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CCNA

200-301, Volume 1

2nd Edition

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CCNA 200-301

Official Cert Guide Volume 1

Second Edition

WENDELL ODOM, CCIE No. 1624

Cisco Press

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Wendell Odom

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About the Author

Wendell Odom, CCIE Enterprise No. 1624, was the first Cisco Press author for Cisco certification guides. He wrote all prior editions of this book, along with books on topics ranging from introductory networking to CCENT, CCNA R&S, CCNA DC, CCNP ROUTE, CCNP QoS, and CCIE R&S. In his four decades as a networker, he has worked as a network engineer, consultant, systems engineer, instructor, and course developer. He now spends his time focused on updating the CCNA books, his blog (www.certskills.com), building his new CCNA YouTube channel (www.youtube.com/@NetworkUpskill), and teaching online (www.certskills.com/courses). You can find him at www.LinkedIn.com/in/WendellOdom, Twitter (@WendellOdom), and at his blog, which provides a variety of free CCNA learning resources.

About the Technical Reviewer

Denise Donohue, CCIE No. 9566 (Routing and Switching), has worked with information systems since the mid-1990s and network architecture since 2004. During that time, she has worked with a wide range of networks, private and public, of all sizes, across most industries. Her focus is on aligning business and technology. Denise has authored several Cisco Press books and frequently shares her knowledge in webinars and seminars, and at conferences.

Dedications

For Fay York Odom (1938–2022), the best mom ever.

Acknowledgments

Brett Bartow and I have been a team for a few decades. He has had more to do with the successes of the Cisco Press product line than anyone else. More than ever, his insights and wisdom have been a key to navigating Cisco's big changes to certifications back in 2020. Now with Cisco's 2023 pivot to a lean development model for certifications, with the possibility of new exam content annually, Brett's leadership matters more than ever. (See "Your Study Plan" for more about what that new lean development cycle means.) He's always a great partner in working through big-picture direction as well as features to make the books the best they can be for our readers. It is always appreciated, but not voiced every time—so thanks, Brett, for your consistent leadership and wisdom!

Chris Cleveland did the development editing for the very first Cisco Press exam certification guide way back in 1998, and he still can't seem to get away from us! Seriously, when Brett and I first discuss any new book, my first priority is to ask whether Chris has time to develop the book—and lobby if there are any barriers! It's always a pleasure working with you, Chris.

The technical editors also have a meaningful positive impact on the books. And we got Denise Donohue to do it! Denise and I teamed up to write the *CCIE R&S Official Cert Guide* for two editions, and she has written extensively herself—which is why I wondered if we could get her help. Her deep technical skills, along with her unique insights into the book authoring process, have been a great help to both weed out the mistakes and get good advice on how to improve the chapters.

Cisco's move to an annual exam update cadence (they at least consider updating each exam once per year) has more impact on the production side of our publishing process than it does on the authoring side. Knowing early that both Sandra and Tonya are back at it, finding ways to continue the high quality while being creative with the new publication cycle sets me more at ease. When writing, I could rest knowing that the second half of the process, which happens after I've finished 99 percent of my work, will be done well!

Thanks to all the production team for making the magic happen. I usually do not interact with you directly, beyond Sandra and Tonya, but I see your work, and the books truly improve through the process! From fixing all my grammar and passive-voice sentences to pulling the design and layout together, they do it all; thanks for putting it all together and making it look easy.

A special thank you to you readers who write in with suggestions and possible errors, and especially those of you who post online at the Cisco Learning Network and at my blog (www.certskills.com). More so than any edition I can remember, reader comments have had more to do with changes I made to improve existing content in these editions. The comments I received directly and those I overheard by participating at CLN made this edition a better book. (See the heading "Feedback Information" just a page or so back to see how to get in touch with us!)

My wonderful wife, Kris, and I reached our 25th anniversary while working on this edition. She makes this challenging work lifestyle a breeze, even happily scheduling our 25th-anniversary vacation around the book schedule! Thanks to my daughter Hannah for the perspectives on how 20-somethings think about learning and studying. And thanks to Jesus Christ, Lord of everything in my life.

Contents at a Glance

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Reader Services

To access additional content for this book, simply register your product. To start the registration process, go to www.ciscopress.com/register and log in or create an account.* Enter the product ISBN 9780138229634 and click **Submit**. After the process is complete, you will find any available bonus content under Registered Products.

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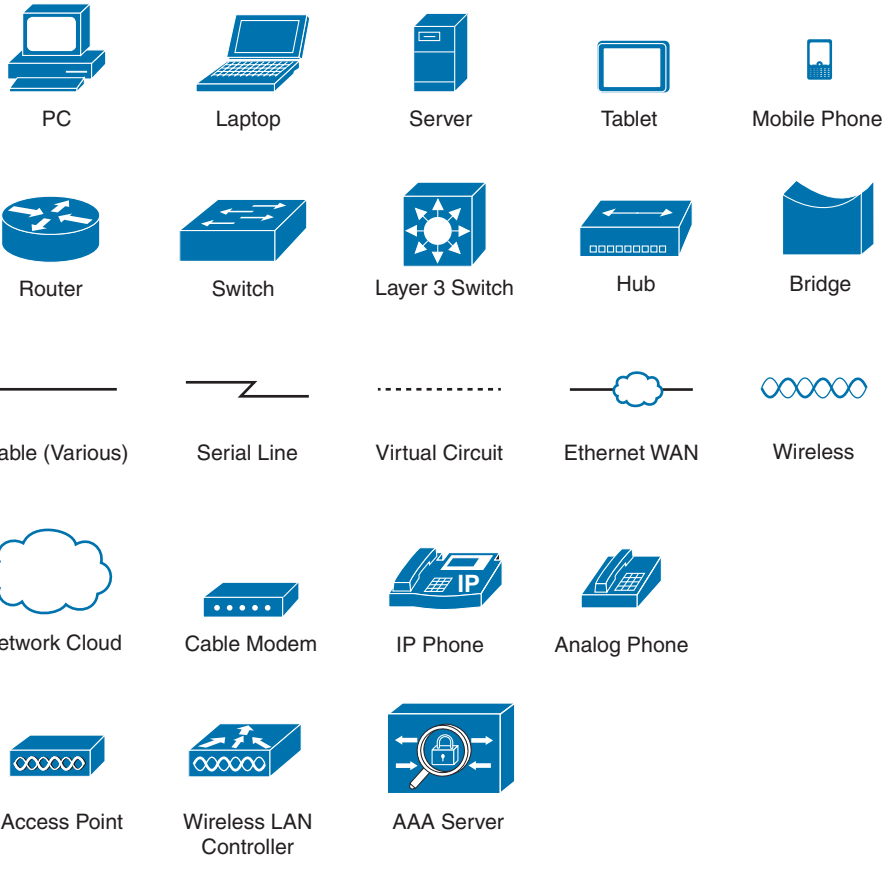

Command Syntax Conventions

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

Do not skip the intro!

You are setting out on a journey to achieve your CCNA certification. For many, that step happens at the beginning of a new career path. For others, CCNA validates their knowledge and skills already learned on the job.

Regardless of your path, the journey takes some time and effort. I encourage you to spend some time in the Introduction to learn more about CCNA and the books so you can have the best experience preparing for CCNA! To that end, this introduction discusses these main points:

Cisco Certifications and the CCNA

Book Features

Book Elements (Reference)

About Getting Hands-on Skills

About IP Subnetting

Cisco Certifications and the CCNA

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. Cisco has been the dominant vendor in networking for decades. If you want to be taken seriously as a network engineer, building your Cisco skills using Cisco certifications makes perfect sense. Where to start? CCNA.

Cisco Certifications as of 2024

The changes Cisco made in 2020 consolidated the certification tracks from about ten tracks down to the five tracks shown in Figure I-1. Cisco next made changes to various exams in 2023 and 2024; those changes updated the exams but maintained the same five tracks. The CCNA, CCNP, and CCIE certification levels progress through higher challenge levels, with CCNA as the foundation for all.

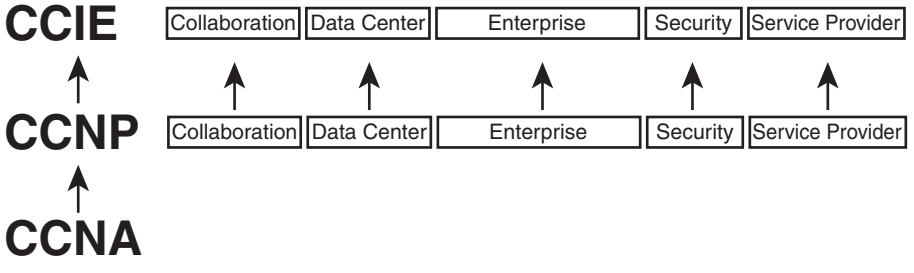

Figure I-1 *Cisco CCNA, CCNP, and CCIE Certifications*

The following list gives a few details of the history of these certification tracks: They are

CCNA – Cisco Certified Network Associate: Cisco began CCNA with a single CCNA certification back in 1998. They later expanded CCNA to include ten different CCNA

certifications about different technology areas. Cisco retired all the varieties of CCNA back in 2020, leaving us again with a single CCNA certification, now referred to as simply "CCNA."

CCNP – Cisco Certified Network Professional: Cisco followed the same progression with different CCNP certifications over time, starting with one in 1998. The big changes in 2020 consolidated the lineup to five CCNP certifications, all of which benefit from having knowledge of CCNA before moving on to CCNP.

CCIE – Cisco Certified Internetwork Expert: First introduced in 1993, these expert-level certifications require both a written exam plus a one-day practical exam with extensive hands-on lab challenges.

Beyond the CCNA, CCNP, and CCIE certifications, Cisco offers two other certification tracks, one for network automation and another for cybersecurity. The CCNA certification can be helpful as a foundation for those tracks as well. They are

DevNet Certifications: The DevNet Associate, DevNet Professional, and DevNet Expert certifications mirror the progression of CCNA/CCNP/CCIE, just without using those specific acronyms. The DevNet certifications focus on software development and APIs that matter to managing networks.

CyberOps Certifications: The CyberOps Associate and CyberOps Professional certifications mirror the progression of CCNA/CCNP. These security exams focus on security concepts, security monitoring, host-based analysis, network intrusion analysis, and security policies and procedures.

How to Get Your CCNA Certification

As you saw in Figure I-1, all career certification paths now begin with CCNA. So how do you get the CCNA certification? Today, you have one and only one option to achieve CCNA certification:

Take and pass one exam: The Cisco 200-301 CCNA exam.

To take the 200-301 exam, or any Cisco exam, you will use the services of Pearson VUE. The process works something like this:

1. Establish a login at https://vue.com/cisco (or use your existing login).
2. Register for, schedule a time and place, and pay for the Cisco 200-301 exam, all from the VUE website.
3. Take the exam at the VUE testing center or from home with a video proctor watching to prevent cheating.
4. You will receive a notice of your score, and whether you passed, before you leave the testing center.

Content in the CCNA 200-301 Exam

We've all thought it, wondered, for almost every important test we ever took, and maybe even asked the teacher: "What's on the test?" For the CCNA exam, and for all Cisco certification exams, Cisco tells us.

Cisco publishes an exam blueprint for every Cisco exam, with the blueprint listing the exam topics for the exam. To find them, browse www.cisco.com/go/certifications, look for the CCNA page, and navigate until you see the exam topics. And if you haven't already done so, create a bookmark folder for CCNA content in your web browser and bookmark a link to this page.

The exam blueprint organizes the exam topics into groups called domains. The document also tells us the percentage of points on the exam that come from each domain. For instance, every CCNA exam should score 25 percent of your points from the exam topics in the IP Connectivity domain. The exam does not tell you the domain associated with each question, but the percentages give us a better idea of the importance of the domains for the exam. Figure I-2 shows the domains of the CCNA 200-301 Version 1.1 blueprint, the percentages, and the number of primary exam topics in each.

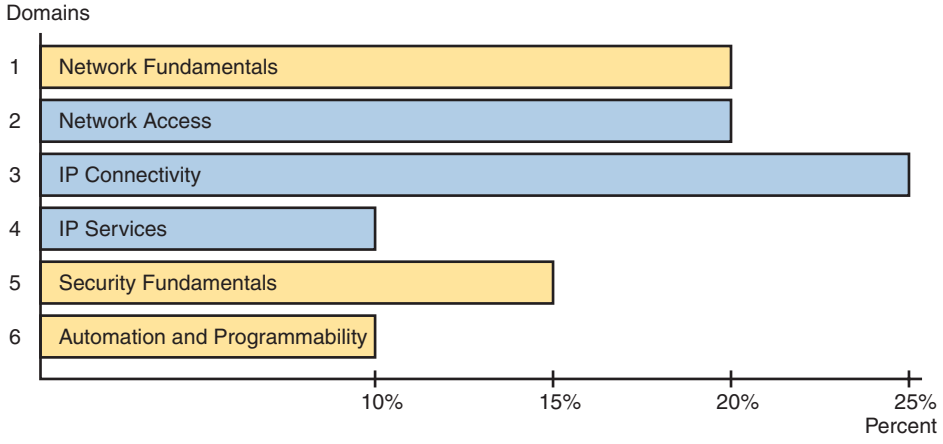

Figure I-2 *CCNA 200-301 Domains and Percentage of Exam Score*

Within each domain, the exam topic document lists exam topics that follow two different styles of wording. The main exam topics use a verb in the phrase that tells you the level of mastery required; I call those primary exam topics. The exam topics document shows subtopics that I refer to as secondary exam topics. Those do not have a verb, but list more technology details (nouns), and assume the verb from the primary exam topic. For instance, the following excerpt from the exam topics document lists one primary exam topic with the *describe* verb, with more detail added by two secondary exam topics.

1.13 Describe switching concepts

1.13.a MAC learning and aging

1.13.b Frame switching

Exam Topic Verbs (Depth) and Nouns (Breadth)

Understanding an exam topic requires that you think about each exam topic wording, focusing on the verbs and nouns. The nouns identify the technical topics, such as LAN switching, IP routing, protocols like OSPF, and so on. The verbs in each primary exam topic inform us about the type and depth of knowledge and skill tested per the exam topics.

For example, consider the following primary exam topic:

Describe IPsec remote access and site-to-site VPNs

I'm sure you know what the word *describe* means in the normal use of the term. But for people who build exams, the verb has special meaning as to what the exam questions should and should not require of the test taker. For instance, you should be ready to describe whatever "IPsec remote access and site-to-site VPNs" are. But the exam should not ask you to perform higher performance verbs, like *analyze* or *configure*.

Figure I-3 shows a pyramid with verbs found in Cisco exam blueprints. It shows the lower-skill verbs at the bottom and higher skills at the top. An exam topic with a lower verb should not be tested with questions from higher knowledge and skill levels. For instance, with the exam topic "describe…first hop redundancy protocols," you should not expect to need to configure, verify, or troubleshoot the feature.

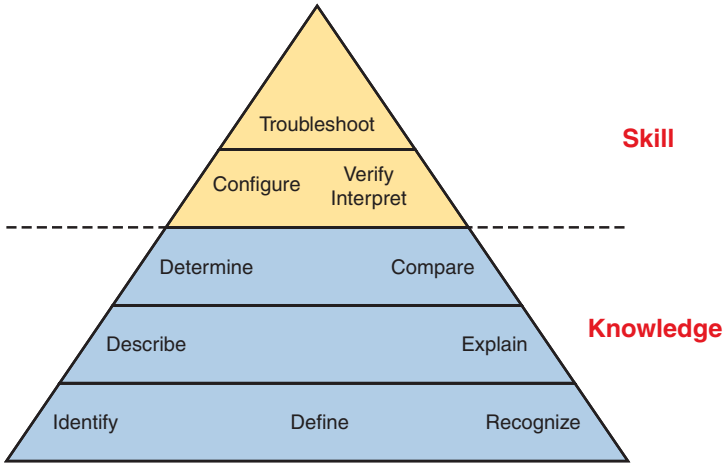

Figure I-3 *Cisco Exam Topic Verbs*

Knowing that, how should you study? Well, instead of a many-layer pyramid, think of it as two layers: Knowledge and Skill. When learning content whose exam topics use verbs from the lower three rows of the pyramid, study the same way no matter which of those verbs the exam topic uses. Learn the topic well. Be ready to describe it, explain it, and interpret the meaning. For content with exam topics with the verbs *configure* and *verify*, think of those as including the first level of knowledge, plus also requiring configuration and verification skills. Also, think about the common configuration mistakes so you can troubleshoot those mistakes.

Comparing the Exam and Exam Topics

Cisco tells us that the exam can include more technical topics than those listed as nouns in the exam topics. Cisco also tells us that the exam topics give us general guidance. Once you get into the content, you will understand what they mean: any noun listed in the exam topics has many related protocols, standards, features, concepts, or device commands that Cisco did not list in the exam topics. Let's explore that concept to give you some perspective.

First, to see what Cisco tells us about the exam versus the exam topics, return to cs.co/go/certifications or cisco.com/go/ccna. Find the CCNA exam topics and open the PDF version (the text we need to consider is currently only in the PDF version). Open the PDF and spend 10–15 seconds scanning it.

Did you read the first two paragraphs, the ones before the list of exam topics? Or did you skip those and move straight to the long list of exam topics? Many people skip those paragraphs. One of those tells us much about the exam versus the exam topics, so I've copied it here, with emphasis added:

> The following topics are ***general guidelines*** for the content likely to be included on the exam. However, ***other related topics may also appear on any specific delivery of the exam***. To better reflect the contents of the exam and for clarity purposes, the ***guidelines below may change at any time without notice***.

Together, the first two emphasized phrases tell us that the exam may go beyond the literal words in the exam topics. Let me give you a couple of examples. First, prerequisite knowledge must be inferred from the literal exam topics. For instance, consider this exam topic:

Configure and verify IPv4 addressing and subnetting

The skills to configure IPv4 addresses take only a few minutes to learn. Understanding what the numbers mean takes much longer. In fact, I'd say 95 percent of your work will be to understand the prerequisite knowledge—but the exam topics do not list those prerequisites, like understanding subnetting concepts, applying the subnet mask to an address, calculating the range of addresses in a subnet, and so on.

I develop the scope of the books with the preceding in mind. You will certainly read about all topics that appear in the exam topics. Consider that view a narrow interpretation of the exam topics. But you will also learn about terms, concepts, and product features not specifically mentioned in the exam topics, from my broad and deep interpretation of the exam topics, based on Cisco's approach to their exams. We try to predict what Cisco will include, starting from the exam topics. Figure I-4 shows the idea.

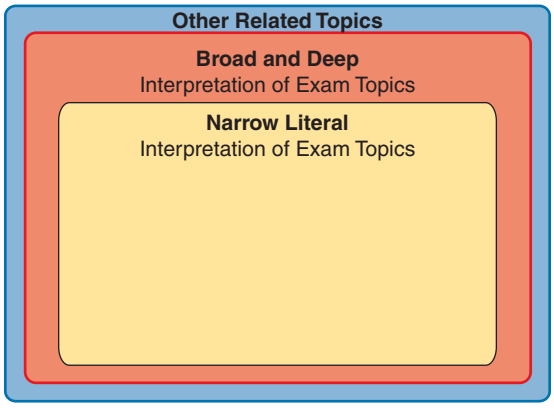

Figure I-4 *Scope Concept: Exam Versus Exam Topics*

Although we can build a book around the exam topics, we cannot predict every concept and command included in the actual CCNA exam. The general nature of the exam topics, the allowance of "other related topics," plus other factors, make predicting all exam content impossible. But we do promise to discuss 100 percent of the exam topic details and to diligently seek the right balance of a broad interpretation of those topics to make you well prepared for the exam.

How to Prepare for the Generalized Exam Topics

Given the possibility of topic areas not listed in the exam topics, how should you go about preparing for the CCNA exam? Let me give you a few suggestions.

1. Follow the suggestions in the upcoming section "Your Study Plan" just before Chapter 1.
2. Practice hands-on Command Line Interface (CLI) skills. The later section of the Introduction titled "About Building Hands-On Skills" discusses some ways to practice.
3. Pay close attention to troubleshooting topics in the book.
4. Practice all math-related skills, over time, until you master them.
5. Ensure you know all exam topic content as listed in the exam topics. Read the exam topics, consider your own literal interpretation, and when uncertain or confused, dig in and study further.
6. Trust that the book uses its broad interpretation of the exam topics to help you learn as much as possible that might be on the exam.

Types of Questions on the CCNA 200-301 Exam

You can expect the following kinds of questions on the exam; just be aware that the style of questions may change over time.

- Multiple-choice, single-answer
- Multiple-choice, multiple-answer
- Drag-and-drop
- Lab

For the multichoice questions, the exam software gives us a few important advantages:

- There is no penalty for guessing.
- Multichoice questions with a single correct answer require you to answer and allow only one answer.
- Multichoice questions with multiple correct answers tell you the number of correct answers and warn you if you have not selected that many answers.

For instance, if a question tells you there are two correct answers, and you select only one and then try to move to the next question, the app reminds you that you should choose another answer before moving on.

As for drag-and-drop, some questions use simple text blocks that you move from one list to another. However, you might see questions where you move items in a network diagram or some other creative use of drag-and-drop.

Finally, Cisco introduced lab questions (formally called performance-based questions) in 2022. Lab questions present you with a lab scenario with a lab pod of virtual routers and switches running in the background; you get console access to a few devices. Your job: find the missing or broken configuration and reconfigure the devices so that the lab scenario works. The best way to practice for these questions is to practice in the lab; more on that in the section titled "About Building Hands-On Skills."

As an aside, prior Cisco exams had Sim questions instead of lab questions. Sim questions required the same from us: read the scenario and fix the configuration. However, Sim questions used simulated Cisco devices with limited command support, which frustrated some test takers. The lab questions use real Cisco operating systems running in a virtual environment, so they provide a much more realistic experience compared to old Sim questions.

Book Features

This book includes many study features beyond the core explanations and examples in each chapter. This section acts as a reference to the various features in the book.

The CCNA Books: Volume 1 and Volume 2

The CCNA exam covers a large amount of content, and it does not fit in a single volume. As a result, Cisco Press has long published books for the CCNA exam as a two-book set. Volume 1 covers about half of the content, and Volume 2 covers the rest, as shown in Figure I-5. To best use both books, start in Volume 1 and work through the book in order, and then do the same with Volume 2.

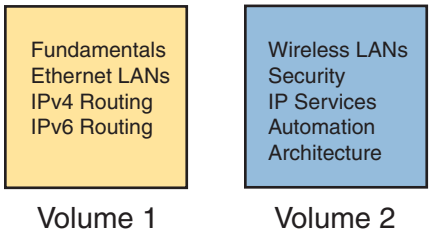

Figure I-5 *Two Books for CCNA 200-301*

When you start each new chapter, review the list of exam topics that begins the chapter. The book does not follow the same order of exam topics in the blueprint, but instead follows a more effective order for learning the topics. For reference, look to Appendix B, "Exam Topics Cross-Reference," in the back of the book. The appendix includes:

- A list of exam topics and the chapter(s) covering each topic
- A list of chapters and the exam topics covered in each chapter

Exam Blueprint Versions and Book Editions

Cisco made minor changes to the CCNA exam blueprint in 2024, the first change to the CCNA 200-301 exam since the year 2020. The much more important change (announced in 2023) had to do with the entire Cisco certification program about how Cisco announces and releases new exams and exam blueprints. Before 2023, when Cisco changed any CCNA or CCNP exam, they also changed the exam number, and the announcement was sudden. Those days are gone.

You should read and understand Cisco's long-term strategy for being more forthright about exam plans as detailed at www.cisco.com/go/certroadmap. Summarizing some key points, when Cisco changes an exam in the future, Cisco will keep the same exam number. To identify the changes, they will use a major.minor version numbering plan for every exam blueprint. More importantly, Cisco tells us when they will consider changing CCNA each year, but we know when Cisco will announce changes and when the new exam will be released, within a few months' timing.

The exam blueprint version changes based on two determinations: 1) whether Cisco will change the exam that year at all, and 2) if so, whether Cisco considers the changes to be major or minor. For instance, Cisco considered making a change to CCNA during February–April 2023 but chose not to change it, announcing that fact in the May–July 2023 timeframe. In 2024, Cisco chose to make minor changes to the CCNA blueprint. As a result, the former CCNA blueprint version 1.0 (major version 1, minor version 0) changed to version 1.1, increasing the minor version by 1.

Looking forward, if the next three future CCNA blueprint changes are also minor, they would be blueprint versions 1.2, 1.3, and 1.4. However, if any of them are major, that version would move to the next major version (2.0), with subsequent minor version changes as 2.1, 2.2, and so on.

Cisco also tells us that each year, internally, Cisco considers what to do with CCNA in the February–April timeframe. They will announce their plans to us all between May–July, and they will release the new exam (if changes are being made) sometime in the six months or so following the announcement.

As for the publishing plans to support that new update cycle, you should read and monitor the publisher's web page at www.ciscopress.com/newcerts. Also, opt in for communications on that page so the publisher will email you about future plans and updates.

Summarizing a few key points about the publisher's plans, this book, the second edition, was written for version 1.1 of the CCNA 200-301 blueprint, but it should be the book used for CCNA for subsequent blueprint versions as well. During the life of this second edition book, Cisco may update the CCNA 200-301 exam blueprint a few times, while this book (plus the Volume 2 second edition book) may remain unchanged. New exam content may be made available as electronic downloads. At some point, a new edition will be appropriate. (Figure I-6 shows one example of what might happen over time, with downloadable PDFs between editions.)

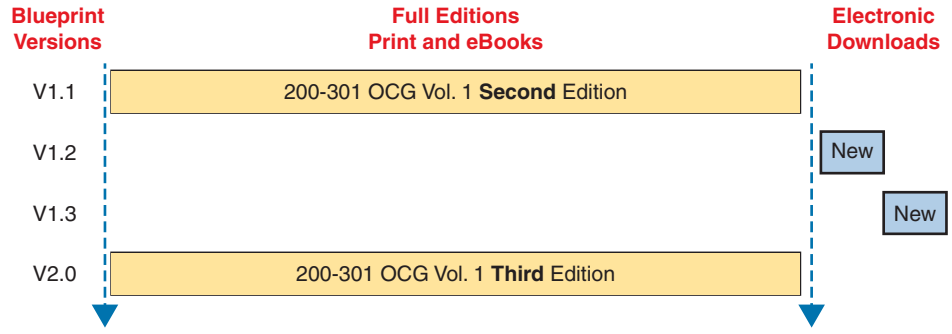

Figure I-6 *Possible Progression of Book Editions, New Content Release, Versus Exams*

NOTE I cannot stress enough: monitor both the Cisco Press and Cisco pages linked in the preceding paragraphs, and opt in for communications at those pages, to stay aware of any exam and publishing plans. Also, consider watching my blog (www.certskills.com), where I expect to post about changes.

When you finish the technology chapters in this book (Chapters 1–29), make sure to also read Chapter 30, "Exam Updates." We post updated versions of that chapter online. We use that chapter to deliver small content updates to you as well as to inform you about future content updates. Make sure to read through that chapter and learn how to download the latest version of the chapter, discovering if new content has been posted after this book was published.

Also, just to reduce confusion about the book titles, note that the prior edition of this book is nearly identical to this book's title. Comparing the titles:

- *CCNA 200-301 Official Cert Guide, Volume 1* (the prior edition, published in 2019, for 200-301 exam blueprint version 1.0)
- *CCNA 200-301 Official Cert Guide, Volume 1*, Second Edition (this edition, published in 2024, for 200-301 exam blueprint version 1.1 and beyond)

Comparing This Edition to the Previous

This book replaces a similar book that applied to the former CCNA 200-301 exam blueprint 1.0. Some of you may buy this book but have already begun studying with the prior edition. The following list of major changes to this book versus the previous one may help you avoid rereading identical or similar content in this book.

Chapter 4: Added a short topic comparing Cisco switch operating systems. Also introduced the WebUI interface for Cisco routers and switches per an exam topic change.

Chapter 6: Explored the differences in the **transport input** configuration command based on device models and operating systems. Also showed how to configure the WebUI on a switch per an exam topic change.

Chapter 7: Revised and expanded sections about Ethernet autonegotiation concepts and auto-MDIX.

Chapter 8: Added a large closing section about troubleshooting VLANs and VLAN trunks.

Chapter 9: Removed EtherChannel load distribution concept details, and added concept details about BPDU Guard, BPDU filter, loop guard, and root guard.

Chapter 10: Expanded/revised the second half of the chapter (Layer 2 EtherChannels), and added a new middle section about verifying BPDU Guard, BPDU filter, loop guard, and root guard.

Chapter 12: Added a few pages comparing public IP networks and public CIDR blocks.

Chapter 15: Added an entire new chapter about subnetting design issues. The chapter was in the prior edition but as a PDF-only appendix.

Chapter 16: (Formerly Chapter 15) Expanded the discussion of router interface autonegotiation and differences between IOS and IOS XE.

Chapter 17: (Formerly Chapter 16) Added a small section discussing possible mistakes with the **ip address** interface subcommand.

Chapter 18: (Formerly Chapter 17) Added two topics: SVI interface auto-state and the configuration of Ethernet switch ports in a router.

Chapter 19: (Formerly Volume 2, Chapter 7) Moved the chapter to Volume 1 from Volume 2 and expanded the discussion of host commands.

Chapters 21–24: (Formerly Chapters 19–21) Chapters 21–24 reorganize and expand the OSPF topics. Chapter 24 closes with a revised section about route selection.

Chapter 28: This new chapter contains the final topic of former Chapter 25 (IPv6 NDP), unchanged. The second half of the chapter has new content about host IPv6 commands and IPv6 address attributes.

If you find the preceding information useful, consider looking in two other places that allow us to provide ongoing updates and to answer questions. First, I expect to post blog posts about the new CCNA exam changes, as always, at my blog (www.certskills.com). Look there for posts in the News section (click the General menu item and then News), for posts made around the time the new exams release.

Second, look to the companion website for this book for details about future exam revisions and publishing plans. The companion website gives the publisher a place to list details about changes moving forward. See this Introduction's later section titled "The Companion Website for Online Content" for the instructions for finding the site.

Chapter Features

Beginning to study CCNA can be overwhelming at first due to the volume. The best way to overcome that reaction requires a change in mindset: *treat each chapter as a separate study task*. Breaking your study into manageable tasks helps a lot.

Each chapter of this book is a self-contained short course about one small topic area, organized for reading and study. I create chapters so they average about 20 pages to cover

the technology so that no one chapter takes too long to complete. Each chapter breaks down as follows:

"Do I Know This Already?" quizzes: Each chapter begins with a pre-chapter quiz so you can self-assess how much you know coming into the chapter.

Foundation Topics: This is the heading for the core content section of the chapter, with average length of 20 pages.

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.

Do not read the "Foundation Topics" section of chapter after chapter without pausing to review and study. Each "Chapter Review" section uses a variety of other book features to help you study and internalize that chapter's content, including the following:

- **Review Key Topics:** All the content in the books matters, but some matters more. Cisco Press certification guides use a Key Topic icon next to those items in the "Foundation Topics" section. The "Chapter Review" section lists the key topics in a table. You can scan the chapter to review them or review the Key Topics more conveniently using the companion website.
- **Complete Tables from Memory:** We convert some tables in the book to interactive study tables called memory tables. You access memory tables from the companion website. Memory tables repeat the table, but with parts of the table removed. You can then fill in the table to exercise your memory and click to check your work.
- **Key Terms You Should Know:** The "Chapter Review" section lists the key terminology from the chapter. For a manual process with the book, think about each term and use the Glossary to cross-check your own mental definitions. Alternately, review the key terms with the "Key Terms Flashcards" app on the companion website.
- **Labs:** You should practice hands-on skills for any exam topics with the *configure* and *verify* verbs. The upcoming section titled "About Building Hands-On Skills" discusses your lab options. Also, the Chapter and Part Reviews refer you to lab exercises specific to the chapter or part.
- **Command References:** Some book chapters discuss the configure and verify exam topics, so they list various router and switch commands. The "Chapter Review" section of those chapters includes command reference tables, useful both for reference and for study. Just cover one column of the table and see how much you can remember and complete mentally.
- **Review DIKTA Questions:** Even if you used the DIKTA questions to begin the chapter, re-answering those questions can prove a useful way to review facts. By design, I do not mention the DIKTA questions in the "Chapter Review" sections but do suggest using them again for all chapters in a part during Part Review. Use the Pearson Test Prep (PTP) web app to easily use those questions any time you have a few minutes, a device, and Internet access.
- **Subnetting Exercises:** Several chapters ask you to perform some math processes related to either IPv4 or IPv6 addressing. The "Chapter Review" section asks you

to do additional practice problems, where applicable. The problems can be found in Appendices D through I, in PDF form, on the companion website, along with those same exercises as interactive web apps.

Part Features

Your second mindset change: Use the book parts as major milestones in your study journey. Each part groups a small number of related chapters together. Take the time at the end of each part to review all topics in the part, effectively rewarding yourself with a chance to deepen your knowledge and internalize more of the content before moving to the next part. Figure I-7 shows the concept.

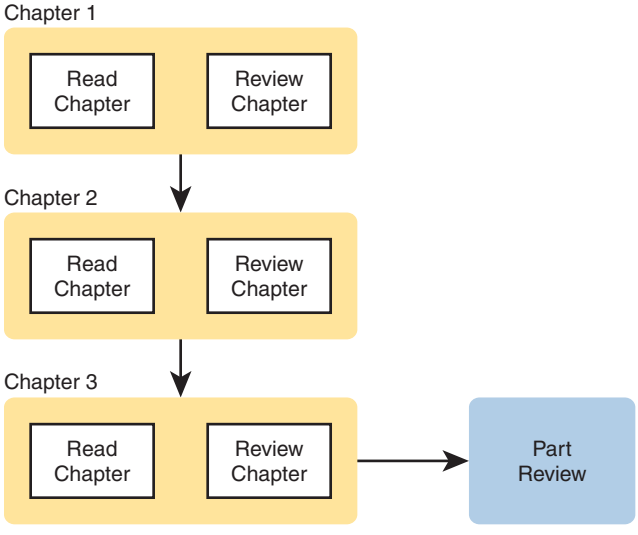

Figure I-7 *Part Review: The Second Review of Most Content*

The Part Review element at the end of each part suggests review and study activities. Spaced reviews—that is, reviewing content several times over the course of your study—help improve retention. Using the Chapter and Part Review process, the Part Review serves as your second review of the content in each chapter. The Part Review repeats some Chapter Review activities and offers some new ones, including a reminder to use practice questions set aside specifically for Part Review.

The Companion Website for Online Content

Some Chapter and Part Review tasks can be done from the book. However, several of them work better as an interactive online tool. For instance, you can take a "Do I Know This Already?" quiz by reading the pages of the book, but you can also use the PTP testing software. As another example, when you want to review the key terms from a chapter, you can find all those in electronic flashcards.

This book's companion website hosts all the electronic components of the book. The companion website gives you a big advantage: you can do most of your Chapter and

Part Review work from anywhere using the interactive tools on the site. The advantages include

- **Easier to use:** Instead of having to print out copies of the appendices and do the work on paper, you can use these new apps, which 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.
- **Good break from reading:** Sometimes looking at a static page after reading a chapter lets your mind wander. Breaking up your reading with some review from the keyboard can help keep you focused on the activity.

The interactive Chapter Review elements should improve your chances of passing as well. Our in-depth reader surveys over the years show that those who do the Chapter and Part Reviews learn more. Those who use the interactive review elements tend to do the review tasks more often. So, take advantage of the tools and maybe you will be more successful as well. Table I-1 summarizes these interactive 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	The "Chapter Review" section lists the key topics. To review, flip pages in the chapter.	Key Topics Table app with links to view each key topic
Config Checklist	This list of steps, in text, describes how to configure a feature.	Config Checklist app, where you complete the checklist by adding commands
Key Terms	Terms are listed in each "Chapter Review" section; review using the end-of-book Glossary.	Key Terms Flash Cards app
Appendices Subnetting Practice	Appendices D–I provide static text practice problems and answers in the PDF appendices.	A variety of apps, one per problem type, in the "Memory Tables and Practice Exercises" section
In-chapter Subnetting practice	Look at the problems in the chapter and refer to the answer tables at the end of the chapter.	App that offers a fill-in-the-blank answer space and grades your answer

The companion website also includes links to download, navigate, or stream for these types of content:

- Pearson Sim Lite Desktop App
- Pearson Test Prep (PTP) Desktop App
- Pearson Test Prep (PTP) Web App
- Videos

How to Access the Companion Website

To access the companion website, which gives you access to the electronic content with this book, start by establishing a login at www.ciscopress.com and register your book. To do so, simply go to www.ciscopress.com/register and enter the ISBN of the print book: 9780138229634. 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.

Note that if you buy the *Premium Edition eBook and Practice Test* version of this book 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.

How to Access the Pearson Test Prep (PTP) App

You have two options for installing and using the Pearson Test Prep application: a web app and a desktop app. To use the Pearson Test Prep application, start by finding the registration code that comes with the book. You can find the code in these ways:

- You can get your access code by registering the print ISBN 9780138229634 on ciscopress.com/register. Make sure to use the print book ISBN, regardless of whether you purchased an eBook or the print book. After you register the book, your access code will be populated on your account page under the Registered Products tab. Instructions for how to redeem the code are available on the book's companion website by clicking the Access Bonus Content link.
- If you 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. Just log in at ciscopress.com, click Account to see details of your account, and click the digital purchases tab.

NOTE After you register your book, your code can always be found in your account under the Registered Products tab.

Once you have the access code, to find instructions about both the PTP web app and the desktop app, follow these steps:

Step 1. Open this book's companion website as shown earlier in this Introduction under the heading, "How to Access the Companion Website."

Step 2. Click the **Practice Exams** button.

Step 3. Follow the instructions listed there for both installing the desktop app and using the web app.

Note that if you want to use the web app only at this point, just navigate to pearsontestprep.com, log in using the same credentials used to register your book or purchase the Premium Edition, and register this book's practice tests using the registration code you just found. The process should take only a couple of minutes.

Feature Reference

The following list provides an easy reference to get the basic idea behind each book feature:

- **Practice exam:** The book gives you the rights to the Pearson Test Prep (PTP) testing software, available as a web app and a desktop app. Use the access code on a piece of cardboard in the sleeve in the back of the book, and use the companion website to download the desktop app or navigate to the web app (or just go to www.pearsontestprep.com).
- **eBook:** Pearson offers an eBook version of this book that includes extra practice tests as compared to the print book. The product includes two versions of the eBook: PDF (for reading on your computer) and EPUB (for reading on your tablet, mobile device, or Kindle, Nook, or other e-reader). It also includes additional practice test questions and enhanced practice test features, including links from each question to the specific heading in the eBook file.
- **Mentoring videos:** The companion website also includes a number of videos about other topics as mentioned in individual chapters. Some of the videos explain common mistakes made with CCNA topics, whereas others provide sample CCNA questions with explanations.
- **Subnetting videos:** The companion website 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 appendices/web apps:** The companion website contains appendices with a set of subnetting practice problems and answers. This is a great resource to practice building subnetting skills. You can use these same practice problems with applications from the "Memory Tables and Practice Exercises" section of the companion website.
- **CCNA 200-301 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 companion website.
- **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, Pearson has created a mapping guide that maps each of the labs in the simulator to the specific sections in each volume of the CCNA Cert Guide. You can get this mapping guide free on the Extras tab on the book product page: www.ciscopress.com/title/9780138229634.
- **Author's websites:** The author maintains a blog site that has a large number of free lab exercises about CCNA content, additional sample questions, and other exercises. Additionally, the site indexes all content so you can study based on the book chapters and parts. To find it, navigate to www.certskills.com. Additionally, look for CCNA activities and lectures at his YouTube channel (www.youtube.com/@networkupskill).

Book Organization, Chapters, and Appendices

This book contains 29 chapters about CCNA topics organized into seven parts. The core chapters cover the following topics:

- **Part I: Introduction to Networking**
  - **Chapter 1, "Introduction to TCP/IP Networking,"** introduces the central ideas and terms used by TCP/IP and explains the TCP/IP networking model.
  - **Chapter 2, "Fundamentals of Ethernet LANs,"** introduces the concepts and terms used when building Ethernet LANs.
  - **Chapter 3, "Fundamentals of WANs and IP Routing,"** covers the basics of the data-link layer for WANs in the context of IP routing but emphasizes the main network layer protocol for TCP/IP. This chapter introduces the basics of IPv4, including IPv4 addressing and routing.
- **Part II: Implementing Ethernet LANs**
  - **Chapter 4, "Using the Command-Line Interface,"** explains how to access the text-based user interface of Cisco Catalyst LAN switches.
  - **Chapter 5, "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 6, "Configuring Basic Switch Management,"** explains how to configure Cisco switches for basic management features, such as remote access using Telnet and SSH.
  - **Chapter 7, "Configuring and Verifying Switch Interfaces,"** shows how to configure a variety of switch features that apply to interfaces, including duplex/speed.
- **Part III: Implementing VLANs and STP**
  - **Chapter 8, "Implementing Ethernet Virtual LANs,"** explains the concepts and configuration surrounding virtual LANs, including VLAN trunking.
  - **Chapter 9, "Spanning Tree Protocol Concepts,"** discusses the concepts behind IEEE Spanning Tree Protocol (STP), including Rapid STP (RSTP) and how they make some switch interfaces block frames to prevent frames from looping continuously around a redundant switched LAN.
  - **Chapter 10, "RSTP and EtherChannel Configuration,"** shows how to configure and verify RSTP and Layer 2 EtherChannels on Cisco switches.
- **Part IV: IPv4 Addressing**
  - **Chapter 11, "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 12, "Analyzing Classful IPv4 Networks,"** explains how 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 13, "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 14, "Analyzing Existing Subnets,"** describes how 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.
- **Chapter 15, "Subnet Design,"** discusses IPv4 subnetting from the perspective of creating a list of useful subnets, based on a subnet mask, from one Class A, B, or C network.

- **Part V: IPv4 Routing**
  - **Chapter 16, "Operating Cisco Routers,"** is like Chapter 8, focusing on basic device management, but it focuses on routers instead of switches.
  - **Chapter 17, "Configuring IPv4 Addresses and Static Routes,"** discusses how to add IPv4 address configuration to router interfaces and how to configure static IPv4 routes.
  - **Chapter 18, "IP Routing in the LAN,"** shows to a configuration and troubleshooting depth different methods to route between VLANs, including Router-on-a-Stick (ROAS), Layer 3 switching with SVIs, Layer 3 switching with routed ports, and using Layer 3 EtherChannels.
  - **Chapter 19, "IP Addressing on Hosts,"** discusses how IP hosts receive their IPv4 settings from either static configuration or using DHCP.
  - **Chapter 20, "Troubleshooting IPv4 Routing,"** focuses on how to use two key troubleshooting tools to find routing problems: the **ping** and **traceroute** commands.
- **Part VI: OSPF**
  - **Chapter 21, "Understanding OSPF Concepts,"** introduces the fundamental operation of the Open Shortest Path First (OSPF) protocol, focusing on link state fundamentals, neighbor relationships, flooding link state data, and calculating routes based on the lowest cost metric.
  - **Chapter 22, "Implementing Basic OSPF Features,"** shows the most basic OSPF configuration using two methods: OSPF router subcommands and interface subcommands.
  - **Chapter 23, "Implementing Optional OSPF Features,"** discusses a wide variety of OSPF configuration options.
  - **Chapter 24, "OSPF Neighbors and Route Selection,"** examines the conditions that must be true before two routers will succeed in becoming OSPF neighbors. It also takes a closer look at the choices a router makes when choosing between competing routes and how the router uses those routes.

- **Part VII: IP Version 6**
  - **Chapter 25, "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 26, "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 27, "Implementing IPv6 Addressing on Routers,"** shows how to configure IPv6 routing and addresses on routers, while discussing a variety of special IPv6 addresses.
  - **Chapter 28, "Implementing IPv6 Addressing on Hosts,"** discusses how IPv6 hosts receive their IPv6 settings from either static configuration, DHCP, or SLAAC. It also discusses the NDP protocol suite.
  - **Chapter 29, "Implementing IPv6 Routing,"** shows how to add static routes to an IPv6 router's routing table.
- **Part VIII: Exam Updates**
  - **Chapter 30, "*CCNA 200-301 Official Cert Guide, Volume 1*, Second Edition, Exam Updates,"** has two purposes. First, the author will update this appendix with new content mid-edition as needed. The appendix details the download instructions. Additionally, it discusses Cisco's open approach to exam revision and release, called the Cisco Certification Roadmap.
- **Part IX: Appendixes**
  - **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, "Exam Topics Cross-Reference,"** provides some tables to help you find where each exam objective is covered in the book.
  - **Appendix C, "Answers to the 'Do I Know This Already?' Quizzes,"** includes the explanations to all the "Do I Know This Already" quizzes.
  - The **Glossary** contains definitions for all the terms listed in the "Key Terms You Should Know" sections at the conclusion of the chapters.
- **Online Appendixes**
- **Practice Appendices**

  The following appendixes are available in digital format from the companion website. These appendixes provide additional practice for several networking processes that use some math.
  - **Appendix D, "Practice for Chapter 12: Analyzing Classful IPv4 Networks"**
  - **Appendix E, "Practice for Chapter 13: Analyzing Subnet Masks"**
  - **Appendix F, "Practice for Chapter 14: Analyzing Existing Subnets"**
  - **Appendix G, "Practice for Chapter 15: Subnet Design"**

- **Appendix H, "Practice for Chapter 25: Fundamentals of IP Version 6"**
- **Appendix I, "Practice for Chapter 27: Implementing IPv6 Addressing on Routers"**

- **Miscellaneous Appendices**
  - **Appendix J, "Study Planner,"** is a spreadsheet with major study milestones, where you can track your progress through your study.
- **Content from Previous Editions**

  From edition to edition, some readers have asked that we keep some select chapters with the book. Keeping content that Cisco removed from the exam, but that may still be useful, can help the average reader as well as instructors who use the materials to teach courses with this book. The following appendices hold this edition's content from previous editions:
  - **Appendix K, "Topics from Previous Editions,"** is a collection of small topics from prior editions. None of the topics justify a complete appendix by themselves, so we collect the small topics into this single appendix.
  - **Appendix L, "LAN Troubleshooting,"** examines the most common LAN switching issues and how to discover those issues when troubleshooting a network.
  - **Appendix M, "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 appendix explains those challenges.

About Building Hands-On Skills

To do well on the CCNA exam, 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.

For the exam, CLI skills help you in a couple of ways. First, lab questions require CLI skills. Each lab question can take 7–8 minutes if you know the topic, so poor CLI skills can cost several minutes per lab question. Additionally, any question type can ask about CLI commands, so the more comfortable you are remembering commands, parameters, and what they do, the more points you will pick up on the exam.

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

I created some lab exercises called Config Labs and put them on my blog. Each Config Lab details a straightforward lab exercise. It begins with a scenario, a topology, and existing configuration. You choose the configuration to add to each device to meet the goals of the scenario.

To make the labs accessible to all, the blog has no login requirements and no cost. You can do each lab just by viewing the page, reading, and writing your answer on paper or

typing it in an editor. Optionally, you can attempt most labs in the Cisco Packet Tracer Simulator. In either case, the Config Lab page lists the intended answer, so you can check your work.

To find the Config Labs, first go to www.certskills.com. Navigate from the top menus for "Labs." Alternatively, use the advanced search link, from which you can combine search parameters to choose a book chapter or part, and to search for Config Lab posts.

Note that the blog organizes these Config Lab posts by book chapter, so you can easily use them 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 a desktop simulator app called Pearson Network Simulator Lite (or NetSim Lite) that comes with this book.

Pearson builds a CCNA Simulator app designed to help you learn most of the CCNA configure and verify exam topics. They also make a free lite version of the Simulator, included with this book. The lite version gives you the means to experience the Cisco CLI just after a 5–10-minute installation process. No need to go buy real gear or buy a full simulator to start learning the CLI. Just install the Sim Lite from the companion website.

This latest version of NetSim Lite includes labs associated with Part II of this book, plus a few more from Part III. (Part II is the first book part that includes any CLI commands.) So, make sure to use the NetSim Lite to learn the basics of the CLI to get a good start.

Of course, one reason that you get access to the NetSim Lite 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.

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 CCNA certification. 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 included with the book. Both have the same base code, same user interface, and same types of labs. Try the Lite version to decide if you want to buy the full product.

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 the Sort by Chapter tab in the Simulator's user interface.

At the time this book was published, Pearson had no plan to update its CCNA Simulator product to a new version, as the current edition covers the latest exam topics. A software update will be issued that maps the labs to the organization of the new Cert Guide chapter structure by the summer of 2024.

More Lab Options

Many other lab options exist. For instance, you can use real Cisco routers and switches. You can buy them, new or used, or borrow them at work. For example, you can buy routers and switches that are useful for CCNA learning but are two or three product generations old. You can also find sites from which you can rent time on real devices or virtual devices.

Cisco also makes a free simulator that works very well as a learning tool: Cisco Packet Tracer. Unlike the Pearson Network Simulator, it does not include lab exercises that direct you as to how to go about learning each topic. However, you can usually find lab exercises that rely on Packet Tracer, like the Config Labs at my blog. If interested in more information about Packet Tracer, check out www.certskills.com/ptinstall.

Cisco offers a virtualization product that lets you run router and switch operating system (OS) images in a virtual environment on your PC. This tool, the Cisco Modeling Labs–Personal Edition (CML PE), lets you create a lab topology, start the operating system for each device, and connect to the CLI of real router and switch OS images. There is a fee, and you may need a PC hardware upgrade to use it effectively. Check out www.cisco.com/go/cml for more information, and inquire for more information at the Cisco Learning Network's CML community (learningnetwork.cisco.com).

The next two options work somewhat like CML PE, but with free software but no Cisco Operating Systems supplied. GNS3 (gns3.com) and EVE-NG (eve-ng.net) support creating topologies of virtual routers and switches that run real Cisco operating systems. Both have free options. However, both require that you provide the OS images. Also, as with CML PE, you may need to buy a small server or at least upgrade your personal computer to run more than a few routers and switches in a lab topology.

This book does not tell you what option to use, but you should plan on getting some hands-on practice somehow. For people starting with CCNA, many use some simulator like Pearson Sim Lite and the free Cisco Packet Tracer simulator. If you go far in your Cisco certification journey, you will likely try at least one of the virtualization options and also use real gear. The important thing to know is that most people need to practice using the Cisco CLI to be ready to pass these exams.

About IP Subnetting

IP addressing and subnetting skills remain as one of the top five most important topics for real networking jobs and for the CCNA exam. This book devotes Part IV to the topic, with several practice problem appendices to match. You can learn all you need for CCNA from those in-book chapters, and you can practice with the appendices. You can even use the interactive versions of the appendices on the companion website.

Because IP subnetting is so important, I created a video course called "IP Subnetting from Beginning to Mastery LiveLessons." You can buy the course outright from Cisco Press or access the course at O'Reilly Learning (learning.oreilly.com). This video course

teaches IPv4 subnetting from start to finish. The course includes instruction on all aspects of IPv4 subnetting, many examples, and close to 100 video practice exercises.

However, to be clear, you do not need to buy the subnetting course; the book has all you need to learn subnetting well. But if you prefer to use the IP Subnetting video course, you do not have to use the course and read the chapters in this book's Part IV. Instead, use one of these plans if you get the video course:

- Learn from the first 19 lessons in the course, which cover the same content as Part IV of this book—and again ignore the chapters in Part IV.
- Study primarily from the book chapters and supplement your reading with the video course. Because the course teaches the topics in a different order, use the information in Table I-2 to decide what video course lessons to use.

Table I-2 *Using the IP Subnetting Video Course Instead of Volume 1, Part IV*

Volume 1 Chapter	Video Course Lessons
11	1–3, 10
12	11, 12
13	8, 9
14	4–7
15	13–19

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 for the latest details.

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CHAPTER 22

Implementing Basic OSPF Features

This chapter covers the following exam topics:

- **3.0 IP Connectivity**
  - **3.2 Determine how a router makes a forwarding decision by default**
    - **3.2.b Administrative distance**
    - **3.2.c Routing protocol metric**
  - **3.4 Configure and verify single area OSPFv2**
    - **3.4.a Neighbor adjacencies**
    - **3.4.b Point-to-point**
    - **3.4.c Broadcast (DR/BR selection)**
    - **3.4.d Router ID**

OSPFv2 requires only a few configuration commands if you rely on default settings. To use OSPF, all you need to do is enable OSPF on each interface you intend to use in the network, and OSPF uses messages to discover neighbors and learn routes through those neighbors. OSPF performs many background tasks, and you can discover details about that work using a large number of OSPF **show** commands. However, configuring OSPF, using mostly default settings for all the optional features, requires only a few commands. This chapter sets about to help you learn those minimal settings.

The first major section of this chapter focuses on traditional OSPFv2 configuration using the **network** command, along with the large variety of associated **show** commands. This section teaches you how to make OSPFv2 operate with default settings and convince yourself that it really is working through use of those **show** commands.

The second major section shows an alternative configuration option called OSPF interface mode, in contrast with the traditional OSPF configuration shown in the first section of the chapter. This mode uses the **ip ospf** *process-id* **area** *area-number* configuration command instead of the **network** command.

Along the way, the first major section includes the detail of how to set the OSPF router ID (RID). While optional, configuring a predictable and stable OSPF RID allows easier operation and troubleshooting of OSPF and may be the most important of the optional OSPF settings.

"Do I Know This Already?" Quiz

Take the quiz (either here or use the PTP software) if you want to use the score to help you decide how much time to spend on this chapter. The letter answers are listed at the bottom

of the page following the quiz. Appendix C, found both at the end of the book as well as on the companion website, includes both the answers and explanations. You can also find both answers and explanations in the PTP testing software.

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

Foundation Topics Section	Questions
Implementing OSPFv2 Using network Commands	1–4
Implementing OSPFv2 Using Interface Subcommands	5, 6

1. Which of the following **network** commands, following the command **router ospf 1**, enables OSPF on interfaces whose IP addresses are 10.1.1.1, 10.1.100.1, and 10.1.120.1?
   a. **network 10.0.0.0 0.0.0.0 area 0**
   b. **network 10.0.0.0 0.255.255.255 area 0**
   c. **network 10.0.0.0 0.0.0.255 area 0**
   d. **network 10.0.0.0 0.0.255.255 area 0**
2. Which of the following **network** commands, following the command **router ospf 1**, tells this router to start using OSPF on interfaces whose IP addresses are 10.1.1.1, 10.1.100.1, and 10.1.120.1?
   a. **network 10.1.0.0 0.0.255.255 area 0**
   b. **network 10.0.0.0 0.255.255.0 area 0**
   c. **network 10.1.1.0 0.x.1x.0 area 0**
   d. **network 10.1.1.0 255.0.0.0 area 0**
3. Which of the following commands list the OSPF neighbors off interface serial 0/0? (Choose two answers.)
   a. **show ip ospf neighbor**
   b. **show ip ospf interface brief**
   c. **show ip neighbor**
   d. **show ip interface**
   e. **show ip ospf neighbor serial 0/0**
4. When reloading and choosing a new OSPF router ID (RID), a router had working interfaces loopback 1 with IP address 10.8.8.8, loopback 2 with address 10.7.7.7, and GigabitEthernet0/0/0 with 10.9.9.9. The router did not have a **router-id** command in the OSPF process configuration. What RID did the router choose?
   a. 10.7.7.7
   b. 10.8.8.8
   c. 10.9.9.9
   d. The router would fail to choose an RID.

5. An engineer migrates from a more traditional OSPFv2 configuration that uses **network** commands in OSPF configuration mode to instead use OSPFv2 interface configuration. Which of the following commands configures the area number assigned to an interface in this new configuration?
   a. The **area** command in interface configuration mode
   b. The **ip ospf** command in interface configuration mode
   c. The **router ospf** command in interface configuration mode
   d. The **network** command in interface configuration mode
6. An enterprise avoids using the OSPF **network** command, instead preferring to enable OSPF per-interface with the **ip ospf** *process-id* **area** *area-id* interface subcommand. Which **show** command identifies whether an interface has been configured with the **ip ospf** *process-id* **area** *area-id* interface subcommand? (Choose two answers.)
   a. The **show ip ospf interface** command
   b. The **show ip ospf interface brief** command
   c. The **show ip ospf neighbor** command
   d. The **show ip protocols** command

Foundation Topics

Implementing OSPFv2 Using network Commands

After an OSPF design has been chosen—a task that can be complex in larger IP internetworks—the configuration can be as simple as enabling OSPF on each router interface and placing that interface in the correct OSPF area. This first major section of the chapter focuses on the required configuration using the traditional OSPFv2 **network** command along with one optional configuration setting: how to set the **OSPF router-id**. Additionally, this section works through how to show the various lists and tables that confirm how OSPF is working.

For reference and study, the following list outlines the configuration steps covered in this first major section of the chapter:

Config Checklist

Step 1. Use the **router ospf** *process-id* global command to enter OSPF configuration mode for a particular OSPF process.

Step 2. (Optional) Configure the OSPF router ID by doing the following:
   a. Use the **router-id** *id-value* router subcommand to define the router ID, or
   b. Use the **interface loopback** *number* global command, along with an **ip address** *address mask* command, to configure an IP address on a loopback interface (chooses the highest IP address of all working loopbacks), or
   c. Rely on an interface IP address (chooses the highest IP address of all working nonloopbacks).

Step 3. Use one or more **network** *ip-address wildcard-mask* **area** *area-id* router subcommands to enable OSPFv2 on any interfaces matched by the configured address and mask, enabling OSPF on the interface for the listed area.

Figure 22-1 shows the relationship between the OSPF configuration commands, with the idea that the configuration creates a routing process in one part of the configuration, and then indirectly enables OSPF on each interface. The configuration does not name the interfaces on which OSPF is enabled, instead requiring IOS to apply some logic by comparing the OSPF **network** command to the interface **ip address** commands. The upcoming example discusses more about this logic.

Key Topic

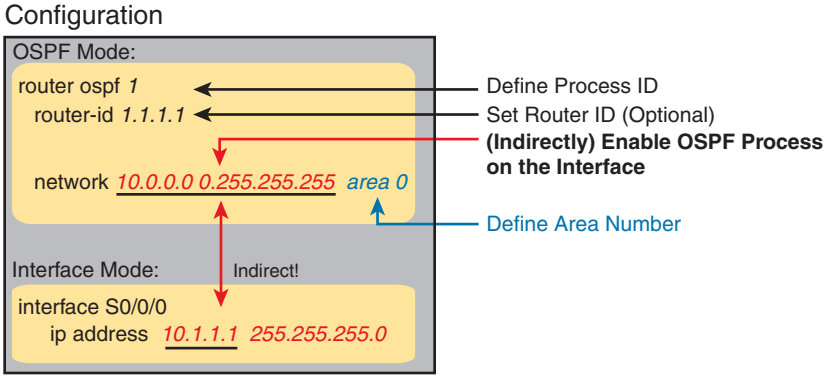

Figure 22-1 *Organization of OSPFv2 Configuration with the* **network** *Command*

OSPF Single-Area Configuration

Figure 22-2 shows a sample network that will be used for most examples throughout this chapter. All links reside in area 0, making the area design a single-area design, with four routers. You can think of Router R1 as a router at a central site, with WAN links to each remote site. Routers R2 and R3 might be at one large remote site that needs two WAN links and two routers for WAN redundancy, with both routers connected to the LAN at that remote site. Router R4 might be a typical smaller remote site with a single router needed for that site.

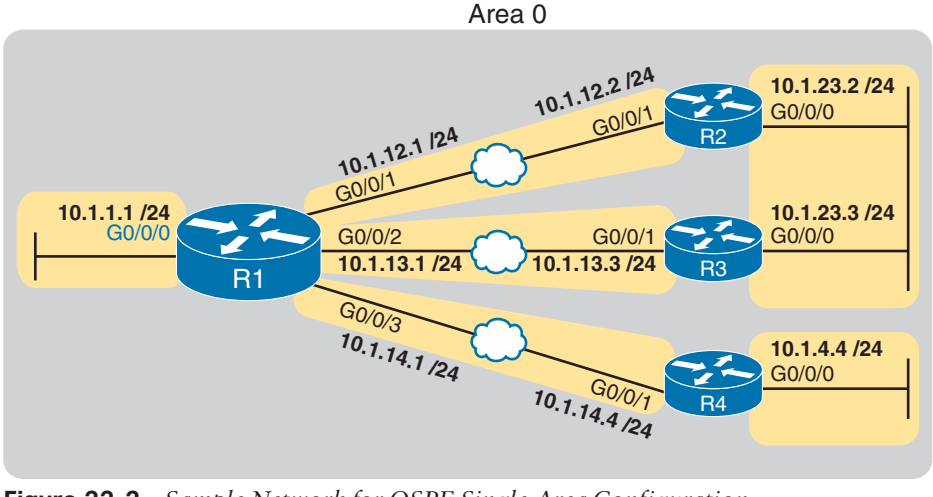

Figure 22-2 *Sample Network for OSPF Single-Area Configuration*

Example 22-1 shows the IPv4 addressing configuration on Router R1, before getting into the OSPF detail.

Example 22-1 *IPv4 Address Configuration on R1*

```
interface GigabitEthernet0/0/0
 ip address 10.1.1.1 255.255.255.0
!
interface GigabitEthernet0/0/1
 ip address 10.1.12.1 255.255.255.0
!
interface GigabitEthernet0/0/2
 ip address 10.1.13.1 255.255.255.0
!
interface GigabitEthernet0/0/3
 ip address 10.1.14.1 255.255.255.0
```

The OSPF configuration begins with the **router ospf** *process-id* global command, which puts the user in OSPF configuration mode, and sets the OSPF *process-id* value. The *process-id* number just needs to be unique on the local router, matching between various commands in a router. The *process-id* does not need to match between neighboring routers or other routers in the same area. The value can be any integer between 1 and 65,535.

Second, the configuration needs one or more **network** commands in OSPF mode. These commands tell the router to find its local interfaces that match the first two parameters on the **network** command. Then, for each matched interface, the router enables OSPF on those interfaces, discovers neighbors, creates neighbor relationships, and assigns the interface to the area listed in the **network** command. (Note that the area can be configured as either an integer or a dotted-decimal number, but this book makes a habit of configuring the area number as an integer. The integer area numbers range from 0 through 4,294,967,295.)

Example 22-2 shows an example configuration on Router R1 from Figure 22-2. The **router ospf 1** command enables OSPF process 1, and the single **network** command enables OSPF on all interfaces shown in the figure.

Example 22-2 *OSPF Single-Area Configuration on R1 Using One* **network** *Command*

```
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
```

For the specific **network** command in Example 22-2, any matched interfaces are assigned to area 0. However, the first two parameters—the *ip_address* and *wildcard_mask* parameter values of 10.0.0.0 and 0.255.255.255—need some explaining. In this case, the command matches all interfaces shown for Router R1; the next topic explains why.

Wildcard Matching with the network Command

The key to understanding the traditional OSPFv2 configuration shown in this first example is to understand the OSPF **network** command. The OSPF **network** command compares the

---

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

1 B **2** A **3** A, E **4** B **5** B **6** A, D

first parameter in the command to each interface IP address on the local router, trying to find a match. However, rather than comparing the entire number in the **network** command to the entire IPv4 address on the interface, the router can compare a subset of the octets, based on the wildcard mask, as follows:

Key Topic

Wildcard 0.0.0.0: Compare all four octets. In other words, the numbers must exactly match.

Wildcard 0.0.0.255: Compare the first three octets only. Ignore the last octet when comparing the numbers.

Wildcard 0.0.255.255: Compare the first two octets only. Ignore the last two octets when comparing the numbers.

Wildcard 0.255.255.255: Compare the first octet only. Ignore the last three octets when comparing the numbers.

Wildcard 255.255.255.255: Compare nothing; this wildcard mask means that all addresses will match the **network** command.

Basically, a wildcard mask value of decimal 0 in an octet tells IOS to compare to see if the numbers match, and a value of 255 tells IOS to ignore that octet when comparing the numbers.

The **network** command provides many flexible options because of the wildcard mask. For example, in Router R1, many **network** commands could be used, with some matching all interfaces, and some matching a subset of interfaces. Table 22-2 shows a sampling of options, with notes.

Table 22-2 Example OSPF **network** Commands on R1, with Expected Results

Command	Logic in Command	Matched Interfaces
network 10.1.0.0 0.0.255.255	Match addresses that begin with 10.1	G0/0/0 G0/0/1 G0/0/1 G0/0/2
network 10.0.0.0 0.255.255.255	Match addresses that begin with 10	G0/0/0 G0/0/1 G0/0/1 G0/0/2
network 0.0.0.0 255.255.255.255	Match all addresses	G0/0/0 G0/0/1 G0/0/1 G0/0/2
network 10.1.13.0 0.0.0.255	Match addresses that begin with 10.1.13	G0/0/2
network 10.1.13.1 0.0.0.0	Match one address: 10.1.13.1	G0/0/2

The wildcard mask gives the local router its rules for matching its own interfaces. To show examples of the different options, Example 22-3 shows the configuration on routers R2, R3, and R4, each using different wildcard masks. Note that all three routers (R2, R3, and R4) enable OSPF on all the interfaces shown in Figure 22-2.

Example 22-3 *OSPF Configuration on Routers R2, R3, and R4*

```
! R2 configuration next - one network command enables OSPF on both interfaces
interface GigabitEthernet0/0/0
 ip address 10.1.23.2 255.255.255.0
!
interface GigabitEthernet0/0/1
 ip address 10.1.12.2 255.255.255.0
!
router ospf 1
 network 10.0.0.0 0.255.255.255 area 0
```

```
! R3 configuration next - One network command per interface
interface GigabitEthernet0/0/0
 ip address 10.1.23.3 255.255.255.0
!
interface GigabitEthernet0/0/1
 ip address 10.1.13.3 255.255.255.0
!
router ospf 1
 network 10.1.13.3 0.0.0.0 area 0
 network 10.1.23.3 0.0.0.0 area 0
```

```
! R4 configuration next - One network command per interface with wildcard 0.0.0.255
interface GigabitEthernet0/0/0
 ip address 10.1.4.4 255.255.255.0
!
interface GigabitEthernet0/0/1
 ip address 10.1.14.4 255.255.255.0
!
router ospf 1
 network 10.1.14.0 0.0.0.255 area 0
 network 10.1.4.0 0.0.0.255 area 0
```

Finally, note that OSPF uses the same wildcard mask logic as defined by Cisco IOS access control lists. The section titled "Finding the Right Wildcard Mask to Match a Subnet" section in Chapter 6 of the *CCNA 200-301 Official Cert Guide, Volume 2*, Second Edition, provides more detail about wildcard masks.

NOTE If the wildcard mask octet in a **network** command is 255, the matching address octet should be configured as a 0. Interestingly, IOS will accept a **network** command that breaks this rule, but if you configure a wildcard mask octet as 255, then IOS changes the corresponding address octet to a 0 before putting it into the running configuration file. For example, IOS will change a typed command that begins with **network 1.2.3.4 0.0.255.255** to **network 1.2.0.0 0.0.255.255**.

Verifying OSPF Operation

As mentioned in Chapter 21, "Understanding OSPF Concepts," OSPF routers use a three-step process to eventually add OSPF-learned routes to the IP routing table. First, they create neighbor relationships. Then they build and flood LSAs between those neighbors so each router in the same area has a copy of the same LSDB. Finally, each router independently computes its own IP routes using the SPF algorithm and adds them to its routing table. This next topic works through how to display the results of each of those steps, which lets you confirm whether OSPF has worked correctly or not.

The **show ip ospf neighbor**, **show ip ospf database**, and **show ip route** commands display information to match each of these three steps, respectively. Figure 22-3 summarizes the commands you can use (and others) when verifying OSPF.

Key Topic

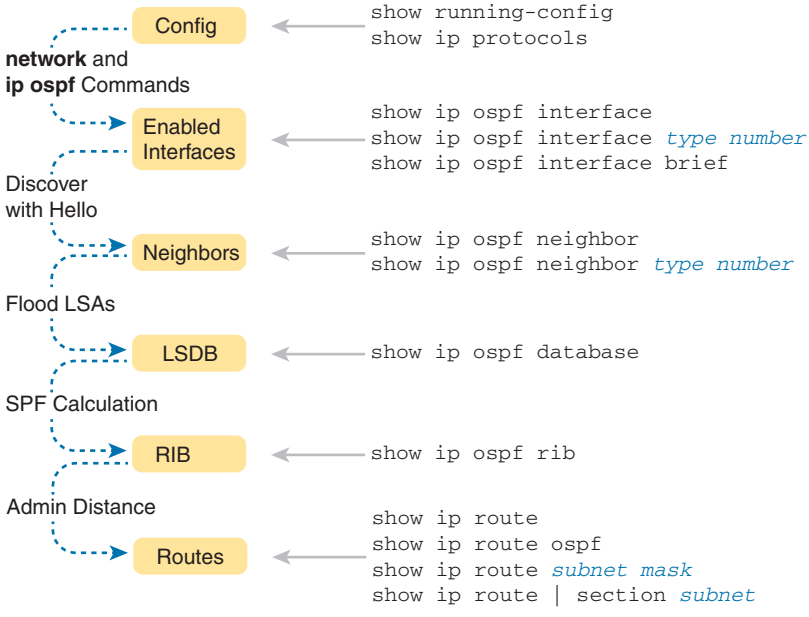

Figure 22-3 *OSPF Verification Commands*

Many engineers begin OSPF verification by looking at the output of the **show ip ospf neighbor** command. For instance, Example 22-4 shows a sample from Router R1, which should have one neighbor relationship each with routers R2, R3, and R4. Example 22-4 shows all three.

Key Topic

Example 22-4 *OSPF Neighbors on Router R1 from Figure 22-2*

```
R1# show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1   FULL/DR         00:00:37    10.1.12.2       GigabitEthernet0/0/1
3.3.3.3           1   FULL/DR         00:00:37    10.1.13.3       GigabitEthernet0/0/2
4.4.4.4           1   FULL/BDR        00:00:34    10.1.14.4       GigabitEthernet0/0/3
```

The detail in the output mentions several important facts, and for most people, working right to left works best in this case. For example, look at the headings:

Interface: This is the local router's interface connected to the neighbor. For example, the first neighbor in the list is reachable through R1's G0/0/1 interface.

Address: This is the neighbor's IP address on that link. Again, this first neighbor, the neighbor, which is R2, uses IP address 10.1.12.2.

State: While many possible states exist, for the details discussed in this chapter, FULL is the correct and fully working state in this case.

Neighbor ID: This is the router ID of the neighbor.

NOTE Examples 22-4 through 22-8 use configuration not shown here that sets the RID values to easily identify the routers, using 2.2.2.2 for Router R2, 3.3.3.3 for Router R3, and so on. The upcoming section "Configuring the OSPF Router ID" shows how to set the RID.

Once OSPF convergence has completed, a router should list each neighbor. On links that use a designated router (DR), the state will also list the role of the neighboring router after the / (DR, BDR, or DROther). As a result, the normal working states will be:

Key Topic

FULL/ -: The neighbor state is full, with the "-" instead of letters meaning that the link does not use a DR/BDR.

FULL/DR: The neighbor state is full, and the neighbor is the DR.

FULL/BDR: The neighbor state is full, and the neighbor is the backup DR (BDR).

FULL/DROTHER: The neighbor state is full, and the neighbor is neither the DR nor BDR. (It also implies that the local router is a DR or BDR because the state is FULL.)

2WAY/DROTHER: The neighbor state is 2-way, and the neighbor is neither the DR nor BDR—that is, a DROther router. (It also implies that the local router is also a DROther router because otherwise the state would reach a full state.)

Once a router's OSPF process forms a working neighbor relationship, the routers exchange the contents of their LSDBs, either directly or through the DR on the subnet. Example 22-5 shows the contents of the LSDB on Router R1. Interestingly, with a single-area design, all the routers will have the same LSDB contents once all neighbors are up and all LSAs have been exchanged. So, the **show ip ospf database** command in Example 22-5 should list the same exact information, no matter on which of the four routers it is issued.

Example 22-5 *OSPF Database on Router R1 from Figure 22-2*

```
R1# show ip ospf database

            OSPF Router with ID (1.1.1.1) (Process ID 1)


                Router Link States (Area 0)
```

```
Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         431         0x8000008F 0x00DCCA 5
2.2.2.2         2.2.2.2         1167        0x8000007F 0x009DA1 2
3.3.3.3         3.3.3.3         441         0x80000005 0x002FB1 1
4.4.4.4         4.4.4.4         530         0x80000004 0x007F39 2


                Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
10.1.12.2       2.2.2.2         1167        0x8000007C 0x00BBD5
10.1.13.3       3.3.3.3         453         0x80000001 0x00A161
10.1.14.1       4.4.4.4         745         0x8000007B 0x004449
10.1.23.3       3.3.3.3         8           0x80000001 0x00658F
```

For the purposes of this book, do not be concerned about the specifics in the output of this command. However, for perspective, note that the LSDB should list one "Router Link State" (Type 1 Router LSA) for each of the routers in the same area, so with the design based on Figure 22-2, the output lists four Type 1 LSAs. Also, with all default settings in this design, the routers will create a total of four Type 2 Network LSAs as shown, one each for the subnets that have a DR and contain at least two routers in that subnet (the three WAN links plus the LAN to which both R2 and R3 connect).

Next, Example 22-6 shows R4's IPv4 routing table with the **show ip route** command. As configured, with all links working, R4 has connected routes to two of those subnets and should learn OSPF routes to the other subnets.

Example 22-6 *IPv4 Routes Added by OSPF on Router R4 from Figure 22-2*

```
R4# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
! Additional legend lines omitted for brevity

Gateway of last resort is not set

      10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
O        10.1.1.0/24 [110/2] via 10.1.14.1, 00:27:24, GigabitEthernet0/0/1
C        10.1.4.0/24 is directly connected, GigabitEthernet0/0/0
L        10.1.4.4/32 is directly connected, GigabitEthernet0/0/0
O        10.1.12.0/24 [110/2] via 10.1.14.1, 00:27:24, GigabitEthernet0/0/1
O        10.1.13.0/24 [110/2] via 10.1.14.1, 00:25:15, GigabitEthernet0/0/1
C        10.1.14.0/24 is directly connected, GigabitEthernet0/0/1
L        10.1.14.4/32 is directly connected, GigabitEthernet0/0/1
O        10.1.23.0/24 [110/3] via 10.1.14.1, 00:27:24, GigabitEthernet0/0/1
```

Any time you want to check OSPF on a router in a small design like the ones in the book, you can count all the subnets, then count the subnets connected to the local router, and know that OSPF should learn routes to the rest of the subnets. Then just use the **show ip route** command and add up how many connected and OSPF routes exist as a quick check of whether all the routes have been learned or not.

In this case, Router R4 has two connected subnets, but six subnets exist per the figure, so Router R4 should learn four OSPF routes. Next look for the code of "O" on the left, which identifies a route as being learned by OSPF. The output lists four such IP routes: one for the LAN subnet off Router R1, one for the LAN subnet connected to both R2 and R3, and one each for the WAN subnets from R1 to R2 and R1 to R3.

Next, examine the first route (to subnet 10.1.1.0/24). It lists the subnet ID and mask, identifying the subnet. It also lists two numbers in brackets. The first, 110, is the administrative distance of the route. All the OSPF routes in this example use the default of 110 (see Table 24-4 in Chapter 24, "OSPF Neighbors and Route Selection," for the list of administrative distance values). The second number, 2, is the OSPF metric for this route. The route also lists the forwarding instructions: the next-hop IP address (10.1.14.1) and R4's outgoing interface (G0/0/1).

NOTE The section "Floating Static Routes" in Chapter 17, "Configuring IPv4 Addresses and Static Routes," introduced the concept of administrative distance; however, the section "Multiple Routes Learned from Competing Sources," in Chapter 24 discusses the topic in more depth.

Verifying OSPF Configuration

Once you can configure OSPF with confidence, you will likely verify OSPF focusing on **OSPF neighbors** and the IP routing table as just discussed. However, if OSPF does not work immediately, you may need to circle back and check the configuration. To do so, you can use these steps:

- If you have enable mode access, use the **show running-config** command to examine the configuration.
- If you have only user mode access, use the **show ip protocols** command to re-create the OSPF configuration.
- Use the **show ip ospf interface [brief]** command to determine whether the router enabled OSPF on the correct interfaces or not based on the configuration.

The best way to verify the configuration begins with the **show running-config** command, of course. However, the **show ip protocols** command repeats the details of the OSPFv2 configuration and does not require enable mode access. Example 22-7 does just that for Router R3.

Example 22-7 *Router R3 Configuration and the* **show ip protocols** *Command*

```
R3# show running-config | section router ospf 1
router ospf 1
  network 10.1.13.3 0.0.0.0 area 0
  network 10.1.23.3 0.0.0.0 area 0
  router-id 3.3.3.3

R3# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 3.3.3.3
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.1.13.3 0.0.0.0 area 0
    10.1.23.3 0.0.0.0 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    1.1.1.1              110      02:05:26
    4.4.4.4              110      02:05:26
    2.2.2.2              110      01:51:16
  Distance: (default is 110)
```

The highlighted output emphasizes some of the configuration. The first highlighted line repeats the parameters on the **router ospf 1** global configuration command. (The second highlighted item points out the router's router ID, which will be discussed in the next section.) The third set of highlighted lines begins with a heading of "Routing for Networks:" followed by two lines that closely resemble the parameters on the configured **network** commands. In fact, closely compare those last two highlighted lines with the **network** configuration commands at the top of the example, and you will see that they mirror each other, but the **show** command just leaves out the word *network*. For instance:

Configuration: **network 10.1.13.3 0.0.0.0 area 0**

show Command: **10.1.13.3 0.0.0.0 area 0**

IOS interprets the **network** commands to choose interfaces on which to run OSPF, so it could be that IOS chooses a different set of interfaces than you predicted. To check the list of interfaces chosen by IOS, use the **show ip ospf interface brief** command, which lists all interfaces that have been enabled for OSPF processing. Verifying the interfaces can be a useful step if you have issues with OSPF neighbors because OSPF must first be enabled on an interface before a router will attempt to discover neighbors on that interface. Example 22-8 shows a sample from Router R1.

Example 22-8 *Router R1* **show ip ospf interface brief** *Command*

```
R1# show ip ospf interface brief
Interface    PID   Area            IP Address/Mask    Cost  State Nbrs F/C
Gi0/0/0      1     0               10.1.1.1/24        1     DR    0/0
Gi0/0/1      1     0               10.1.12.1/24       1     BDR   1/1
Gi0/0/2      1     0               10.1.13.1/24       1     BDR   1/1
Gi0/0/3      1     0               10.1.14.1/24       1     DR    1/1
```

The **show ip ospf interface brief** command lists one line per interface, showing all the interfaces on which OSPF has been enabled. Each line identifies the OSPF process ID (per the **router ospf** *process-id* command), the area, the interface IP address, and the number of neighbors found via each interface.

You may use the command in Example 22-8 quite often, but the **show ip ospf interface** command (without the **brief** keyword) gives much more detail about OSPF per-interface settings. Example 23-4 in Chapter 23, "Implementing Optional OSPF Features," shows an example of the entire output of that command.

Configuring the OSPF Router ID

While OSPF has many other optional features, most enterprise networks that use OSPF choose to configure each router's OSPF router ID. OSPF-speaking routers must have a router ID (RID) for proper operation. By default, routers will choose an interface IP address to use as the RID. However, many network engineers prefer to choose each router's router ID, so command output from commands like **show ip ospf neighbor** lists more recognizable router IDs.

To choose its RID, a Cisco router uses the following process when the router reloads and brings up the OSPF process. Note that the router stops looking for a router ID to use once one of the steps identifies a value to use.

1. If the **router-id** *rid* OSPF subcommand is configured, this value is used as the RID.
2. If any loopback interfaces have an IP address configured, and the interface has an interface status of up, the router picks the highest numeric IP address among these loopback interfaces.
3. The router picks the highest numeric IP address from all other interfaces whose interface status code (first status code) is up. (In other words, an interface in up/down state will be included by OSPF when choosing its router ID.)

The first and third criteria should make some sense right away: the RID is either configured or is taken from a working interface's IP address. However, this book has not yet explained the concept of a *loopback interface*, as mentioned in Step 2.

A loopback interface is a virtual interface that can be configured with the **interface loopback** *interface-number* command, where *interface-number* is an integer. Loopback interfaces are always in an "up and up" state unless administratively placed in a shutdown state. For example, a simple configuration of the command **interface loopback 0**, followed by **ip address 2.2.2.2 255.255.255.0**, would create a loopback interface and assign it an IP address. Because loopback interfaces do not rely on any hardware, these interfaces can be up/up whenever IOS is running, making them good interfaces on which to base an OSPF RID.

Example 22-9 shows the configuration that existed in Routers R1 and R2 before the creation of the **show** command output earlier in this chapter. R1 set its router ID using the direct method, while R2 used a loopback IP address. Example 22-10 that follows shows the output of the **show ip ospf** command on R1, which identifies the OSPF RID used by R1.

Example 22-9 *OSPF Router ID Configuration Examples*

```
! R1 Configuration first
router ospf 1
 router-id 1.1.1.1
 network 10.1.0.0 0.0.255.255 area 0
```

```
! R2 Configuration next
!
interface Loopback2
 ip address 2.2.2.2 255.255.255.255
```

Example 22-10 *Confirming the Current OSPF Router ID*

```
R1# show ip ospf
 Routing Process "ospf 1" with ID 1.1.1.1
! lines omitted for brevity
```

Routers need a stable OSPF RID because any change to the OSPF RID causes a router to close existing neighbor relationships and remove all routes learned through those neighbors. To keep the RID stable, a router chooses its RID when the router first initializes (at power-on or per the **reload** command). So the RID might change at the next reload when the router re-evaluates the RID choice rules based on the current conditions.

However, routers do support one scenario to update their RID without a **reload**, which can be useful for testing in lab. To do so, configure the OSPF **router-id** OSPF subcommand followed by the **clear ip ospf process** EXEC command.

Implementing Multiarea OSPF

Even though the current CCNA 200-301 V1.1 exam blueprint mentions single area but not multiarea OSPF, you only need to learn one more idea to know how to configure multiarea OSPF. So, this chapter takes a brief page to show how.

For example, consider a multiarea OSPF design as shown in Figure 22-4. It uses the same routers and IP addresses as shown earlier in Figure 22-2, on which all the examples in this chapter have been based so far. However, the design shows three areas instead of the single-area design shown in Figure 22-2.

Configuring the routers in a multiarea design is almost just like configuring OSPFv2 for a single area. To configure multiarea OSPF, all you need is a valid OSPF area design (for instance, like Figure 22-4) and a configuration that places each router interface into the correct area per that design. For example, both of R4's interfaces connect to links in area 4, making R4 an internal router, so any **network** commands on Router R4 will list area 4.

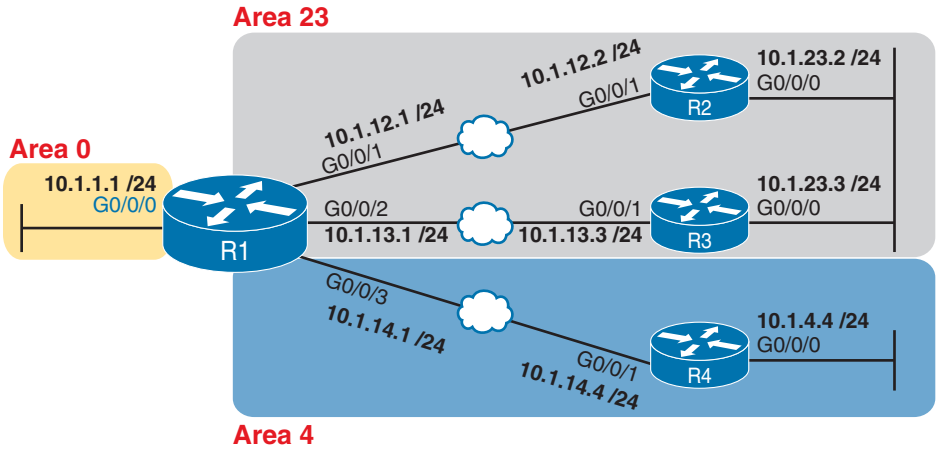

Figure 22-4 *Area Design for an Example Multiarea OSPF Configuration*

Example 22-11 shows a sample configuration for Router R1. To make the configuration clear, it uses **network** commands with a wildcard mask of 0.0.0.0, meaning each **network** command matches a single interface. Each interface will be placed into either area 0, 23, or 4 to match the figure.

Example 22-11 *OSPF Configuration on R1, Placing Interfaces into Different Areas*

```
router ospf 1
 network 10.1.1.1 0.0.0.0 area 0
 network 10.1.12.1 0.0.0.0 area 23
 network 10.1.13.1 0.0.0.0 area 23
 network 10.1.14.1 0.0.0.0 area 4
```

Implementing OSPFv2 Using Interface Subcommands

From the earliest days of OSPFv2 support in Cisco routers, the configuration used the OSPF **network** command as discussed in this chapter. However, that configuration style can be confusing, and it does require some interpretation. As a result, Cisco added another option for OSPFv2 configuration called OSPF interface configuration.

The newer interface-style OSPF configuration still enables OSPF on interfaces, but it does so directly with the **ip ospf** interface subcommand. Instead of matching interfaces with indirect logic using **network** commands, you directly enable OSPFv2 on interfaces by configuring an interface subcommand on each interface.

OSPF Interface Configuration Example

To show how OSPF interface configuration works, this example basically repeats the example shown earlier in the chapter using the traditional OSPFv2 configuration with **network** commands. So, before looking at the OSPFv2 interface configuration, take a moment to look back to review traditional OSPFv2 configuration with Figure 22-2 and Examples 22-2 and 22-3.

After reviewing the traditional configuration, consider this checklist, which details how to convert from the old-style configuration in Example 22-2 and Example 22-3 to use interface configuration:

Config Checklist

Step 1. Use the **no network** *network-id* **area** *area-id* subcommands in OSPF configuration mode to remove the **network** commands.

Step 2. Add one **ip ospf** *process-id* **area** *area-id* command in interface configuration mode under each interface on which OSPF should operate, with the correct OSPF process (*process-id*) and the correct OSPF area number.

Figure 22-5 repeats the design for both the original examples in this chapter and for this upcoming interface configuration example.

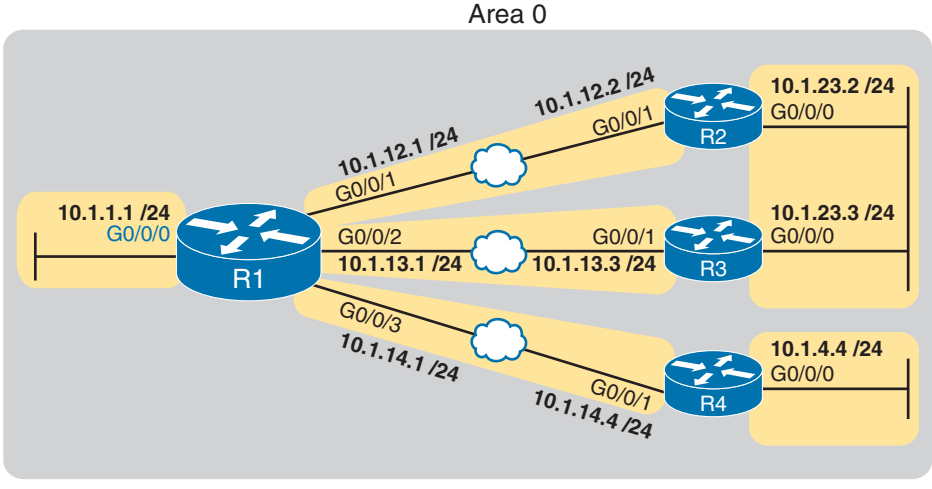

Figure 22-5 *Area Design Used in the Upcoming OSPF Interface Config Example*

Example 22-2 shows a single **network** command: **network 10.0.0.0 0.255.255.255 area 0**. Example 22-12 follows the steps in the migration checklist, beginning with the removal of the previous configuration using the **no network 10.0.0.0 0.255.255.255 area 0** command. The example then shows the addition of the **ip ospf 1 area 0** command on each of the interfaces on Router R1, enabling OSPF process 1 on the interface and placing each interface into area 0.

Example 22-12 *Migrating to Use OSPF Interface Subcommand Configuration*

```
R1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# router ospf 1
R1(config-router)# no network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#
*Apr  8 19:35:24.994: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0/1
from FULL to DOWN, Neighbor Down: Interface down or detached
*Apr  8 19:35:24.994: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on GigabitEthernet0/0/2
from FULL to DOWN, Neighbor Down: Interface down or detached
```

```
*Apr  8 19:35:24.994: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0/3
from FULL to DOWN, Neighbor Down: Interface down or detached
R1(config-router)# interface g0/0/0
R1(config-if)# ip ospf 1 area 0
R1(config-if)# interface g0/0/1
R1(config-if)# ip ospf 1 area 0
R1(config-if)#
*Apr  8 19:35:52.970: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on GigabitEthernet0/0/1
from LOADING to FULL, Loading Done
R1(config-if)# interface g0/0/2
R1(config-if)# ip ospf 1 area 0
R1(config-if)#
*Apr  8 19:36:13.362: %OSPF-5-ADJCHG: Process 1, Nbr 3.3.3.3 on GigabitEthernet0/0/2
from LOADING to FULL, Loading Done
R1(config-if)# interface g0/0/3
R1(config-if)# ip ospf 1 area 0
R1(config-if)#
*Apr  8 19:37:05.398: %OSPF-5-ADJCHG: Process 1, Nbr 4.4.4.4 on GigabitEthernet0/0/3
from LOADING to FULL, Loading Done
R1(config-if)#
```

When reading the example, read from top to bottom, and also consider the details about the failed and recovered neighbor relationships shown in the log messages. Removing the network command disabled OSPF on all interfaces on Router R1, causing all three neighbor relationships to fail. The example then shows the addition of the **ip ospf 1 area 0** command on the LAN interface, which enables OSPF but does not cause a neighbor relationship to form, because no other OSPF routers exist in that subnet. Then the example shows the same command added to each of the WAN links in succession, and in each case, the OSPF neighbor available over that WAN link comes up (as noted in the log messages).

NOTE A router's configuration can include both a **network** router subcommand and an **ip ospf** interface subcommand that enable OSPF on the same interface. If those commands refer to different area numbers, IOS uses the area number from the **ip ospf** interface subcommand. Additionally, multiple **network** commands can match the same interface. In that case, IOS uses the order in which the commands appear in OSPF configuration mode.

Verifying OSPF Interface Configuration

OSPF operates the same way whether you use the new style or old style of configuration. The OSPF area design works the same, neighbor relationships form the same way, routers negotiate to become the DR and BDR the same way, and so on. However, you can see a few small differences in **show** command output when using the newer OSPFv2 configuration if you look closely.

The **show ip protocols** command relists most of the routing protocol configuration, so it does list some different details if you use interface configuration versus the **network** command. With the **ip ospf** interface subcommands, the output lists the phrase "Interfaces Configured Explicitly," as highlighted in Example 22-13. The example first shows the relevant parts of the

show ip protocols command when using interface configuration on Router R1, and then lists the same portions of the command from when R1 used **network** commands.

Example 22-13 *Differences in* **show ip protocols** *Output: Old- and New-Style OSPFv2 Configuration*

```
! First, with the new interface configuration
R1# show ip protocols
! … beginning lines omitted for brevity
  Routing for Networks:
  Routing on Interfaces Configured Explicitly (Area 0):
    GigabitEthernet0/0/0
    GigabitEthernet0/0/1
    GigabitEthernet0/0/2
    GigabitEthernet0/0/3
  Routing Information Sources:
    Gateway         Distance      Last Update
    4.4.4.4              110      00:09:30
    2.2.2.2              110      00:10:49
    3.3.3.3              110      05:20:07
  Distance: (default is 110)
```

```
! For comparison, the old results with the use of the OSPF network command
R1# show ip protocols
! … beginning lines omitted for brevity
  Routing for Networks:
    10.1.0.0 0.0.255.255 area 0
! … ending line omitted for brevity
```

Another small piece of different output exists in the **show ip ospf interface** [*interface*] command. The command lists details about OSPF settings for the interface(s) on which OSPF is enabled. The output also makes a subtle reference to whether that interface was enabled for OSPF with the old or new configuration style. Example 22-14 also begins with output based on interface configuration on Router R1, followed by the output that would exist if R1 still used the old-style **network** command.

Key Topic

Example 22-14 *Differences in* **show ip ospf interface** *Output with OSPFv2 Interface Configuration*

```
! First, with the new interface configuration
R1# show ip ospf interface g0/0/1
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 10.1.12.1/24, Area 0, Attached via Interface Enable
! Lines omitted for brevity
```

```
! For comparison, the old results with the use of the OSPF network command
R1# show ip ospf interface g0/0/1
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 10.1.12.1/24, Area 0, Attached via Network Statement
! … ending line omitted for brevity
```

Other than these small differences in a few **show** commands, the rest of the commands show nothing different depending on the style of configuration. For instance, the **show ip ospf interface brief** command does not change depending on the configuration style, nor do the **show ip ospf database**, **show ip ospf neighbor**, or **show ip route** commands.

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 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 22-3 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 22-3 Chapter Review Tracking

Review Element	Review Date(s)	Resource Used
Review key topics		Book, website
Review key terms		Book, website
Answer DIKTA questions		Book, PTP
Review Config Checklists		Book, website
Review command tables		Book
Do labs		Blog
Watch video		Website

Review All the Key Topics

Key Topic

Table 22-4 Key Topics for Chapter 22

Key Topic Element	Description	Page Number
Figure 22-1	Organization of OSPFv2 configuration with the **network** command	565
List	Example OSPF wildcard masks and their meaning	567
Figure 22-3	OSPF verification commands	569
Example 22-4	Example of the **show ip ospf neighbor** command	569
List	Neighbor states and their meanings	570
List	Rules for setting the router ID	574
Example 22-14	Differences in **show ip ospf interface** output with OSPF interface configuration	579

Key Terms You Should Know

OSPF neighbor, OSPF router-id

Command References

Tables 22-5 and 22-6 list configuration and verification commands used in this chapter. As an easy review exercise, cover the left column in a table, read the right column, and try to recall the command without looking. Then repeat the exercise, covering the right column, and try to recall what the command does.

Table 22-5 Chapter 22 Configuration Command Reference

Command	Description
router ospf *process-id*	Global command that enters OSPF configuration mode for the listed process
network *ip-address wildcard-mask* **area** *area-id*	Router subcommand that enables OSPF on interfaces matching the address/wildcard combination and sets the OSPF area
ip ospf *process-id* **area** *area-number*	Interface subcommand to enable OSPF on the interface and to assign the interface to a specific OSPF area
ip ospf cost *interface-cost*	Interface subcommand that sets the OSPF cost associated with the interface
bandwidth *bandwidth*	Interface subcommand that directly sets the interface bandwidth (Kbps)
auto-cost reference-bandwidth *number*	Router subcommand that tells OSPF the numerator in the Reference_bandwidth/Interface_bandwidth formula used to calculate the OSPF cost based on the interface bandwidth
router-id *id*	OSPF command that statically sets the router ID
interface loopback *number*	Global command to create a loopback interface and to navigate to interface configuration mode for that interface

Table 22-6 Chapter 22 EXEC Command Reference

Command	Description
show ip ospf	Lists information about the OSPF process running on the router, including the OSPF router ID, areas to which the router connects, and the number of interfaces in each area.
show ip ospf interface brief	Lists the interfaces on which the OSPF protocol is enabled (based on the **network** commands), including passive interfaces.
show ip ospf interface [*type number*]	Lists a long section of settings, status, and counters for OSPF operation on all interfaces, or on the listed interface, including the Hello and Dead Timers.
show ip protocols	Shows routing protocol parameters and current timer values.
show ip ospf neighbor [*type number*]	Lists brief output about neighbors, identified by neighbor router ID, including current state, with one line per neighbor; optionally, limits the output to neighbors on the listed interface.
show ip ospf neighbor *neighbor-ID*	Lists the same output as the **show ip ospf neighbor** detail command, but only for the listed neighbor (by neighbor RID).

Command	Description
show ip ospf database	Lists a summary of the LSAs in the database, with one line of output per LSA. It is organized by LSA type (first type 1, then type 2, and so on).
show ip route	Lists all IPv4 routes.
show ip route ospf	Lists routes in the routing table learned by OSPF.
clear ip ospf process	Resets the OSPF process, resetting all neighbor relationships and also causing the process to make a choice of OSPF RID.

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