco Exam Tutorial. To find the Cisco Certification Exam Tutorial, search for "exam tutorial" at www.cisco.com. This tool walks through each type of question Cisco may ask on the exam.

Although the first four types of questions in the list should be somewhat familiar from other tests in school, the last two are more common to IT tests and Cisco exams in particular. Both use a network simulator to ask questions, so that you control and use simulated Cisco devices. In particular:

Sim questions: You see a network topology, a lab scenario, and can access the devices. Your job is to fix a problem with the configuration.

Simlet questions: This style combines sim and testlet question formats. Like a sim question, you see a network topology, a lab scenario, and can access the devices. However, like a testlet, you also see multiple multiple-choice questions. Instead of changing/fixing the configuration, you answer questions about the current state of the network.

These two question styles with the simulator give Cisco the ability to test your configuration skills with sim questions, and your verification and troubleshooting skills with simlet questions.

What's on the CCNA Exams—And What's in the Book?

Ever since I was in grade school, whenever the teacher announced that we were having a test soon, someone would always ask, "What's on the test?" Even in college, people would try to get more information about what would be on the exams. At heart, the goal is to know what to study hard, what to study a little, and what to not study at all.

You can find out more about what's on the exam from two primary sources: this book and from the Cisco website.

The Cisco Published Exam Topics

First, Cisco tells the world the specific topics on each of their exams. Cisco wants the public to know both the variety of topics, and an idea about the kinds of knowledge and skills required for each topic, for every Cisco certification exam. Just go to www.cisco.com/go/certifications, look for the CCENT and CCNA Routing and Switching pages, and navigate until you see the exam topics in Appendix R, "Exam Topic Cross Reference." This PDF appendix lists two cross references: one with a list of the exam topics and the chapters that include something about each topic, as well as the reverse: a list of chapters, with the exam topics included in each chapter.

Cisco does more than just list the topic (for example, IPv4 addressing), but they also list the depth to which you must master the topic. The primary exam topics each list one or more verbs that describe the skill level required. For example, consider the following exam topic, which describes one of the most important topics in both CCENT and CCNA R&S:

Configure, verify, and troubleshoot IPv4 addressing and subnetting

Note that this one exam topic has three verbs (configure, verify, and troubleshoot). So, you should be able to not only configure IPv4 addresses and subnets, but you should understand them well enough to verify that the configuration works, and to troubleshoot problems when it is not working. And if to do that, you need to understand concepts, and you need to have other knowledge, those details are implied. The exam questions will attempt to assess whether you can configure, verify, and troubleshoot.

Note that the list of exam topics provides a certain level of depth. For example, the ICND1 100-105 exam topic list has 41 primary exam topics (topics with verbs), plus additional subtopics that further define that technology area.

You should take the time to not only read the exam topics, but read the short material above the exam topics as listed at the Cisco web page for each certification and exam. Look for notices about the use of unscored items, and the fact that Cisco intends the exam topics to be a set of general guidelines for the exams.

This Book: About the Exam Topics

This book provides a complete study system for the Cisco published exam topics for the ICND1 100-105 exam. All the topics in this book either directly relate to some ICND1 exam topic or provide more basic background knowledge for some exam topic. The scope of the book is based on the exam topics.

For those of you thinking more specifically about the CCNA R&S certification and the CCNA 200-125 single-exam path to CCNA, this book covers about one-half of the CCNA exam topics. The ICND1 book (and ICND1 100-105 exam topics) covers about half of the topics listed for the CCNA 200-125 exam, and the ICND2 book (and the ICND2 200-105 exam topics) cover the other half. In short, for content, CCNA = ICND1 + ICND2.

Book Features

This book, and the similar *CCNA Routing and Switching ICND2 200-105 Official Cert Guide*, go beyond what you would find in a simple technology book. These books give you a study system designed to help you not only learn facts but also to develop the skills need to pass the exams. To do that, in the technology chapters of the book, about three-quarters of the chapter is about the technology, and about one-quarter is for the related study features.

The "Foundation Topics" section of each chapter contains rich content to explain the topics on the exam and to show many examples. This section makes extensive use of figures, with lists and tables for comparisons. It also highlights the most important topics in each chapter as key topics, so you know what to master first in your study.

Most of the book's features tie in some way to the need to study beyond simply reading the "Foundation Topics" section of each chapter. The rest of this section works through these book features. And because the book organizes your study by chapter, and then by part (a part contains multiple chapters), and then a final review at the end of the book, this Introduction discusses the book features introduced by chapter, part, and for final review.

Chapter Features and How to Use Each Chapter

Each chapter of this book is a self-contained short course about one small topic area, organized for reading and study, as follows:

"Do I Know This Already?" quizzes: Each chapter begins with a prechapter quiz.

Foundation Topics: This is the heading for the core content section of the chapter.

Chapter Review: This section includes a list of study tasks useful to help you remember concepts, connect ideas, and practice skills-based content in the chapter.

Figure I-2 shows how each chapter uses these three key elements. You start with the DIKTA quiz. You can use the score to determine whether you already know a lot, or not so much, and determine how to approach reading the Foundation Topics (that is, the technology content in the chapter). When finished, use the chapter review tasks to start working on mastering your memory of the facts and skills with configuration, verification, and troubleshooting.

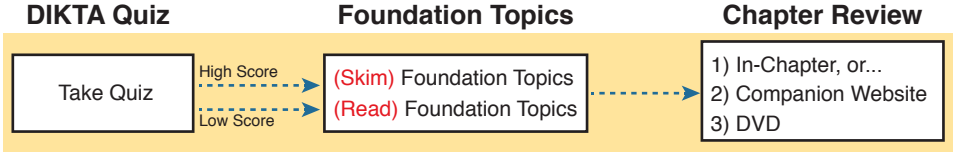

Figure I-2 *Three Primary Tasks for a First Pass Through Each Chapter*

In addition to these three main chapter features, each "Chapter Review" section uses a variety of other book features, including the following:

- **Review Key Topics:** Inside the "Foundation Topics" section, the Key Topic icon appears next to the most important items, for the purpose of later review and mastery. While all content matters, some is, of course, more important to learn, or needs more review to master, so these items are noted as key topics. The chapter review lists the key topics in a table; scan the chapter for these items to review them.
- **Complete Tables from Memory:** Instead of just rereading an important table of information, some tables have been marked as memory tables. These tables exist in the Memory Table app that is available on the DVD and from the companion website. The app shows the table with some content removed, and then reveals the completed table, so you can work on memorizing the content.
- **Key Terms You Should Know:** You do not need to be able to write a formal definition of all terms from scratch. However, you do need to understand each term well enough to understand exam questions and answers. The chapter review lists the key terminology from the chapter. Make sure you have a good understanding of each term, and use the DVD Glossary to cross-check your own mental definitions.
- **Labs:** Many exam topics use verbs list "configure," "verify," and "troubleshoot"; all these refer to skills you should practice at the user interface (CLI) of a router or switch. The chapter review refers you to these other tools. The Introduction's upcoming section titled "About Building Hands-On Skills" discusses your options.

- **Command References:** Some book chapters cover a large amount of router and switch commands. The chapter review includes reference tables for the command used in that chapter, along with an explanation. Use these tables for reference, but also use them for study—just cover one column of the table, and see how much you can remember and complete mentally.
- **Review DIKTA Questions:** Although you have already seen the DIKTA questions from the chapters in a part, re-answering those questions can prove a useful way to review facts. The part review suggests that you repeat the DIKTA questions, but using the Pearson IT Certification Practice Test (PCPT) exam software that comes with the book, for extra practice in answering multiple choice questions on a computer.
- **Subnetting and Other Process Exercises:** Many chapters in the ICND1 book ask you to perform various tasks that use math or use a particular process. The chapter review asks you to do additional practice problems as found in DVD-only PDF appendixes.

Part Features and How to Use Part Review

The book organizes the chapters into parts. Each part contains a number of related chapters. Figure I-3 lists the titles of the parts and the chapters in those parts (by chapter number).

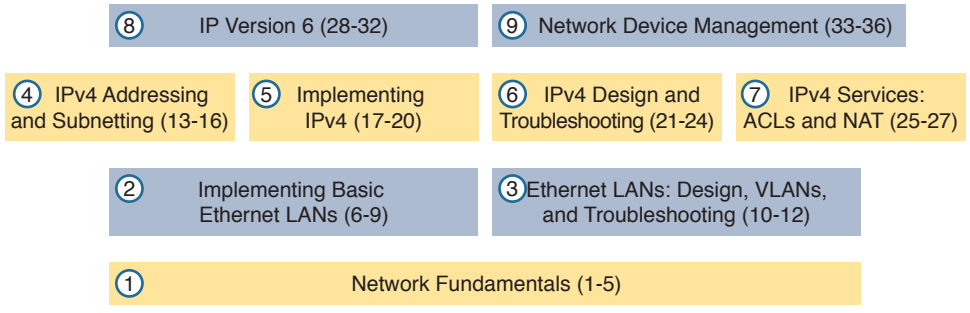

Figure I-3 *The Book Parts (by Title), and Chapter Numbers in Each Part*

Each book part ends with a "Part Review" section that contains a list of activities for study and review, much like the "Chapter Review" section at the end of each chapter. However, because the part review takes place after completing a number of chapters, the part review includes some tasks meant to help pull the ideas together from this larger body of work. The following list explains the types of tasks added to part review beyond the types mentioned for chapter review:

- **Answer Part Review Questions:** The books comes with exam software and databases on questions. One database holds questions written specifically for part review. These questions tend to connect multiple ideas together, to help you think about topics from multiple chapters, and to build the skills needed for the more challenging analysis questions on the exams.
- **Mind Maps:** Mind maps are graphical organizing tools that many people find useful when learning and processing how concepts fit together. The process of creating mind maps helps you build mental connections. The part review elements make use of mind maps in several ways: to connect concepts and the related configuration commands, to connect **show** commands and the related networking concepts, and even to connect terminology. (For more information about mind maps, see the section "About Mind Maps.")

- **Labs:** The "Part Review" section will direct you to the kinds of lab exercises you should do with your chosen lab product, labs that would be more appropriate for this stage of study and review. (Check out the section "About Building Hands-On Skills" for information about lab options.)

In addition to these tasks, many "Part Review" sections have you perform other tasks with book features mentioned in the "Chapter Review" section: repeating DIKTA quiz questions, reviewing key topics, and doing more lab exercises.

Final Review

The "Final Review" chapter at the end of this book lists a series of preparation tasks that you can best use for your final preparation before taking the exam. The "Final Review" chapter focuses on a three-part approach to helping you pass: practicing your skills, practicing answering exam questions, and uncovering your weak spots. To that end, the "Final Review" chapter uses the same familiar book features discussed for the chapter review and part review elements, along with a much larger set of practice questions.

Other Features

In addition to the features in each of the core chapters, this book, as a whole, has additional study resources, including the following:

- **DVD-based practice exam:** The companion DVD contains the powerful Pearson IT Certification Practice Test (PCPT) exam engine. You can take simulated ICND1 exams with the DVD and activation code included in this book. (You can take simulated ICND2 and CCNA R&S exams with the DVD in the *CCNA Routing and Switching ICND2 200-105 Official Cert Guide*.)
- **CCENT ICND1 100-105 Network Simulator Lite:** This lite version of the best-selling CCNA Network Simulator from Pearson provides you with a means, right now, to experience the Cisco command-line interface (CLI). No need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the DVD in the back of this book.
- **eBook:** If you are interested in obtaining an eBook version of this title, we have included a special offer on a coupon card inserted in the DVD sleeve in the back of the book. This offer enables you to purchase the *CCENT/CCNA ICND1 100-105 Official Cert Guide Premium Edition eBook and Practice Test* at a 70 percent discount off the list price. In addition to three versions of the eBook, PDF (for reading on your computer), EPUB (for reading on your tablet, mobile device, or Nook or other eReader), and Mobi (the native Kindle version), you also receive additional practice test questions and enhanced practice test features.
- **Subnetting videos:** The companion DVD contains a series of videos that show you how to calculate various facts about IP addressing and subnetting (in particular, using the shortcuts described in this book).
- **Subnetting practice:** The companion DVD contains five appendixes (D–H) with a set of subnetting practice problems and answers. This is a great resource to practice building subnetting skills. You can also do these same practice problems with applications that you can access from the DVD or the companion web site.

- **Other practice:** The companion DVD contains four other appendixes (I–K) that each contain other practice problems related to a particular chapter from the book. Use these for more practice on the particulars with some of the math- and process-oriented activities in the chapters. You can also do these same practice problems with applications that you can access from the DVD or the companion website.
- **Mentoring videos:** The DVD included with this book includes four other instructional videos, about the following topics: switch basics, CLI navigation, router configuration, and VLANs.
- **Companion website:** The website www.ciscopress.com/title/9781587205804 posts up-to-the-minute materials that further clarify complex exam topics. Check this site regularly for new and updated postings written by the author that provide further insight into the more troublesome topics on the exam.
- **PearsonITCertification.com:** The website www.pearsonitcertification.com is a great resource for all things IT-certification related. Check out the great CCNA articles, videos, blogs, and other certification preparation tools from the industry's best authors and trainers.
- **CCNA Simulator:** If you are looking for more hands-on practice, you might want to consider purchasing the CCNA Network Simulator. You can purchase a copy of this software from Pearson at http://pearsonitcertification.com/networksimulator or other retail outlets. To help you with your studies, I have created a mapping guide that maps each of the labs in the simulator to the specific sections in these CCNA cert guides. You can get this mapping guide for free on the Extras tab of the companion website.
- **Author's website and blogs:** The author maintains a website that hosts tools and links useful when studying for CCENT and CCNA. The site lists information to help you build your own lab, study pages that correspond to each chapter of this book and the ICND1 book, and links to the author's CCENT Skills blog and CCNA Skills blog. Start at www.certskills.com; look to blog.certskills.com for a page about the blogs in particular, with links to the pages with the labs related to this book.

A Big New Feature: Review Applications

One of the single biggest additions to this edition of the book is the addition of study apps for many of the chapter review activities. In the past, all chapter review activities use the book chapter, or the chapter plus a DVD-only appendix. Readers tell us they find that content useful, but the content is static.

This book (and the *CCNA Routing and Switching ICND2 200-105 Official Cert Guide*) are the first Cisco Press Cert Guides with extensive interactive applications. Basically, most every activity that can be done at chapter review can now be done with an application. The applications can be found both on the DVD that comes with the book and on the book's companion website.

The advantages of using these apps are as follows:

- **Easier to use:** Instead of having to print out copies of the appendixes and do the work on paper, these new apps provide you with an easy to use, interactive experience that you can easily run over and over.
- **Convenient:** When you have a spare 5–10 minutes, go to the book's website, and review content from one of your recently finished chapters.

- **Untethered from Book/DVD:** Because these apps are available on the book's companion web page in addition to the DVD, you can access your review activities from anywhere—no need to have the book or DVD with you.
- **Good for tactile learners:** Sometimes looking at a static page after reading a chapter lets your mind wander. Tactile learners may do better by at least typing answers into an app, or clicking inside an app to navigate, to help keep you focused on the activity.

Our in-depth reader surveys show that readers who use the chapter review tools like them, but that not everyone uses the "Chapter Review" sections consistently. So, we want to increase the number of people using the review tools, and make them both more useful and more interesting. Table I-1 summarizes these new applications and the traditional book features that cover the same content.

Table I-1 Book Features with Both Traditional and App Options

Feature	Traditional	App
Key Topic	Table with list; flip pages to find	Key Topics Table app
Config Checklist	Just one of many types of key topics	Config Checklist app
Memory Table	Two static PDF appendixes (one with sparse tables for you to complete, one with completed tables)	Memory Table app
Key Terms	Listed in each "Chapter Review" section, with the Glossary in the back of the book	Glossary Flash Cards app
Subnetting Practice	Appendixes D–H, with practice problems and answers	A variety of apps, one per problem type
Other Practice	Appendixes I–K with practice problems and answers	A variety of apps, one per problem type

How to Get the Electronic Elements of This Book

Traditionally, all chapter review activities use the book chapter plus appendixes, with the appendixes often being located on the DVD. But most of that content is static: useful, but static.

If you buy the print book, and have a DVD drive, you have all the content on the DVD. Just spin the DVD and use the disk menu that should automatically start to explore all content.

If you buy the print book but do not have a DVD drive, you can get the DVD files by registering your book on the Cisco Press website. To do so, simply go to www.ciscopress.com/register and enter the ISBN of the print book: 9781587205804. After you have registered your book, go to your account page and click the **Registered Products** tab. From there, click the **Access Bonus Content** link to get access to the book's companion website.

If you buy the Premium Edition eBook and Practice Test from Cisco Press, your book will automatically be registered on your account page. Simply go to your account page, click the **Registered Products** tab, and select **Access Bonus Content** to access the book's companion website.

If you buy the eBook from some other bookseller, the very last page of your eBook file will contain instructions for how to register the book and access the companion website. The steps are the same as noted earlier for those who buy the print book but do not have a DVD drive.

Book Organization, Chapters, and Appendixes

This book contains 36 core chapters, Chapters 1 through 36, with Chapter 37 as the "Final Review" chapter. Each core chapter covers a subset of the topics on the ICND1 exam. The core chapters are organized into sections. The core chapters cover the following topics:

- **Part I: Networking Fundamentals**
  - **Chapter 1, "Introduction to TCP/IP Networking,"** introduces the central ideas and terms used by TCP/IP, and contrasts the TCP/IP networking model with the OSI model.
  - **Chapter 2, "Fundamentals of Ethernet LANs,"** introduces the concepts and terms used when building Ethernet LANs.
  - **Chapter 3, "Fundamentals of WANs,"** covers the concepts and terms used for the data link layer for WANs, including HDLC.
  - **Chapter 4, "Fundamentals of IPv4 Addressing and Routing":** IP is the main network layer protocol for TCP/IP. This chapter introduces the basics of IPv4, including IPv4 addressing and routing.
  - **Chapter 5, "Fundamentals of TCP/IP Transport and Applications":** This chapter completes most of the detailed discussion of the upper two layers of the TCP/IP model (transport and application), focusing on TCP and applications.
- **Part II: Implementing Basic Ethernet LANs**
  - **Chapter 6, "Using the Command-Line Interface,"** explains how to access the text-based user interface of Cisco Catalyst LAN switches.
  - **Chapter 7, "Analyzing Ethernet LAN Switching,"** shows how to use the Cisco CLI to verify the current status of an Ethernet LAN and how it switches Ethernet frames.
  - **Chapter 8, "Configuring Basic Switch Management,"** explains how to configure Cisco switches for basic management features, such as remote access using Telnet and SSH.
  - **Chapter 9, "Configuring Switch Interfaces,"** shows how to configure a variety of switch features that apply to interfaces, including duplex/speed and port security.
- **Part III: Ethernet LANs: Design, VLANs, and Troubleshooting**
  - **Chapter 10, "Analyzing Ethernet LAN Designs,"** examines various ways to design Ethernet LANs, discussing the pros and cons, and explains common design terminology.
  - **Chapter 11, "Implementing Ethernet Virtual LANs":** This chapter explains the concepts and configuration surrounding virtual LANs, including VLAN trunking.
  - **Chapter 12, "Troubleshooting Ethernet LANs,"** focuses on how to tell whether the switch is doing what it is supposed to be doing, mainly through the use of show commands.

- **Part IV: IP Version 4 Addressing and Subnetting**
  - **Chapter 13, "Perspectives on IPv4 Subnetting,"** walks you through the entire concept of subnetting, from starting with a Class A, B, or C network to a completed subnetting design as implemented in an enterprise IPv4 network.
  - **Chapter 14, "Analyzing Classful IPv4 Networks":** IPv4 addresses originally fell into several classes, with unicast IP addresses being in Class A, B, and C. This chapter explores all things related to address classes and the IP network concept created by those classes.
  - **Chapter 15, "Analyzing Subnet Masks,"** shows how an engineer can analyze the key facts about a subnetting design based on the subnet mask. This chapter shows how to look at the mask and IP network to determine the size of each subnet and the number of subnets.
  - **Chapter 16, "Analyzing Existing Subnets":** Most troubleshooting of IP connectivity problems starts with an IP address and mask. This chapter shows how to take those two facts and find key facts about the IP subnet in which that host resides.
- **Part V: Implementing IPv4**
  - **Chapter 17, "Operating Cisco Routers,"** is like Chapter 8, focusing on basic device management, but it focuses on routers instead of switches.
  - **Chapter 18, "Configuring IPv4 Addresses and Static Routes,"** discusses how to add IPv4 address configuration to router interfaces and how to configure static IPv4 routes.
  - **Chapter 19, "Learning IPv4 Routes with RIPv2,"** explains how routers work together to find all the best routes to each subnet using a routing protocol. This chapter also shows how to configure the RIPv2 routing protocol for use with IPv4.
  - **Chapter 20, "DHCP and IP Networking on Hosts,"** discusses how hosts can be configured with their IPv4 settings, and how they can learn those settings with DHCP.
- **Part VI: IPv4 Design and Troubleshooting**
  - **Chapter 21, "Subnet Design,"** takes a design approach to subnetting. This chapter begins with a classful IPv4 network, and asks why a particular mask might be chosen, and if chosen, what subnet IDs exist.
  - **Chapter 22, "Variable-Length Subnet Masks,"** moves away from the assumption of one subnet mask per network to multiple subnet masks per network—which makes subnetting math and processes much more challenging. This chapter explains those challenges.
  - **Chapter 23, "IPv4 Troubleshooting Tools,"** focuses on how to use two key troubleshooting tools to find routing problems: the **ping** and **traceroute** commands.
  - **Chapter 24, "Troubleshooting IPv4 Routing,"** looks at the most common IPv4 problems and how to find the root causes of those problems when troubleshooting.
- **Part VII: IPv4 Services: ACLs and NAT**
  - **Chapter 25, "Basic IPv4 Access Control Lists":** This chapter examines how standard IP ACLs can filter packets based on the source IP address so that a router will not forward the packet.

- **Chapter 26, "Advanced IPv4 Access Control Lists":** This chapter examines both named and numbered ACLs, and both standard and extended IP ACLs.
- **Chapter 27, "Network Address Translation,"** works through the complete concept, configuration, verification, and troubleshooting sequence for the router NAT feature, including how it helps conserve public IPv4 addresses.

- **Part VIII: IP Version 6**
  - **Chapter 28, "Fundamentals of IP Version 6,"** discusses the most basic concepts of IP version 6, focusing on the rules for writing and interpreting IPv6 addresses.
  - **Chapter 29, "IPv6 Addressing and Subnetting,"** works through the two branches of unicast IPv6 addresses—global unicast addresses and unique local addresses—that act somewhat like IPv4 public and private addresses, respectively.
  - **Chapter 30, "Implementing IPv6 Addressing on Routers,"** shows how to configure IPv6 routing and addresses on routers, while discussing a variety of special IPv6 addresses.
  - **Chapter 31, "Implementing IPv6 Addressing on Hosts,"** mirrors Chapter 20's discussions of IPv4 on hosts, while adding details of how IPv6 uses Stateless Address Auto Configuration (SLAAC).
  - **Chapter 32, "Implementing IPv6 Routing,"** shows how to add static routes to an IPv6 router's routing table.
- **Part IX: Network Device Management**
  - **Chapter 33, "Device Management Protocols,"** discusses the concepts and configuration of some common network management tools: syslog, NTP, CDP, and LLDP.
  - **Chapter 34, "Device Security Features,"** takes the discussion of device passwords a step deeper, and examines how to better secure devices through device hardening.
  - **Chapter 35, "Managing IOS Files,"** explains the IOS file system, focusing on key files like the IOS and configuration files. The chapter shows how to upgrade IOS and to backup/restore the configuration file.
  - **Chapter 36, "IOS License Management,"** discusses the Cisco per-device license management practices through the use of PAK licensing.
- **Part X: Final Review**
  - **Chapter 37, "Final Review,"** suggests a plan for final preparation after you have finished the core parts of the book.
- **Part XI: Appendixes (In Print)**
  - **Appendix A, "Numeric Reference Tables,"** lists several tables of numeric information, including a binary-to-decimal conversion table and a list of powers of 2.
  - **Appendix B, "CCENT/CCNA ICND1 100-105 Exam Updates,"** is a place for the author to add book content mid-edition. Always check online for the latest PDF version of this appendix; the appendix lists download instructions.
  - The **Glossary** contains definitions for all the terms listed in the "Key Terms You Should Know" sections at the conclusion of Chapters 1 through 36.

- **Part XII: DVD Appendixes**

  The following appendixes are available in digital format on the DVD that accompanies this book:

  - **Appendix C, "Answers to the 'Do I Know This Already?' Quizzes,"** includes the explanations to all the questions from Chapters 1 through 36.
  - **Appendix D, "Practice for Chapter 14: Analyzing Classful IPv4 Networks"**
  - **Appendix E, "Practice for Chapter 15: Analyzing Subnet Masks"**
  - **Appendix F, "Practice for Chapter 16: Analyzing Existing Subnets"**
  - **Appendix G, "Practice for Chapter 21: Subnet Design"**
  - **Appendix H, "Practice for Chapter 22: Variable-Length Subnet Masks"**
  - **Appendix I, "Practice for Chapter 25: Basic IPv4 Access Control Lists"**
  - **Appendix J, "Practice for Chapter 28: Fundamentals of IP Version 6"**
  - **Appendix K, "Practice for Chapter 30: Implementing IPv6 Addressing on Routers"**
  - **Appendix L, "Mind Map Solutions,"** shows an image of sample answers for all the part-ending mind map exercises.
  - **Appendix M, "Study Planner,"** is a spreadsheet with major study milestones, where you can track your progress through your study.
  - **Appendix N, "Classless Inter-domain Routing,"** is an extra chapter for anyone interested in reading more about the concepts, terminology, and math related to CIDR.
  - **Appendix O, "Route Summarization,"** is a copy of a chapter that was in the previous edition of this book, but was removed for this edition. It is included here for anyone who has interest, and for instructors who may need the chapter for their existing course.
  - **Appendix P, "Implementing Point-to-Point WANs,"** is a copy of the ICND2 book's chapter about serial WANs. In a lab environment, you may want to use serial WAN links, and you may not have a copy of the ICND2 book. I included this chapter for reference if you need a little more depth about serial links.
  - **Appendix Q, "Topics from Previous Editions,"** is a collection of information about topics that have appeared on previous versions of the CCNA exams. While no longer within this exam's topics, the concepts are still of interest to someone with the CCENT or CCNA certification.
  - **Appendix R, "Exam Topics Cross Reference,"** provides some tables to help you find where each exam objectives is covered in the book.

Reference Information

This short section contains a few topics available for reference elsewhere in the book. You may read these when you first use the book, but you may also skip these topics and refer back to them later. In particular, make sure to note the final page of this introduction, which lists several contact details, including how to get in touch with Cisco Press.

Install the Pearson IT Certification Practice Test Engine and Questions

This book, like many other Cisco Press books, includes the rights to use the Pearson IT Certification Practice Test (PCPT) software, along with rights to use some exam questions related to this book. PCPT allows has many options, including the option to answer

questions in study mode, so you can see the answers and explanations for each question as you go along, or to take a simulated exam that mimics real exam conditions, or to view questions in flash card mode, where all the answers are stripped out, challenging you to answer questions from memory.

You should install PCPT so it is ready to use even for the earliest chapters. This book's Part Review sections ask you specifically to use PCPT, and you can even take the DIKTA chapter pre-quizzes using PCPT.

NOTE The right to use the exams associated with this book is based on an activation code. For those with a print book, the code is in the DVD sleeve at the back of the book. For those who purchase the Premium Edition eBook and Practice Test directly from the Cisco Press website, the code will be populated on your account page after purchase. For those who purchase a Kindle edition, the access code will be supplied directly from Amazon. Note that if you purchase an eBook version from any other source, the practice test is not included, as other vendors are not able to vend the required unique access code. *Do not lose the activation code.*

NOTE Also on this same piece of paper, on the opposite side from the exam activation code, you will find a one-time-use coupon code that gives you 70 percent off the purchase of the *CCENT/CCNA ICND1 100-105 Official Cert Guide, Premium Edition eBook and Practice Test*.

PCPT Exam Databases with This Book

This book includes an activation code that allows you to load a set of practice questions. The questions come in different exams or exam databases. When you install the PCPT software and type in the activation code, the PCPT software downloads the latest version of all these exam databases. And with the ICND1 book alone, you get four different "exams," or four different sets of questions, as listed in Figure I-4.

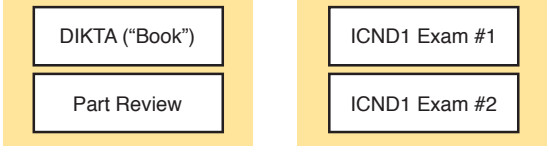

Figure I-4 *PCPT Exams/Exam Databases and When to Use Them*

You can choose to use any of these exam databases at any time, both in study mode and practice exam mode. However, many people find it best to save some of the exams until exam review time, after you have finished reading the entire book. Figure I-4 begins to suggest a plan, spelled out here:

- During part review, use PCPT to review the DIKTA questions for that part, using study mode.
- During part review, use the questions built specifically for part review (the part review questions) for that part of the book, using study mode.
- Save the remaining exams to use with the "Final Review" chapter at the end of the book.

The two modes inside PCPT give you better options for study versus practicing a timed exam event. In study mode, you can see the answers immediately, so you can study the topics more easily. Also, you can choose a subset of the questions in an exam database; for instance, you can view questions from only the chapters in one part of the book.

PCPT practice mode lets you practice an exam event somewhat like the actual exam. It gives you a preset number of questions, from all chapters, with a timed event. Practice exam mode also gives you a score for that timed event.

How to View Only DIKTA Questions by Chapter or Part

Most chapters begin with a "Do I Know This Already?" (DIKTA) quiz. You can take the quiz to start a chapter, take it again during chapter review for more practice, and the "Part Review" sections even suggest that you repeat the questions from all chapters in that part.

You can use the DIKTA quiz as printed in the book, or use the PCPT software. The book lists the questions, with the letter answers on the page following the quiz. Appendix C, on the DVD, lists the answers along with an explanation; you might want to keep that PDF handy.

Using PCPT for these questions has some advantages. It gives you a little more practice in how to read questions from testing software. Also, the explanations to the questions are conveniently located in the PCPT software.

To view these DIKTA questions inside the PCPT software, you need to select **Book Questions**, which is the way PCPT references questions found inside the printed book. Then you have to deselect all chapters (with a single click), and then select one or more chapters, as follows:

Step 1. Start the PCPT software.

Step 2. From the main (home) menu, select the item for this product, with a name like *CCENT/CCNA ICND1 100-105 Official Cert Guide*, and click **Open Exam**.

Step 3. The top of the next window that appears should list some exams; check the **ICND1 Book Questions** box, and uncheck the other boxes. This selects the "book" questions (that is, the DIKTA questions from the beginning of each chapter).

Step 4. On this same window, click at the bottom of the screen to deselect all objectives (chapters). Then select the box beside each chapter in the part of the book you are reviewing.

Step 5. Select any other options on the right side of the window.

Step 6. Click **Start** to start reviewing the questions.

How to View Part Review Questions

The exam databases you get with this book include a database of questions created solely for study during the part review process. DIKTA questions focus more on facts, to help you determine whether you know the facts contained within the chapter. The part review questions instead focus more on application of those facts to typical real scenarios, and look more like real exam questions.

To view these questions, follow the same process as you did with DIKTA/book questions, but select the Part Review database rather than the book database. PCPT has a clear name for this database: Part Review Questions.

About Mind Maps

Mind maps are a type of visual organization tool that you can use for many purposes. For instance, you can use mind maps as an alternative way to take notes.

You can also use mind maps to improve how your brain organizes concepts. Mind maps improve your brain's connections and relationships between ideas. When you spend time thinking about an area of study, and organize your ideas into a mind map, you strengthen existing mental connections and create new connections, all into your own frame of reference.

In short, mind maps help you internalize what you learn.

Each mind map begins with a blank piece of paper or blank window in a mind mapping application. You then add a large central idea, with branches that move out in any direction. The branches contain smaller concepts, ideas, commands, pictures, whatever idea needs to be represented. Any concepts that can be grouped should be put near each other. As need be, you can create deeper and deeper branches, although for this book's purposes, most mind maps will not go beyond a couple of levels.

NOTE Many books have been written about mind maps, but Tony Buzan often gets credit for formalizing and popularizing mind maps. You can learn more about mind maps at his website, www.thinkbuzan.com.

For example, Figure I-5 shows a sample mind map that begins to output some of the IPv6 content from Part VIII of the ICND1 book. You might create this kind of mind map when reviewing IPv6 addressing concepts, starting with the big topic of "IPv6 addressing," and then writing down random terms and ideas. As you start to organize them mentally, you draw lines connecting the ideas, reorganize them, and eventually reach the point where you believe the organization of ideas makes sense to you.

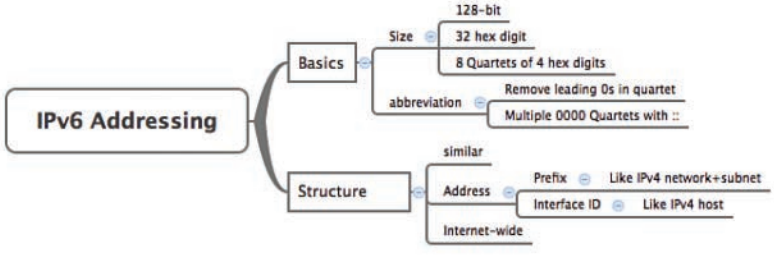

Figure I-5 *Sample Mind Map*

Mind maps may be the least popular but most effective study tool suggested in this book. I personally find a huge improvement in learning new areas of study when I mind map; I hope you will make the effort to try these tools and see if they work well for you too.

Finally, for mind mapping tools, you can just draw them on a blank piece of paper, or find and download a mind map application. I have used Mind Node Pro on a Mac, and we build the sample mind maps with XMIND, which has free versions for Windows, Linux, and OS X.

About Building Hands-On Skills

You need skills in using Cisco routers and switches, specifically the Cisco command-line interface (CLI). The Cisco CLI is a text-based command-and-response user interface; you type a command, and the device (a router or switch) displays messages in response. To answer sim and simlet questions on the exams, you need to know a lot of commands, and you need to be able to navigate to the right place in the CLI to use those commands.

This next section walks through the options of what is included in the book, with a brief description of lab options outside the book.

Config Lab Exercises

Some router and switch features require multiple configuration commands. Part of the skill you need to learn is to remember which configuration commands work together, which ones are required, and which ones are optional. So, the challenge level goes beyond just picking the right parameters on one command. You have to choose which commands to use, in which combination, typically on multiple devices. And getting good at that kind of task requires practice.

The Config Labs feature, introduced as a new feature in this edition of the book, helps provide that practice. Each lab presents a sample lab topology, with some requirements, and you have to decide what to configure on each device. The answer then shows a sample configuration. You job is to create the configuration, and then check your answer versus the supplied answer.

Also for the first time, this edition places the content not only outside the book but also onto the author's blog site. To reach my blog sites for ICND1 content or for ICND2 content (two different blogs), you can start at my blog launch site (blog.certskills.com), and click from there.

blog.certskills.com/ccent/ Wendell's CCENT (ICND1): In the menus, navigate to **Hands On… Config Lab**

blog.certskills.com/ccna/ Wendell's CCNA (ICND2): In the menus, navigate to **Hands On… Config Lab**

Both blogs are geared toward helping you pass the exams, so feel free to look around. Note that the Config Lab posts should show an image like this in the summary:

Figure I-6 *Config Lab Logo in the Author's Blogs*

These Config Labs have several benefits, including the following:

Untethered and responsive: Do them from anywhere, from any web browser, from your phone or tablet, untethered from the book or DVD.

Designed for idle moments: Each lab is designed as a 5- to 10-minute exercise if all you are doing is typing in a text editor or writing your answer on paper.

Two outcomes, both good: Practice getting better and faster with basic configuration, or if you get lost, you have discovered a topic that you can now go back and reread to complete your knowledge. Either way, you are a step closer to being ready for the exam!

Blog format: Allows easy adds and changes by me, and easy comments by you.

Self-assessment: As part of final review, you should be able to do all the Config Labs, without help, and with confidence.

Note that the blog organizes these Config Lab posts by book chapter, so you can easily use these at both chapter review and part review. See the "Your Study Plan" element that follows the Introduction for more details about those review sections.

A Quick Start with Pearson Network Simulator Lite

The decision of how to get hands-on skills can be a little scary at first. The good news: You have a free and simple first step to experience the CLI: Install and use the Pearson NetSim Lite that comes with this book.

This book comes with a lite version of the best-selling CCNA Network Simulator from Pearson, which provides you with a means, right now, to experience the Cisco CLI. No need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the DVD in the back of this book.

The labs with this latest version of NetSim Lite includes labs associated with Part II of this book. Part I includes concepts only, with Part II being the first part with commands. So, make sure and use the NetSim Lite to learn the basics of the CLI to get a good start.

Of course, one reason that NetSim Lite comes on the DVD is that the publisher hopes you will buy the full product. However, even if you do not use the full product, you can still learn from the labs that come with NetSim Lite while deciding about what options to pursue.

NOTE The ICND1 and ICND2 books each contain a different version of the Sim Lite product, each with labs that match the book content. If you bought both books, make sure you install both Sim Lite products.

The Pearson Network Simulator

The Config Labs and the Pearson Network Simulator Lite both fill specific needs, and they both come with the book. However, you need more than those two tools.

The single best option for lab work to do along with this book is the paid version of the Pearson Network Simulator. This simulator product simulates Cisco routers and switches so that you can learn for the CCENT and CCNA R&S certifications. But more importantly, it focuses on learning for the exam by providing a large number of useful lab exercises. Reader surveys tell us that those people who use the Simulator along with the book love the learning process, and rave about how the book and Simulator work well together.

Of course, you need to make a decision for yourself, and consider all the options. Thankfully, you can get a great idea of how the full Simulator product works by using the Pearson Network Simulator Lite product include with the book. Both have the same base code and same user interface, and the same types of labs. Try the Lite version, and check out the full product. There is a full product for CCENT only, and another for CCNA R&S (which includes all the labs in the CCENT product, plus others for the ICND2 parts of the content).

Note that the Simulator and the books work on a different release schedule. For a time in 2016, the Simulator will be the Simulator created for the previous versions of the exams (ICND1 100-101, ICND2 200-101, and CCNA 200-120). That product includes approximately 80 percent of the CLI topics in the ICND1 100-105 and 200-105 books. So during that time, the Simulator is still very useful.

On a practical note, when you want to do labs when reading a chapter or doing part review, the Simulator organizes the labs to match the book. Just look for "Sort by Chapter" tab in the Simulator's user interface. However, during the months in 2016 for which the Simulator is the older edition listing the older exams in the title, you will need to refer to a PDF that lists those labs versus this book's organization. You can find that PDF on the book product page under the Downloads tab here: www.ciscopress.com/title/9781587205804.

More Lab Options

If you decide against using the full Pearson Network Simulator, you still need hands-on experience. You should plan to use some lab environment to practice as much CLI as possible.

First, you can use real Cisco routers and switches. You can buy them, new or used, or borrow them at work. You can rent them for a fee. If you have the right mix of gear, you could even do the Config Lab exercises from my blog on that gear, or try and re-create examples from the book.

Cisco offers a virtualization product that lets you run router and switch operating system (OS) images in a virtual environment. This tool, the Virtual Internet Routing Lab (VIRL; http://virl.cisco.com), lets you create a lab topology, start the topology, and connect to real router and switch OS images. Check out http://virl.cisco.com for more information.

You can even rent virtual Cisco router and switch lab pods from Cisco, in an offering called Cisco Learning Labs (www.cisco.com/go/learninglabs).

All these previously mentioned options cost some money, but the next two are generally free to the user, but with a different catch for each. First, GNS3 works somewhat like VIRL, creating a virtual environment running real Cisco IOS. However, GNS3 is not a Cisco product, and cannot provide you with the IOS images for legal reasons.

Cisco also makes a simulator that works very well as a learning tool: Cisco Packet Tracer. However, Cisco intends Packet Tracer for use by people currently enrolled in Cisco Networking Academy courses, and not for the general public. So, if you are part of a Cisco Academy, definitely use Packet Tracer.

This book does not tell you what option to use, but you should plan on getting some hands-on practice somehow. The important thing to know is that most people need to practice using the Cisco CLI to be ready to pass these exams.

For More Information

If you have any comments about the book, submit them via www.ciscopress.com. Just go to the website, select **Contact Us**, and type your message.

Cisco might make changes that affect the CCNA certification from time to time. You should always check www.cisco.com/go/ccna and www.cisco.com/go/ccent for the latest details.

The *CCENT/CCNA ICND1 100-105 Official Cert Guide* helps you attain CCENT and CCNA Routing and Switching certification. This is the CCNA ICND1 certification book from the only Cisco-authorized publisher. We at Cisco Press believe that this book certainly can help you achieve CCNA certification, but the real work is up to you! I trust that your time will be well spent.

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Your Study Plan

You just got this book. You have probably already read (or quickly skimmed) the Introduction. You are probably now wondering whether to start reading here or skip ahead to Chapter 1, "Introduction to TCP/IP Networking."

Stop to read this section about how to create your own study plan for the exam(s) you plan to take (ICND1 100-105, ICND2 200-105, and/or CCNA 200-125). Your study will go much better if you take time (maybe 15 minutes) to think about a few key points about how to study before starting on this journey. That is what this section will help you do.

A Brief Perspective on Cisco Certification Exams

Cisco sets the bar pretty high for passing the ICND1, ICND2, and CCNA R&S exams. Most anyone can study and pass these exams, but it takes more than just a quick read through the book and the cash to pay for the exam.

The challenge of these exams comes from many angles. Each of these exams covers a lot of concepts and many commands specific to Cisco devices. Beyond knowledge, these Cisco exams also require deep skills. You must be able to analyze and predict what really happens in a network. You must be able to configure Cisco devices to work correctly in those networks. And you must be ready to troubleshoot problems when the network does not work correctly.

The more challenging questions on these exams work a lot like a jigsaw puzzle, but with four out of every five puzzle pieces not even in the room. To solve the puzzle, you have to mentally re-create the missing pieces. To do that, you must know each networking concept and remember how the concepts work together.

For instance, the ICND1 exam includes many troubleshooting topics. A simple question might ask you why a host cannot communicate with some server. The question would supply some of the information, like some pieces of the jigsaw puzzle, as represented with the white pieces in Figure 1. You have to apply your knowledge of IPv4 routing, IP addressing, and Ethernet LAN switching to the scenario in the question to come up with some of the other pieces of the puzzle. For a given question, some pieces of the puzzle may remain a mystery, but with enough of the puzzle filled in, you should be able to answer the question. And some pieces will just remain unknown for a given question.

These skills require that you prepare by doing more than just reading and memorizing what you read. Of course, you need to read many pages in this book to learn many individual facts and how these facts relate to each other. But a big part of this book lists exercises beyond reading, exercises that help you build the skills to solve these networking puzzles.

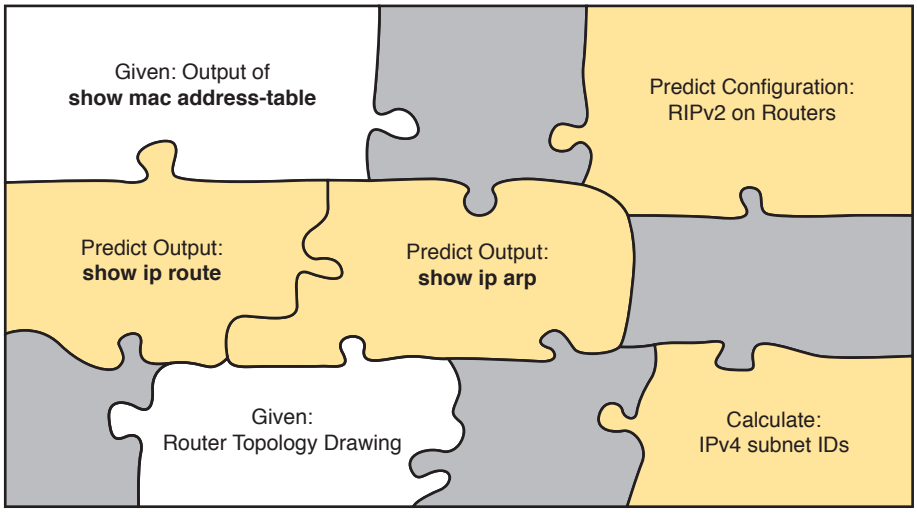

Figure 1 *Filling In Puzzle Pieces with Your Analysis Skills*

Five Study Plan Steps

These exams are challenging, but many people pass them every day. So, what do you need to do to be ready to pass, beyond reading and remembering all the facts? You need to develop skills. You need to mentally link each idea with other related ideas. Doing that requires additional work. To help you along the way, the next few pages give you five key planning steps to take so that you can more effectively build those skills and make those connections, before you dive into this exciting but challenging world of learning networking on Cisco gear.

Step 1: Think in Terms of Parts and Chapters

The first step in your study plan is to get the right mindset about the size and nature of the task you have set out to accomplish. This is a large book. So you cannot think about the book as one huge task or you might get discouraged. Besides, you never sit down to read 900 pages in one study session. So break the task down into smaller tasks.

The good news here is that the book is designed with obvious breakpoints and built-in extensive review activities. In short, the book is more of a study system than a book.

So the first step in your study plan is to visualize the book not as one large book, but as 9 parts. Then, within each part, visualize an average of 4 chapters. Your study plan has you working through the chapters in each part, and then reviewing the material in that part before moving on, as shown in Figure 2.

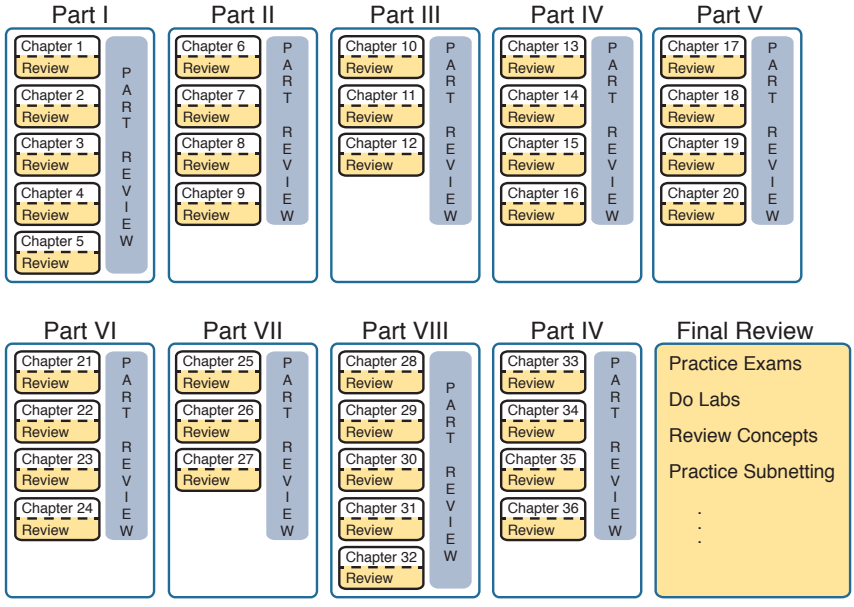

Figure 2 *9 Parts, with an Average of 4 Chapters Each, with Part Reviews*

Now your plan has the following:

1 large task: Read and master all content in the book.

9 medium tasks/book: Read and master a part.

4 small tasks/part: Read and master a chapter.

Step 2: Build Your Study Habits Around the Chapter

For your second step, possibly the most important step, approach each chapter with the same process: read it, and then study the chapter before moving on.

Each chapter follows the same design with three parts, as shown in Figure 3. The chapter pre-quiz (called a DIKTA quiz, or Do I Know This Already? quiz) helps you decide how much time to spend reading versus skimming the core of the chapter, called the Foundation Topics. The Chapter Review section then gives you instructions about how to study and review what you just read.

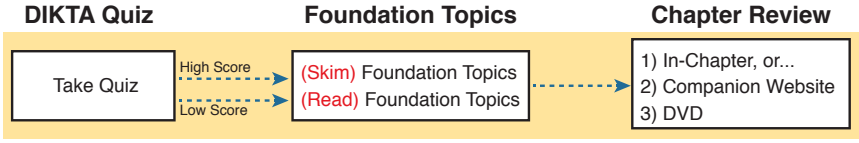

Figure 3 *Suggested Approach to Each Chapter*

The book has no long chapters, on purpose. They average just over 20 pages for the Foundation Topics. By keeping the size reasonable, you can complete all of a chapter in one or two short study sessions. Go into each study session that begins a new chapter thinking that you have a chance to complete the chapter, or at least make a great start on it. And if you do not have enough time, look for the major headings inside the chapter—each chapter

has two to three major headings, and those make a great place to stop reading when you need to wait to complete the reading in the next study sessions.

The Chapter Review tasks are very important to your exam-day success. Doing these tasks after you've read the chapter really does help you get ready. Do not put off using these tasks until later! The chapter-ending review tasks help you with the first phase of deepening your knowledge and skills of the key topics, remembering terms, and linking the concepts together in your brain so that you can remember how it all fits together. The following list describes most of the activities you will find in the "Chapter Review" sections:

- Review key topics
- Review key terms
- Repeat the DIKTA questions
- Review memory tables
- Re-create config checklists
- Review command tables
- Do lab exercises
- Do subnetting exercises

Check out the upcoming section titled "Find Review Activities on the Web and DVD?" later in this planning section for more details.

Step 3: Use Book Parts for Major Milestones

Studies show that to master a concept and/or skill, you should plan to go through multiple study sessions to review the concept and to practice the skill. The "Chapter Review" section at the end of each chapter is the first such review, while the Part Review, at the end of each part, acts as that second review.

Plan time to do the Part Review task at the end of each part, using the Part Review elements found at the end of each Part. You should expect to spend about as much time on one Part Review as you would on one entire chapter, or maybe a little more for some parts. So in terms of planning your time, think of the Part Review itself as another chapter.

Figure 4 lists the names of the parts in this book, with some color coding. Note that Parts II and III are related (Ethernet), and Parts IV through VII are also related (IP version 4). Each part ends with a Part Review section of 2 to 4 pages, with notes about what tools and activities to use.

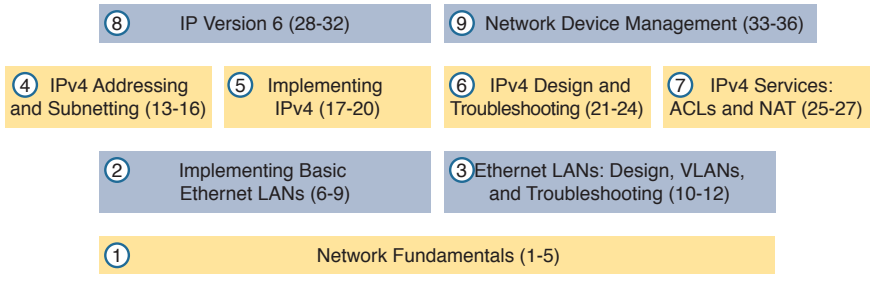

Figure 4 *Parts as Major Milestones*

Chapter Review and Part Review differ in some ways. Chapter Review tasks tend to provide a lot of context, so you can focus on mentally adding a specific piece of knowledge, or practicing a specific skill. Part Review activities instead remove a lot of the context, more like real life and the real exams. Removing that context means that you have to exercise your own knowledge and skills. The result: You uncover your weaknesses. The better you become at uncovering weaknesses, and then learning what you are missing in that area, the better prepared you will be for the exam.

The Part Review sections use the following kinds of tools in additional to some of the same tools used for Chapter Review:

- Mind maps
- Part Review questions with PCPT
- Labs

Also, consider setting a goal date for finishing each part of the book (and a reward, as well). Plan a break, some family time, some time out exercising, eating some good food, whatever helps you get refreshed and motivated for the next part.

Step 4: Use the Final Review Chapter to Refine Skills and Uncover Weaknesses

Your fourth step has one overall task: Follow the details outlined in Chapter 37, "Final Review," at the end of this book for what to do between finishing the book and taking the exam.

The "Final Review" chapter has two major goals. First, it helps you further develop the analytical skills you need to answer the more complicated questions on the exam. Many questions require that you connect ideas about concepts, configuration, verification, and troubleshooting. The closer you get to taking the exam, the less reading you should do, and the more you should do other learning activities; this chapter's tasks give you activities to further develop these skills.

The tasks in the "Final Review" chapter also help you uncover your weak areas. This final element gives you repetition with high-challenge exam questions, uncovering any gaps in your knowledge. Many of the questions are purposefully designed to test your knowledge of the most common mistakes and misconceptions, helping you avoid some of the common pitfalls people experience with the actual exam.

Step 5: Set Goals and Track Your Progress

Your fifth study plan step spans the entire timeline of your study effort. Before you start reading the book and doing the rest of these study tasks, take the time to make a plan, set some goals, and be ready to track your progress.

While making lists of tasks may or may not appeal to you, depending on your personality, goal setting can help everyone studying for these exams. And to do the goal setting, you need to know what tasks you plan to do.

NOTE If you read this, and decide that you want to try to do better with goal setting beyond your exam study, check out a blog series I wrote about planning your networking career here: http://blog.certskills.com/ccna/tag/development-plan/.

As for the list of tasks to do when studying, you do not have to use a detailed task list. (You could list every single task in every chapter-ending Chapter Review section, every task in the Part Reviews, and every task in the "Final Review" chapter.) However, listing the major tasks can be enough.

You should track at least two tasks for each typical chapter: reading the "Foundation Topics" section and doing the Chapter Review at the end of the chapter. And, of course, do not forget to list tasks for Part Reviews and Final Review. Table 1 shows a sample for Part I of this book.

Table 1 Sample Excerpt from a Planning Table

Element	Task	Goal Date	First Date Completed	Second Date Completed (Optional)
Chapter 1	Read Foundation Topics			
Chapter 1	Do Chapter Review tasks			
Chapter 2	Read Foundation Topics			
Chapter 2	Do Chapter Review tasks			
Chapter 3	Read Foundation Topics			
Chapter 3	Do Chapter Review tasks			
Part I Review	Do Part Review activities			

NOTE Appendix M, "Study Planner," on the DVD that comes with this book, contains a complete planning checklist like Table 1 for the tasks in this book. This spreadsheet allows you to update and save the file to note your goal dates and the tasks you have completed.

Use your goal dates as a way to manage your study, and not as a way to get discouraged if you miss a date. Pick reasonable dates that you can meet. When setting your goals, think about how fast you read and the length of each chapter's "Foundation Topics" section, as listed in the table of contents. Then, when you finish a task sooner than planned, move up the next few goal dates.

If you miss a few dates, do *not* start skipping the tasks listed at the ends of the chapters! Instead, think about what is impacting your schedule—real life, commitment, and so on—and either adjust your goals or work a little harder on your study.

Things to Do Before Starting the First Chapter

Now that you understand the big ideas behind a good study plan for the book, take a few more minutes for a few overhead actions that will help. Before leaving this section, look at some other tasks you should do either now, or around the time you are reading the first few chapters, to help make a good start in the book.

Find Review Activities on the Web and DVD

The earlier editions of the book have used review activities that relied on the chapter, plus PDF appendixes found on the DVD. Some activities also rely on the PCPT testing software.

This edition is the first Cisco Press certification guide to offer a large set of apps to use instead of the traditional study features. The Introduction's section titled "A Big New Feature: Review Applications" detailed some of the reasons.

I encourage you to go ahead and access the book's companion website to find the review apps and explore. Also, spin the DVD, and find the review apps there. Both methods organize the review activities by chapter and by part.

Note that this book includes the traditional methods of review as well, with instructions in the book, and matching PDF appendixes in some cases. For instance, all the subnetting exercises can be done in an app, but those same exercises exist in DVD-only appendixes—you choose which works better for you.

Should I Plan to Use the Two-Exam Path or One-Exam Path?

You do not have to make this choice today, but you can be mulling the decision while you study.

To get a CCNA Routing and Switching certification, you choose either a one-exam or two-exam path. Which should you use? The following is my opinion, but it's based on chatter and opinions from readers from many years. You can consider the one-exam path if

- You already know about half the topics well, through prior experience or study.
- You have already proven that you are excellent at learning through self-study.

Otherwise, in my opinion, you would be better off taking the two-exam path. First, there is no cost savings for most people with the one-exam path. Check the exam prices in your country, for ICND1, ICND2, and CCNA, and then make some comparisons. Assume you pass the tests on the first try: traditionally, the cost is identical for both the ICND1 + ICND2 path and the CCNA path. Or, assume that you fail each exam once: again, the costs are identical.

Next, consider the number of topics. From a content perspective, CCNA = ICND1 + ICND2. So, both paths require learning the same content.

Next, which would you rather have done in school: take a final exam over a single semester's material, or a final exam covering the whole year? It is just harder to prepare for an exam that covers more material, so the two-exam path gain has an advantage.

Finally, the most compelling reason for the two-exam path is that you probably have no experience with Cisco exams yet. I hope you have a chance to pass many Cisco exams during your career. The two-exam path gets you to that first exam attempt sooner, and the exam experience teaches you things about the exam and yourself that no study tool can teach you.

Thankfully, you do not have to decide now. In fact, you can study the entire ICND1 book and all the while ponder whether to use the one-exam or two-exam path to CCNA R&S. At that point, you can make a better decision about which path works better for you.

Study Options for Those Taking the 200-125 CCNA Exam

Studying for the two-exam path has an obvious approach: just use the ICND1 book for the ICND1 exam, and the ICND2 book for the ICND2 exam. Simple enough.

If you do plan to take the 200-125 CCNA R&S exam, you have a couple of study options. First, to be clear: The 200-125 CCNA exam covers the topics in the combined ICND1 and ICND2 books. So, using both the ICND1 and ICND2 books covers everything for the 200-125 CCNA R&S exam. The only question is when to read each part of the two books. You have two reasonable options when going with the one-exam option:

- Complete all the ICND1 book, then move on to the ICND2 book.
- Move back and forth between the ICND1 and ICND2 books, by part, based on topics, as shown in Figure 5.

The first option is pretty obvious, but the second one is less obvious. Figure 5 shows a study plan in which you complete the Ethernet parts in the ICND1, then the Ethernet part in ICND2. Similarly, you complete the IPv4 parts in ICND1, then ICND2, and then the IPv6 part in both books, and then the final part in both books.

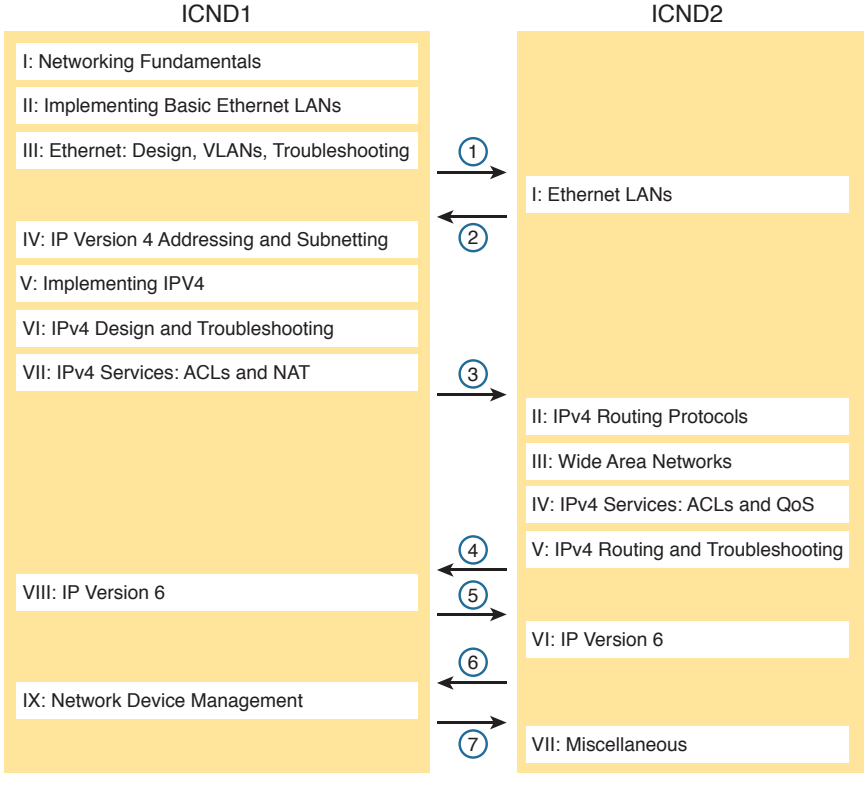

Figure 5 *Alternate Reading Plan for CCNA: Moving Between Books by Part*

Personally, I am a fan of completing the ICND1 book completely, and then moving on to the ICND2 book. However, for those of you with a large amount of experience already, this alternate reading plan may work well.

Other Small Tasks Before Getting Started

You need to do a few overhead tasks to install software, find some PDFs, and so on. You can do these tasks now or do them in your spare moments when you need a study break during the first few chapters of the book. But do these early. That way, if you do stumble upon an installation problem, you have time to work through it before you need a particular tool.

Register (for free) at the Cisco Learning Network (CLN, http://learningnetwork.cisco.com) and join the CCENT/CCNA R&S study group. This group allows you to both lurk and participate in discussions about topics related to the ICND1 exam, ICND2 exam, and CCNA R&S exam. Register (for free), join the groups, and set up an email filter to redirect the messages to a separate folder. Even if you do not spend time reading all the posts yet, later, when you have time to read, you can browse through the posts to find interesting topics (or just search the posts from the CLN website).

Explore the electronic elements of this book, as detailed in the Introduction's section titled "How to Get the Electronic Elements of This Book." That includes the installation of the PCPT and Sim Lite software.

Also find my blog site as listed in the Introduction, and bookmark the pages that list the config labs, to have those handy for later study. (The URL is http://blog.certskills.com/ccent/category/hands-on/config-lab.)

Getting Started: Now

Now dive in to your first of many short, manageable tasks: reading the relatively short Chapter 1. Enjoy!

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CHAPTER 22

Variable-Length Subnet Masks

This chapter covers the following exam topics:

1.0 Network Fundamentals

1.8 Configure, verify, and troubleshoot IPv4 addressing and subnetting

IPv4 addressing and subnetting use a lot of terms, a lot of small math steps, and a lot of concepts that fit together. While learning those concepts, it helps to keep things as simple as possible. One way this book has kept the discussion simpler so far was to show examples that use one mask only inside a single Class A, B, or C network.

This chapter removes that restriction by introducing variable-length subnet masks (VLSM). VLSM simply means that the subnet design uses more than one mask in the same classful network. VLSM has some advantages and disadvantages, but when learning, the main challenge is that a subnetting design that uses VLSM requires more math, and it requires that you think about some other issues as well. This chapter walks you through the concepts, the issues, and the math.

"Do I Know This Already?" Quiz

Take the quiz (either here, or use the PCPT software) if you want to use the score to help you decide how much time to spend on this chapter. The answers are at the bottom of the page following the quiz, and the explanations are in DVD Appendix C and in the PCPT software.

Table 22-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
VLSM Concepts and Configuration	1–2
Finding VLSM Overlaps	3–4
Adding a New Subnet to an Existing VLSM Design	5

1. Which of the following routing protocols support VLSM? (Choose three answers.)
   a. RIPv1
   b. RIPv2
   c. EIGRP
   d. OSPF

2. What does the acronym VLSM stand for?
   a. Variable-length subnet mask
   b. Very long subnet mask
   c. Vociferous longitudinal subnet mask
   d. Vector-length subnet mask
   e. Vector loop subnet mask

3. R1 has configured interface Fa0/0 with the **ip address 10.5.48.1 255.255.240.0** command. Which of the following subnets, when configured on another interface on R1, would not be considered an overlapping VLSM subnet?
   a. 10.5.0.0 255.255.240.0
   b. 10.4.0.0 255.254.0.0
   c. 10.5.32.0 255.255.224.0
   d. 10.5.0.0 255.255.128.0

4. R4 has a connected route for 172.16.8.0/22. Which of the following answers lists a subnet that overlaps with this subnet?
   a. 172.16.0.0/21
   b. 172.16.6.0/23
   c. 172.16.16.0/20
   d. 172.16.11.0/25

5. A design already includes subnets 192.168.1.0/26, 192.168.1.128/30, and 192.168.1.160/29. Which of the following subnets is the numerically lowest subnet ID that could be added to the design, if you wanted to add a subnet that uses a /28 mask?
   a. 192.168.1.144/28
   b. 192.168.1.112/28
   c. 192.168.1.64/28
   d. 192.168.1.80/28
   e. 192.168.1.96/28

Foundation Topics

VLSM Concepts and Configuration

VLSM occurs when an internetwork uses more than one mask for different subnets of a single Class A, B, or C network. Figure 22-1 shows an example of VLSM used in Class A network 10.0.0.0.

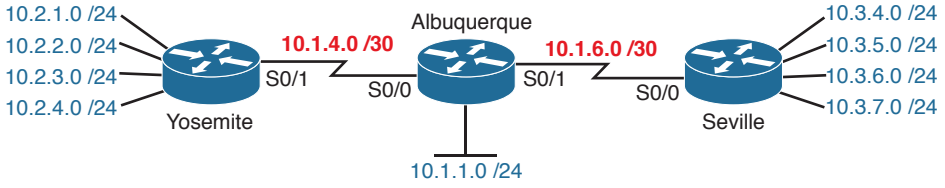

Figure 22-1 *VLSM in Network 10.0.0.0: Masks /24 and /30*

Figure 22-1 shows a typical choice of using a /30 prefix (mask 255.255.255.252) on point-to-point serial links, with mask /24 (255.255.255.0) on the LAN subnets. All subnets are of Class A network 10.0.0.0, with two masks being used, therefore meeting the definition of VLSM.

Oddly enough, a common mistake occurs when people think that VLSM means "using more than one mask in some internetwork" rather than "using more than one mask *in a single classful network*." For example, if in one internetwork diagram, all subnets of network 10.0.0.0 use a 255.255.240.0 mask, and all subnets of network 11.0.0.0 use a 255.255.255.0 mask, the design uses two different masks. However, Class A network 10.0.0.0 uses only one mask, and Class A network 11.0.0.0 uses only one mask. In that case, the design does not use VLSM.

VLSM provides many benefits for real networks, mainly related to how you allocate and use your IP address space. Because a mask defines the size of the subnet (the number of host addresses in the subnet), VLSM allows engineers to better match the need for addresses with the size of the subnet. For example, for subnets that need fewer addresses, the engineer uses a mask with fewer host bits, so the subnet has fewer host IP addresses. This flexibility reduces the number of wasted IP addresses in each subnet. By wasting fewer addresses, more space remains to allocate more subnets.

VLSM can be helpful for both public and private IP addresses, but the benefits are more dramatic with public networks. With public networks, the address savings help engineers avoid having to obtain another registered IP network number from regional IP address assignment authorities. With private networks, as defined in RFC 1918, running out of addresses is not as big a negative, because you can always grab another private network from RFC 1918 if you run out.

Classless and Classful Routing Protocols

Before you can deploy a VLSM design, you must first use a routing protocol that supports VLSM. To support VLSM, the routing protocol must advertise the mask along with each subnet. Without mask information, the router receiving the update would be confused.

Answers to the "Do I Know This Already?" quiz:

1 B, C, D **2** A **3** A **4** D **5** C

For example, if a router learned a route for 10.1.8.0, but with no mask information, what does that mean? Is that subnet 10.1.8.0/24? 10.1.8.0/23? 10.1.8.0/30? The dotted-decimal number 10.1.8.0 happens to be a valid subnet number with a variety of masks, and because multiple masks can be used with VLSM, the router has no good way to make an educated guess. To effectively support VLSM, the routing protocol needs to advertise the correct mask along with each subnet so that the receiving router knows the exact subnet that is being advertised.

By definition, *classless routing protocols* advertise the mask with each advertised route, and *classful routing protocols* do not. The classless routing protocols, as noted in Table 22-2, are the newer, more advanced routing protocols. Not only do these more advanced classless routing protocols support VLSM, but they also support manual route summarization, which allows a routing protocol to advertise one route for a larger subnet instead of multiple routes for smaller subnets.

Key Topic

Table 22-2 Classless and Classful Interior IP Routing Protocols

Routing Protocol	Is It Classless?	Sends Mask in Updates?	Supports VLSM?	Supports Manual Route Summarization?
RIPv1	No	No	No	No
RIPv2	Yes	Yes	Yes	Yes
EIGRP	Yes	Yes	Yes	Yes
OSPF	Yes	Yes	Yes	Yes

Beyond VLSM itself, the routing protocols do not have to be configured to support VLSM or to be classless. There is no command to enable or disable the fact that classless routing protocols include the mask with each route. The only configuration choice you must make is to use a classless routing protocol.

VLSM Configuration and Verification

Cisco routers do not configure VLSM, enable or disable it, or need any configuration to use it. From a configuration perspective, VLSM is simply a side effect of using the **ip address** interface subcommand. Routers collectively configure VLSM by virtue of having IP addresses in the same classful network but with different masks.

For example, Example 22-1 shows two of the interfaces from router Yosemite from Figure 22-1. The example shows the IP address assignments on two interfaces, one with a /24 mask and one with a /30 mask, both with IP addresses in Class A network 10.0.0.0.

Example 22-1 *Configuring Two Interfaces on Yosemite, Resulting in VLSM*

```
Yosemite# configure terminal
Yosemite(config)# interface Fa0/0
Yosemite(config-if)# ip address 10.2.1.1 255.255.255.0
Yosemite(config-if)# interface S0/1
Yosemite(config-if)# ip address 10.1.4.1 255.255.255.252
```

The use of VLSM can also be detected by a detailed look at the output of the **show ip route** command. This command lists routes in groups, by classful network, so that you see all the subnets of a single Class A, B, or C network all in a row. Just look down the list, and

look to see, if any, how many different masks are listed. For example, Example 22-2 lists the routing table on Albuquerque from Figure 22-1; Albuquerque uses masks /24 and /30 inside network 10.0.0.0, as noted in the highlighted line in the example.

Example 22-2 *Albuquerque Routing Table with VLSM*

```
Albuquerque# show ip route
! Legend omitted for brevity

     10.0.0.0/8 is variably subnetted, 14 subnets, 3 masks
D       10.2.1.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.2.2.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.2.3.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.2.4.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.3.4.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.5.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.6.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.7.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
C       10.1.1.0/24 is directly connected, FastEthernet0/0
L       10.1.1.1/32 is directly connected, FastEthernet0/0
C       10.1.6.0/30 is directly connected, Serial0/1
L       10.1.6.1/32 is directly connected, Serial0/1
C       10.1.4.0/30 is directly connected, Serial0/0
L       10.1.4.1/32 is directly connected, Serial0/0
```

NOTE For the purposes of understanding whether a design uses VLSM, ignore the /32 "local" routes that a router automatically creates for its own interface IP addresses.

So ends the discussion of VLSM as an end to itself. This chapter is devoted to VLSM, but it took a mere three to four pages to fully describe it. Why the entire VLSM chapter? Well, to work with VLSM, to find problems with it, to add subnets to an existing design, and to design using VLSM from scratch—in other words, to apply VLSM to real networks—takes skill and practice. To do these same tasks on the exam requires skill and practice. The rest of this chapter examines the skills to apply VLSM and provides some practice for these two key areas:

- Finding VLSM overlaps
- Adding new VLSM subnets without overlaps

Finding VLSM Overlaps

Key Topic

Regardless of whether a design uses VLSM, the subnets used in any IP internetwork design should not overlap their address ranges. When subnets in different locations overlap their addresses, a router's routing table entries overlap. As a result, hosts in different locations can be assigned the same IP address. Routers clearly cannot route packets correctly in these cases. In short, a design that uses overlapping subnets is considered to be an incorrect design and should not be used.

This section begins with a short discussion about VLSM design, to drive home the ideas behind VLSM overlaps. It then gets into an operational and troubleshooting approach to the topic, by looking at existing designs and trying to find any existing overlaps.

Designing Subnetting Plans with VLSM

When creating a subnetting plan using VLSM, you have to be much more careful in choosing what subnets to use. First, whatever masks you use in a VLSM design, each subnet ID must be a valid subnet ID given the mask that you use for that subnet.

For example, consider a subnet plan for Class B network 172.16.0.0. To create a subnet with a /24 mask, the subnet ID must be a subnet ID that you could choose if you subnetted the whole Class B network with that same mask. Chapter 21, "Subnet Design," discusses how to find those subnets in depth, but with a Class B network and a /24 mask, the possible subnet IDs should be easy to calculate by now: 172.16.0.0 (the zero subnet), then 172.16.1.0, 172.16.2.0, 172.16.3.0, 172.16.4.0, and so on, up through 172.16.255.0.

NOTE Subnet IDs must always follow this important binary rule as noted back in Chapter 16, "Analyzing Existing Subnets": In binary, each subnet ID has a host field of all binary 0s. If you use the math and processes to find all subnet IDs per Chapter 21, all those subnet IDs happen to have binary 0s in the host fields.

Now expand your thinking about subnet IDs to a VLSM design. To begin, you would decide that you need some subnets with one mask, other subnets with another mask, and so on, to meet the requirements for different sizes of different subnets. For instance, imagine you start with a brand-new VLSM design, with Class B network 172.16.0.0. You plan to have some subnets with /22 masks, some with /23, and some with /24. You might develop then a planning diagram, or at least draw the ideas, with something like Figure 22-2.

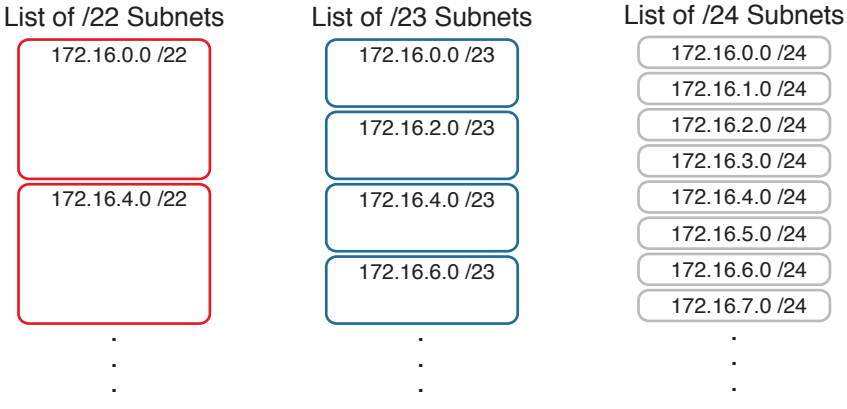

Figure 22-2 *Possible Subnet IDs of Network 172.16.0.0, with /22, /23, and /24 Masks*

The drawing shows the first few subnet IDs available with each mask, but you cannot use all subnets from all three lists in a design. As soon as you choose to use one subnet from any column, you remove some subnets from the other lists because subnets cannot overlap. Overlapping subnets are subnets whose range of addresses include some of the same addresses.

As an example, Figure 22-3 shows the same list of the first few possible /22, /23, and /24 subnets of Class B network 172.16.0.0. However, it shows a check mark beside two subnets that have been allocated for use; that is, on paper, the person making the subnetting plan has decided to use these two subnets somewhere in the network. The subnets with a dark gray shading and an *X* in them can no longer be used because they have some overlapping addresses with the subnets that have check marks (172.16.3.0/24 and 172.16.4.0/22).

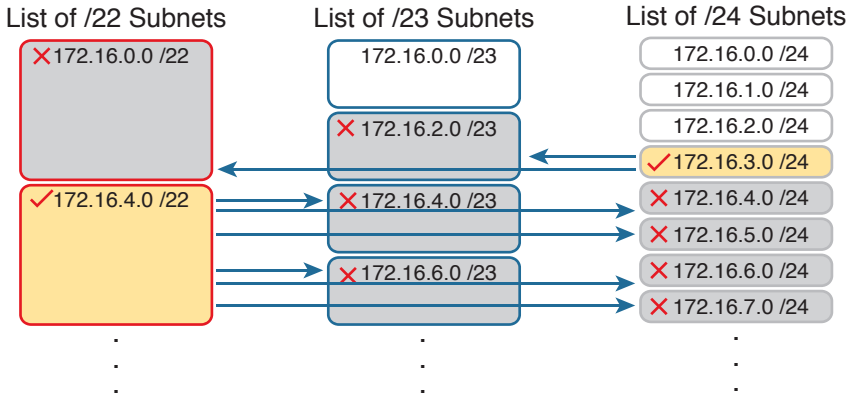

Figure 22-3 *Selecting Two Subnets Disallows Other Subnets in Different Columns*

Just to complete the example, first look at subnet 172.16.4.0 on the lower left. That subnet includes addresses from the subnet ID of 172.16.4.0 through the subnet broadcast address of 172.16.7.255. As you can see just by looking at the subnet IDs to the right, all the subnets referenced with the arrowed lines are within that same range of addresses.

Now look to the upper right of the figure, to subnet 172.16.3.0/24. The subnet has a range of 172.16.3.0–172.16.3.255 including the subnet ID and subnet broadcast address. That subnet overlaps with the two subnets referenced to the left. For instance, subnet 172.16.0.0/22 includes the range from 172.16.0.0–172.16.3.255. But because there is some overlap, once the design has allocated the 172.16.3.0/24 subnet, the 172.16.2.0/23 and 172.16.0.0/22 subnets could not be used without causing problems, because:

A subnetting design, whether using VLSM or not, should not allow subnets whose address ranges overlap. If overlapping subnets are implemented, routing problems occur and some hosts simply cannot communicate outside their subnets.

These address overlaps are easier to see when not using VLSM. When not using VLSM, overlapped subnets have identical subnet IDs, so to find overlaps, you just have to look at the subnet IDs. With VLSM, overlapped subnets may not have the same subnet ID, as was the case in this most recent example with the subnets across the top of Figure 22-3. To find these overlaps, you have to look at the entire range of addresses in each subnet, from subnet ID to subnet broadcast address, and compare the range to the other subnets in the design.

An Example of Finding a VLSM Overlap

For example, imagine that a practice question for the CCENT exam shows Figure 22-4. It uses a single Class B network (172.16.0.0), with VLSM, because it uses three different masks: /23, /24, and /30.

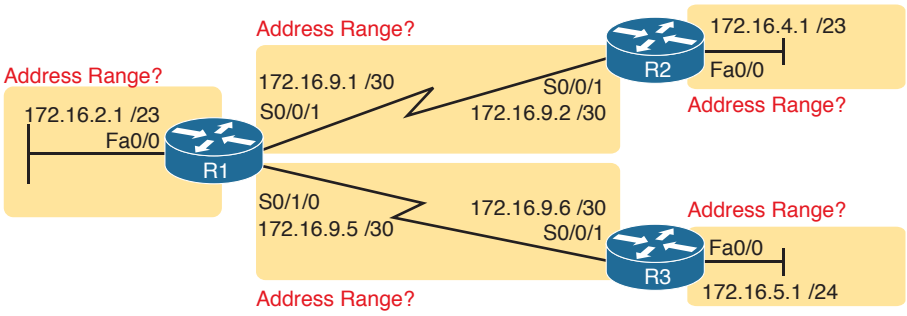

Figure 22-4 *VLSM Design with Possible Overlap*

Now imagine that the exam question shows you the figure, and either directly or indirectly asks whether overlapping subnets exist. This type of question might simply tell you that some hosts cannot ping each other, or it might not even mention that the root cause could be that some of the subnets overlap. To answer such a question, you could follow this simple but possibly laborious process:

Key Topic

Step 1. Calculate the subnet ID and subnet broadcast address of each subnet, which gives you the range of addresses in that subnet.

Step 2. List the subnet IDs in numerical order (along with their subnet broadcast addresses).

Step 3. Scan the list from top to bottom, comparing each pair of adjacent entries, to see whether their range of addresses overlaps.

For example, Table 22-3 completes the first two steps based on Figure 22-4, listing the subnet IDs and subnet broadcast addresses, in numerical order based on the subnet IDs.

Table 22-3 Subnet IDs and Broadcast Addresses, in Numerical Order, from Figure 22-4

Subnet	Subnet Number	Broadcast Address
R1 LAN	172.16.2.0	172.16.3.255
R2 LAN	172.16.4.0	172.16.5.255
R3 LAN	172.16.5.0	172.16.5.255
R1-R2 serial	172.16.9.0	172.16.9.3
R1-R3 serial	172.16.9.4	172.16.9.7

The VLSM design is invalid in this case because of the overlap between R2's LAN subnet and R3's LAN subnet. As for the process, Step 3 states the somewhat obvious step of comparing the address ranges to see whether any overlaps occur. Note that, in this case, none of the subnet numbers are identical, but two entries (highlighted) do overlap. The design is invalid because of the overlap, and one of these two subnets would need to be changed.

As far as the three-step process works, note that if two adjacent entries in the list overlap, compare three entries at the next step. The two subnets already marked as overlapped can overlap with the next subnet in the list. For example, the three subnets in the following list overlap in that the first subnet overlaps with the second and third subnets in the list. If you

followed the process shown here, you would have first noticed the overlap between the first two subnets in the list, so you would then also need to check the next subnet in the list to find out if it overlapped.

10.1.0.0/16 (subnet ID 10.1.0.0, broadcast 10.1.255.255)

10.1.200.0/24 (subnet ID 10.1.200.0, broadcast 10.1.200.255)

10.1.250.0/24 (subnet ID 10.1.250.0, broadcast 10.1.250.255)

Practice Finding VLSM Overlaps

As typical of anything to with applying IP addressing and subnetting, practice helps. To that end, Table 22-4 lists three practice problems. Just start with the five IP addresses listed in a single column, and then follow the three-step process outlined in the previous section to find any VLSM overlaps. The answers can be found near the end of this chapter, in the section "Answers to Earlier Practice Problems."

Table 22-4 VLSM Overlap Practice Problems

Problem 1	Problem 2	Problem 3
10.1.34.9/22	172.16.126.151/22	192.168.1.253/30
10.1.29.101/23	172.16.122.57/27	192.168.1.113/28
10.1.23.254/22	172.16.122.33/30	192.168.1.245/29
10.1.17.1/21	172.16.122.1/30	192.168.1.125/30
10.1.1.1/20	172.16.128.151/20	192.168.1.122/30

Adding a New Subnet to an Existing VLSM Design

The task described in this section happens frequently in real networks: choosing new subnets to add to an existing design. In real life, you can use IP Address Management (IPAM) tools that help you choose a new subnet so that you do not cause an overlap. However, for both real life and for the CCENT and CCNA Routing and Switching exams, you need to be ready to do the mental process and math of choosing a subnet that does not create an overlapped VLSM subnet condition. In other words, you need to pick a new subnet and not make a mistake!

For example, consider the internetwork shown earlier in Figure 22-2, with classful network 172.16.0.0. An exam question might suggest that a new subnet, with a /23 prefix length, needs to be added to the design. The question might also say, "Pick the numerically lowest subnet number that can be used for the new subnet." In other words, if both 172.16.4.0 and 172.16.6.0 would work, use 172.16.4.0.

So, you really have a couple of tasks: To find all the subnet IDs that could be used, rule out the ones that would cause an overlap, and then check to see whether the question guides you to pick either the numerically lowest (or highest) subnet ID. This list outlines the specific steps:

Key Topic

Step 1. Pick the subnet mask (prefix length) for the new subnet, based on the design requirements (if not already listed as part of the question).

Step 2. Calculate all possible subnet numbers of the classful network using the mask from Step 1, along with the subnet broadcast addresses.

Step 3. Make a list of existing subnet IDs and matching subnet broadcast addresses.

Step 4. Compare the existing subnets to the candidate new subnets to rule out overlapping new subnets.

Step 5. Choose the new subnet ID from the remaining subnets identified at Step 4, paying attention to whether the question asks for the numerically lowest or numerically highest subnet ID.

An Example of Adding a New VLSM Subnet

For example, Figure 22-5 shows an existing internetwork that uses VLSM. (The figure uses the same IP addresses as shown in Figure 22-4, but with R3's LAN IP address changed to fix the VLSM overlap shown in Figure 22-4.) In this case, you need to add a new subnet to support 300 hosts. Imagine that the question tells you to use the smallest subnet (least number of hosts) to meet that requirement. You use some math and logic you learned earlier in your study to choose mask /23, which gives you 9 host bits, for $2^9 - 2 = 510$ hosts in the subnet.

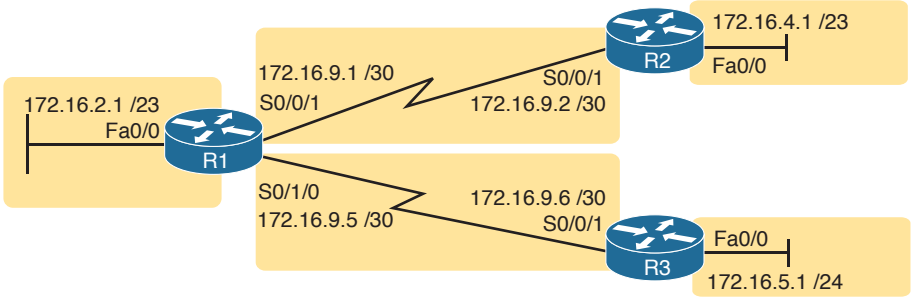

Figure 22-5 *Internetwork to Which You Need to Add a /23 Subnet, Network 172.16.0.0*

At this point, just follow the steps listed before Figure 22-5. For Step 1, you have already been given the mask (/23). For Step 2, you need to list all the subnet numbers and broadcast addresses of 172.16.0.0, assuming the /23 mask. You will not use all these subnets, but you need the list for comparison to the existing subnets. Table 22-5 shows the results, at least for the first five possible /23 subnets.

Table 22-5 First Five Possible /23 Subnets

Subnet	Subnet Number	Subnet Broadcast Address
First (zero)	172.16.0.0	172.16.1.255
Second	172.16.2.0	172.16.3.255
Third	172.16.4.0	172.16.5.255
Fourth	172.16.6.0	172.16.7.255
Fifth	172.16.8.0	172.16.9.255

Next, at Step 3, list the existing subnet numbers and broadcast addresses, as shown earlier in Figure 22-5. To do so, do the usual math to take an IP address/mask to then find the subnet ID and subnet broadcast address. Table 22-6 summarizes that information, including the locations, subnet numbers, and subnet broadcast addresses.

Table 22-6 Existing Subnet IDs and Broadcast Addresses from Figure 22-5

Subnet	Subnet Number	Subnet Broadcast Address
R1 LAN	172.16.2.0	172.16.3.255
R2 LAN	172.16.4.0	172.16.5.255
R3 LAN	172.16.6.0	172.16.6.255
R1-R2 serial	172.16.9.0	172.16.9.3
R1-R3 serial	172.16.9.4	172.16.9.7

At this point, you have all the information you need to look for the overlap at Step 4. Simply compare the range of numbers for the subnets in the previous two tables. Which of the possible new /23 subnets (Table 22-5) overlap with the existing subnets (Table 22-6)? In this case, the second through fifth subnets in Table 22-5 overlap, so rule those out as candidates to be used. (Table 22-5 denotes those subnets with gray highlights.)

Step 5 has more to do with the exam than with real network design, but it is still worth listing as a separate step. Multiple-choice questions sometimes need to force you into a single answer, and asking for the numerically lowest or highest subnet does that. This particular example asks for the numerically lowest subnet number, which in this case is 172.16.0.0/23.

NOTE The answer, 172.16.0.0/23, happens to be a zero subnet. For the exam, the zero subnet should be avoided if (a) the question implies the use of classful routing protocols or (b) the routers are configured with the **no ip subnet-zero** global configuration command. Otherwise, assume that the zero subnet can be used.

Chapter Review

One key to doing well on the exams is to perform repetitive spaced review sessions. Review this chapter's material using either the tools in the book, DVD, or interactive tools for the same material found on the book's companion website. Refer to the "Your Study Plan" element for more details. Table 22-7 outlines the key review elements and where you can find them. To better track your study progress, record when you completed these activities in the second column.

Table 22-7 Chapter Review Tracking

Review Element	Review Date(s)	Resource Used
Review key topics		Book, DVD/website
Review key terms		Book, DVD/website
Repeat DIKTA questions		Book, PCPT
Review memory tables		Book, DVD/website
Practice finding VLSM overlaps		DVD Appendix H, DVD/website
Practice adding new VLSM subnets		DVD Appendix H, DVD/website

Review All the Key Topics

Key Topic

Table 22-8 Key Topics for Chapter 22

Key Topic Element	Description	Page Number
Table 22-2	Classless and classful routing protocols listed and compared	531
Text	Rule about subnetting designs cannot allow subnets to overlap	532
List	Steps to analyze an existing design to discover any VLSM overlaps	535
List	Steps to follow when adding a new subnet to an existing VLSM design	536

Key Terms You Should Know

classful routing protocol, classless routing protocol, overlapping subnets, variable-length subnet masks (VLSM)

Additional Practice for This Chapter's Processes

For additional practice with finding VLSM overlaps and adding a new subnet to a VLSM design, you may do the same set of practice problems using your choice of tools:

Application: Use the Variable-Length Subnet Masks application on the DVD or companion website.

PDF: Alternatively, practice the same problems found in both these apps using DVD Appendix H, "Practice for Chapter 22: Variable-Length Subnet Masks."

Answers to Earlier Practice Problems

22

Answers to Practice Finding VLSM Overlaps

This section lists the answers to the three practice problems in the section "Practice Finding VLSM Overlaps," as listed earlier in Table 22-4. Note that the tables that list details of the answer reordered the subnets as part of the process.

In Problem 1, the second and third subnet IDs listed in Table 22-9 happen to overlap. The second subnet's range completely includes the range of addresses in the third subnet.

Table 22-9 VLSM Overlap Problem 1 Answers (Overlaps Highlighted)

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	10.1.1.1/20	10.1.0.0	10.1.15.255
2	10.1.17.1/21	10.1.16.0	10.1.23.255
3	10.1.23.254/22	10.1.20.0	10.1.23.255
4	10.1.29.101/23	10.1.28.0	10.1.29.255
5	10.1.34.9/22	10.1.32.0	10.1.35.255

In Problem 2, again the second and third subnet IDs (listed in Table 22-10) happen to overlap, and again, the second subnet's range completely includes the range of addresses in the third subnet. Also, the second and third subnet IDs are the same value, so the overlap is more obvious.

Table 22-10 VLSM Overlap Problem 2 Answers (Overlaps Highlighted)

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	172.16.122.1/30	172.16.122.0	172.16.122.3
2	172.16.122.57/27	172.16.122.32	172.16.122.63
3	172.16.122.33/30	172.16.122.32	172.16.122.35
4	172.16.126.151/22	172.16.124.0	172.16.127.255
5	172.16.128.151/20	172.16.128.0	172.16.143.255

In Problem 3, three subnets overlap. Subnet 1's range completely includes the range of addresses in the second and third subnets, as shown in Table 22-11. Note that the second and third subnets do not overlap with each other, so for the process in this book to find all the overlaps, after you find that the first two subnets overlap, you should compare the next entry in the table (3) with both of the two known-to-overlap entries (1 and 2).

Table 22-11 VLSM Overlap Problem 3 Answers (Overlaps Highlighted)

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	192.168.1.113/28	192.168.1.112	192.168.1.127
2	192.168.1.122/30	192.168.1.120	192.168.1.123
3	192.168.1.125/30	192.168.1.124	192.168.1.127
4	192.168.1.245/29	192.168.1.240	192.168.1.247
5	192.168.1.253/30	192.168.1.252	192.168.1.255

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