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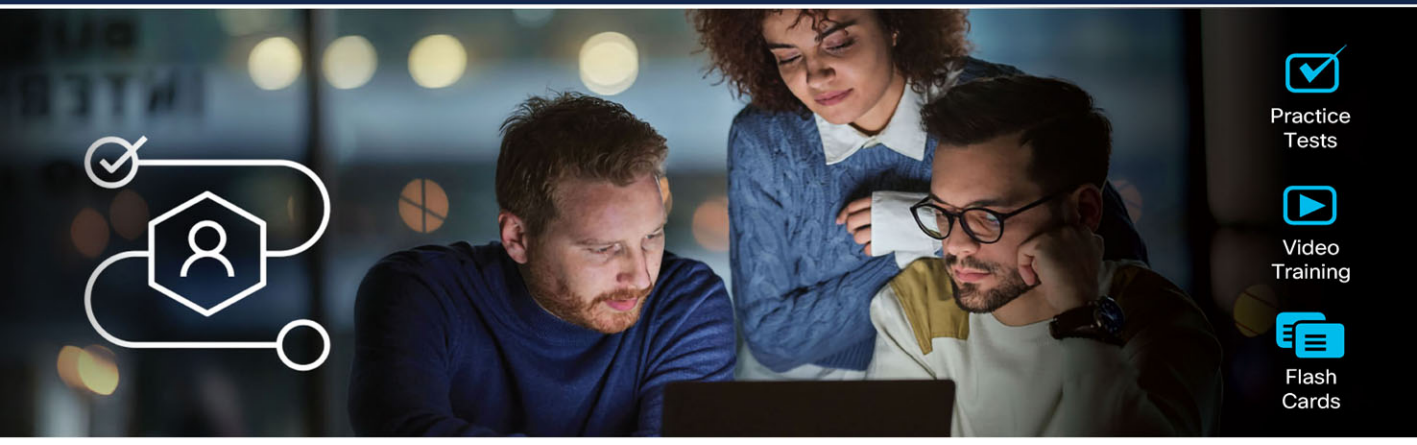

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CCNA
200-301, Volume 2

2nd Edition

Wendell Odom, CCIE® No. 1624
Jason Gooley, CCIEx2 (RS, SP) No. 38759
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CCNA 200-301

Official Cert Guide Volume 2

Second Edition

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Cisco Press

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Wendell Odom
Jason Gooley
David Hucaby

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Dedications

Wendell Odom:

For Raymond Lanier Odom, still the best dad ever.

Jason Gooley:

To my family: Mother, thank you for always being my guiding light from up above. To my wife, Jamie, your love and support mean the world to me. To my children, Kaleigh and Jaxon, always believe in yourself and go for your dreams, no matter how lofty they may seem. To my father, thanks for believing in that stubborn kid so many years ago! To my brother, thanks for always having my back broham. Thank you, God—without you none of this would be possible!

Acknowledgments

Wendell Odom:

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. 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 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 to go 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 the early draft of 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 perspectives on how 20-somethings think about learning and studying. And thanks to Jesus Christ, Lord of everything in my life.

Jason Gooley:

I would like to thank Wendell for trusting me and having me on this amazing journey. Looking forward to our future work together!

Thank you to everyone at Pearson and Cisco Press for always making sure our products are of the best quality!

Thank you to my wife, Jamie, and my children, Kaleigh and Jaxon, for putting up with your father's crazy projects!!!

Contents at a Glance

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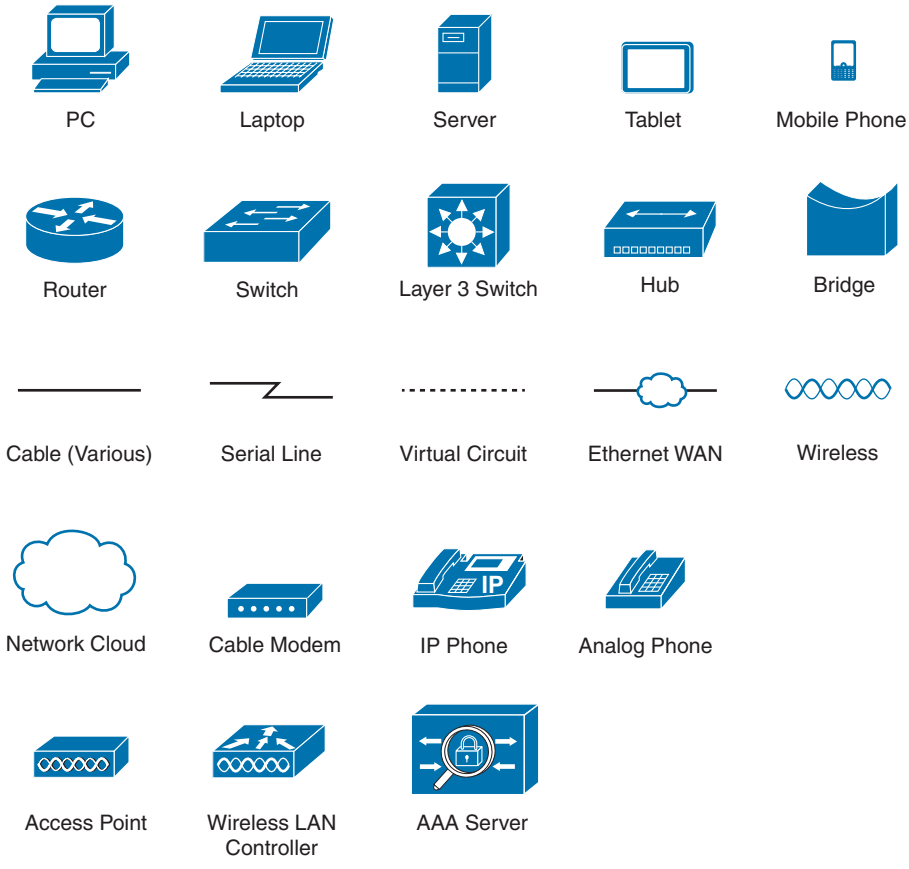


Command Syntax Conventions

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

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

Introduction

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.

Surprisingly for an entry-level exam, the CCNA 200-301 exam includes more content by volume than many of the CCNP-level exams. As a result, Cisco Press publishes the Certification Guide for CCNA as two volumes. You can refer to the books as Volume 1 and Volume 2, but more formally, the books are

- *CCNA 200-301 Official Cert Guide, Volume 1*, Second Edition
- *CCNA 200-301 Official Cert Guide, Volume 2*, Second Edition (this book)

If you have already used the Volume 1 book and read or skimmed its Introduction, you do not need to read the entire Introduction to this book. This book has the same features and style as Volume 1. However, you might be interested to review the section titled "Book Organization, Chapters, and Appendixes," for information specific to this book.

Regardless of your path to CCNA, 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

CCNA acts as the entry point to a hierarchy of Cisco certifications. CCNA includes the foundational topics, with CCNP as the next higher challenge level, followed by CCIE. Figure I-1 shows the hierarchy, with more detail about each in the list that follows.

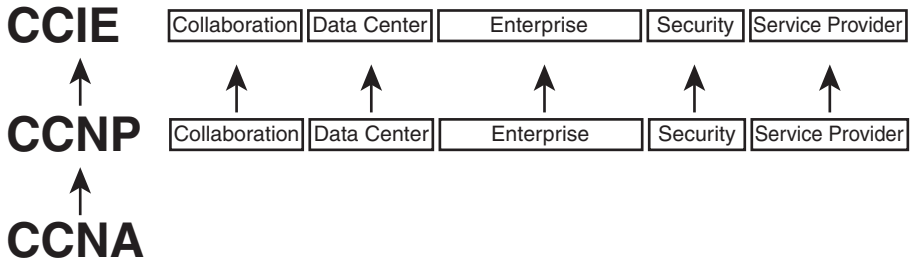


Figure I-1 *Cisco CCNA, CCNP, and CCIE Certifications*

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.

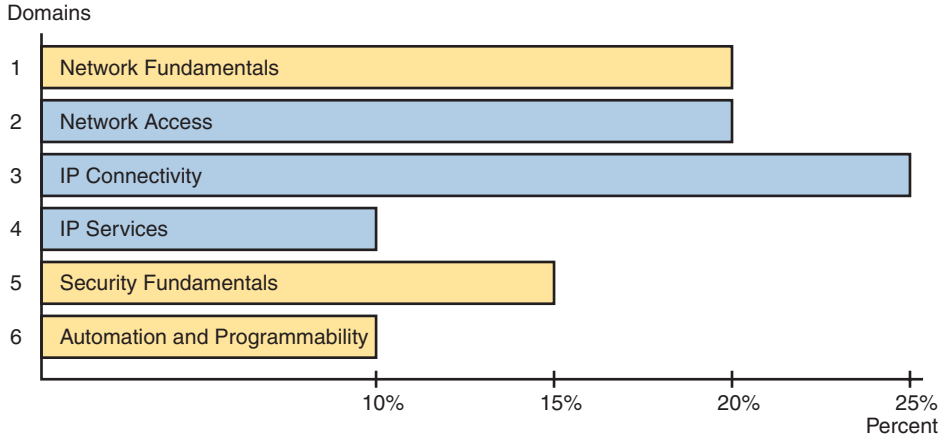


Figure I-2 *CCNA 200-301 Domains and Percentage of Exam Score*

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.

1.11 Describe wireless principles

1.11.a Nonoverlapping Wi-Fi channels

1.11.b SSID

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.

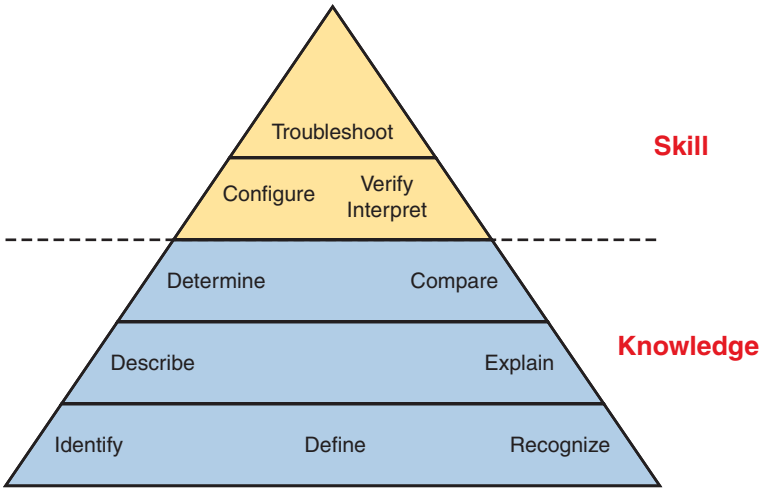


Figure I-3 *Cisco Exam Topic Verbs*

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

To understand 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***.

The first bold phrase mentions the most obvious point about the exam topics: They make a general statement. They do not detail every concept, fact, configuration option, and fact hidden in verification command output. Instead, anyone who cares about a Cisco exam like CCNA has to make a judgment about exactly what details the exam topic includes and excludes—and those judgements are subjective.

Our interpretation and expansion of the exam topics dictate what we choose to include and omit from the books. But we know from long experience that narrow interpretation can cover a large amount of CCNA content, but leave out too much. To cover as much as possible, we use a broad and deep interpretation. That has worked well throughout the 25 plus years for this book and its predecessors. It also matches the overwhelming feedback from reader surveys. In short, we shoot for the middle box in the concept drawing in Figure I-4.

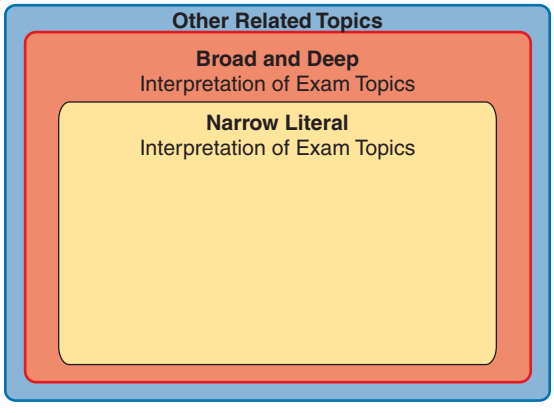


Figure I-4 *Scope Concept: Exam Versus Exam Topics*

Cisco tells us the exam can ask questions about topics outside the exam topics. Look back again to the copy of the text that begins the exam blueprint PDF, to the bold phrase with the term "other related topics." Yes, the exam might ask things outside even a broad interpretation of the exam topics, as implied by the outer ring in Figure I-4.

When choosing book content, I also make some predictions as to what those other related topics might be. Given the policies, we cannot possibly predict and include everything you might see on your exam. What we do promise is to cover each exam topic based on a broad and deep interpretation.

How to Prepare for the Generalized Exam Topics

Given the general nature of Cisco exam topics, plus the possibility of topic areas not listed in the exam topics, how should you go about preparing for the CCNA exam? Most importantly, strive to master all information and skills implied by the exam topics. On exam day, you may still see a few questions about topics you have not studied—but you should know far more than enough to pass the exam.

So, how do you master the topics listed in the exam blueprint? Let me give you a few suggestions.

1. Follow the suggestions in Volume 1's section "Your Study Plan" just before Chapter 1 of that book.
2. Practice hands-on 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 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.

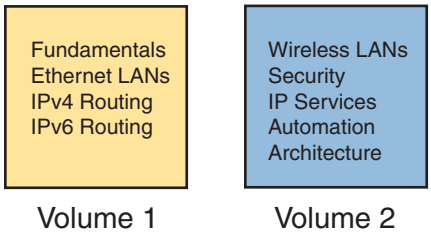


Figure I-5 *Two Books for CCNA 200-301*

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 1 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.)

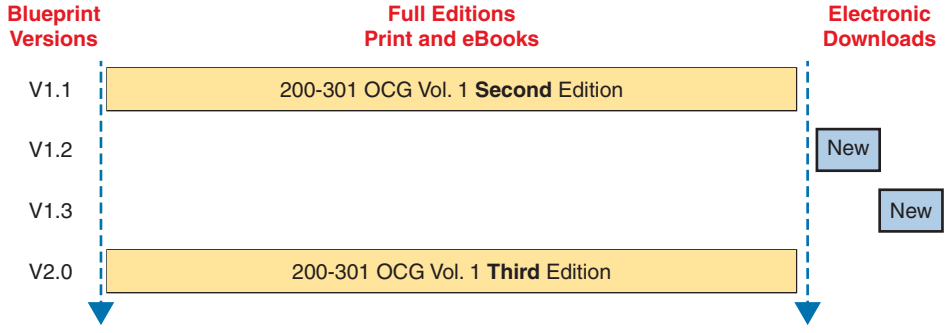


Figure I-6 *Possible Progression of Book Editions, New Content Release, Versus Exams*

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 1–24), make sure to also read Chapter 25, "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 2* (the prior edition, published in 2019 for 200-301 exam blueprint version 1.0)
- *CCNA 200-301 Official Cert Guide, Volume 2*, 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 may help you avoid rereading identical or similar content in this book.

Chapter 4: (Formerly Volume 1, Chapter 29) Added examples and GUI screenshots for wireless LAN configuration using a WLC with IOS XE.

Chapter 7: (Formerly Chapter 3) Significant rewrite; added more about rules for ACL editing, and noted differences with ACLs between IOS and IOS XE.

Chapter 8: New chapter about matching different protocols using ACLs.

Chapter 10: (Formerly Chapter 5) Revised password type discussion and added IOS versus IOS XE details.

Chapter 13: (Formerly Chapter 9) Added CDP/LLDP timers and LLDP-MED with TLVs.

Chapter 14: (Formerly Chapter 10) Revised NAT chapter to simplify and strengthen the examples.

Chapter 16: (Formerly Chapter 12) Split FHRP into a separate chapter, expanding discussions to give more detail on VRRP and GLBP.

Chapter 17: (Formerly Chapter 12) Split SNMP, FTP, and TFTP from FHRP into a separate chapter. Expanded the SNMP section and revised the IFS topic with IOS XE examples.

Chapter 18: (Formerly Chapter 13) Added topics for UTP cabling, multigig Ethernet, multimode Ethernet for campus LANs, and improved PoE descriptions.

Chapter 19: (Formerly Chapter 14) Updated notes about 5G WAN, and added detail on IPsec.

Chapter 20: (Formerly Chapter 15) Added concepts of containers and VRFs, and adds cloud management topics including Meraki.

Chapters 21–22: (Formerly Chapters 16 and 17) Updated for various software version updates and product rebranding, and adds the AI/ML topic.

Chapter 23: (Formerly Chapter 18) Updated for exam topic change to include API authentication.

Chapter 24: (Formerly Chapter 19) Updated for exam topic change to replace the descriptions of Puppet and Chef with new information about Terraform.

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 mid-year 2024 when Cisco should announce their plans.

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.

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.

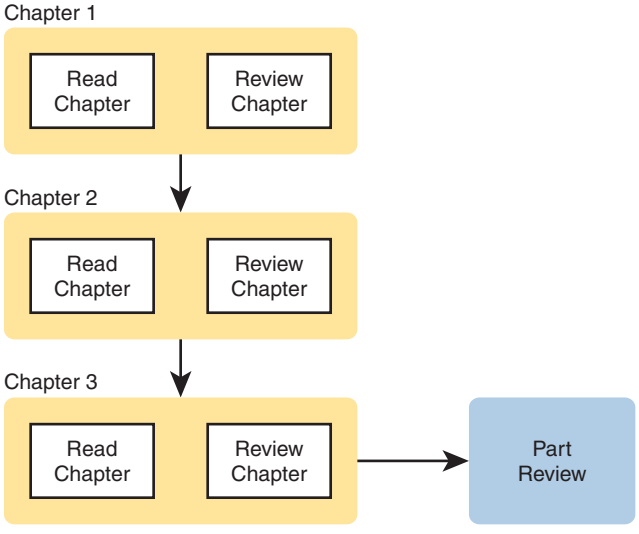


Figure I-7 *Part Review: The Second Review of Most Content*

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 appendixes 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
Appendixes: ACL Practice	Appendix E provides static text practice problems and answers in the PDF appendixes.	Apps with the same practice problems, found in the "Memory Tables and Practice Exercises" section

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: **9780138214951.** 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 9780138214951 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.
- **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/9780138214951.
- **Author's website and blogs:** The author maintains a website that hosts tools and links useful when studying for CCNA. In particular, the site 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 Appendixes

This book contains 24 chapters about CCNA topics organized into seven parts. The core chapters cover the following topics:

- **Part I: Wireless LANs**
  - **Chapter 1, "Fundamentals of Wireless Networks,"** includes the foundational concepts of wireless 802.11 LANs, including wireless topologies and basic wireless radio communications protocols.

- **Chapter 2, "Analyzing Cisco Wireless Architectures,"** turns your attention to the questions related to the systematic and architectural issues surrounding how to build wireless LANs and explains the primary options available for use.
- **Chapter 3, "Securing Wireless Networks,"** explains the unique security challenges that exist in a wireless LAN and the protocols and standards used to prevent different kinds of attacks.
- **Chapter 4, "Building a Wireless LAN,"** shows how to configure and secure a wireless LAN using a Wireless LAN Controller (WLC).

- **Part II: IP Access Control Lists**
  - **Chapter 5, "Introduction to TCP/IP Transport and Applications,"** completes most of the detailed discussion of the upper two layers of the TCP/IP model (transport and application), focusing on TCP and applications.
  - **Chapter 6, "Basic IPv4 Access Control Lists,"** examines how standard IP ACLs can filter packets based on the source IP address so that a router will not forward the packet.
  - **Chapter 7, "Named and Extended IP ACLs,"** examines both named and numbered ACLs, and both standard and extended IP ACLs.
  - **Chapter 8, "Applied IP ACLs,"** shows how to match overhead protocols like DNS, DHCP, and OSPF with ACLs.
- **Part III: Security Services**
  - **Chapter 9, "Security Architectures,"** discusses a wide range of fundamental concepts in network security.
  - **Chapter 10, "Securing Network Devices,"** shows how to secure the router and switch CLI and introduces the concepts behind firewalls and intrusion prevention systems (IPSs).
  - **Chapter 11, "Implementing Switch Port Security,"** explains the concepts as well as how to configure and verify switch port security, a switch feature that does basic MAC-based monitoring of the devices that send data into a switch.
  - **Chapter 12, "DHCP Snooping and ARP Inspection,"** shows how to implement two related switch security features, with one focusing on reacting to suspicious DHCP messages and the other reacting to suspicious ARP messages.
- **Part IV: IP Services**
  - **Chapter 13, "Device Management Protocols,"** discusses the concepts and configuration of some common network management tools: syslog, NTP, CDP, and LLDP.
  - **Chapter 14, "Network Address Translation,"** works through the complete concept, configuration, verification, and troubleshooting sequence for the router NAT feature, including how it helps conserve public IPv4 addresses.

- **Chapter 15, "Quality of Service (QoS),"** discusses a wide variety of concepts all related to the broad topic of QoS.
- **Chapter 16, "First Hop Redundancy Protocols,"** explains the purpose, functions, and concepts of FHRPs, including HSRP, VRRP, and GLBP.
- **Chapter 17, "SNMP, FTP, and TFTP,"** discusses three protocols often used for managing network devices: SNMP, TFTP, and FTP.

- **Part V: Network Architecture**
  - **Chapter 18, "LAN Architecture,"** examines various ways to design Ethernet LANs, discussing the pros and cons, and explains common design terminology, including Power over Ethernet (PoE).
  - **Chapter 19, "WAN Architecture,"** discusses the concepts behind three WAN alternatives: Metro Ethernet, MPLS VPNs, and Internet VPNs.
  - **Chapter 20, "Cloud Architecture,"** explains the basic concepts and then generally discusses the impact that cloud computing has on a typical enterprise network, including the foundational concepts of server virtualization.
- **Part VI: Network Automation**
  - **Chapter 21, "Introduction to Controller-Based Networking,"** discusses many concepts and terms related to how Software-Defined Networking (SDN) and network programmability are impacting typical enterprise networks.
  - **Chapter 22, "Cisco Software-Defined Access (Cisco SD-Access),"** discusses Cisco's Software-Defined Networking (SDN) offering for the enterprise, including the Cisco Catalyst Center (formerly Cisco DNA Center) controller.
  - **Chapter 23, "Understanding REST and JSON,"** explains the foundational concepts of REST APIs, data structures, and how JSON can be useful for exchanging data using APIs.
  - **Chapter 24, "Understanding Ansible and Terraform,"** discusses the need for configuration management software and introduces the basics of each of these configuration management tools.
- **Part VII: Exam Updates and Final Review**
  - **Chapter 25, "*CCNA 200-301 Official Cert Guide, Volume 2*, Second Edition, Exam Updates,"** is a place for the author to add book content mid-edition. Always check online for the latest PDF version of this appendix; the appendix lists download instructions.
  - **Chapter 26, "Final Review,"** suggests a plan for final preparation after you have finished the core parts of the book, in particular explaining the many study options available in the book.
- **Part VIII: Print 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 many of the terms used in the book, including the terms listed in the "Key Terms You Should Know" sections at the conclusion of the chapters.

- **Part IX: Online Appendixes**
  - **Appendix D, "Topics from Previous Editions"**
  - **Appendix E, "Practice for Chapter 6: Basic IPv4 Access Control Lists"**
  - **Appendix F, "Study Planner,"** is a spreadsheet with major study milestones, where you can track your progress through your study.

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 an 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 for Volume 2 (which differs from the NetSim Lite that comes with Volume 1) includes labs about IP ACLs.

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 these 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.

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.

The *CCNA 200-301 Official Cert Guide*, *Volume 2*, Second Edition, helps you attain CCNA certification. This is the CCNA certification book from the only Cisco-authorized publisher. We at Cisco Press believe that this book certainly can help you achieve CCNA certification, but the real work is up to you! I trust that your time will be well spent.

Figure Credits

Figure 17.10: FileZilla

Figure 20.11: Amazon Web Services, Inc.

Figure 23.8: Postman, Inc.

Figure 24.3: GitHub, Inc.

Figures 26.3, 26.4: Pearson Education, Inc.

CHAPTER 16

First Hop Redundancy Protocols

This chapter covers the following exam topics:

3.0 IP Connectivity

3.5 Describe the purpose, functions, and concepts of First Hop Redundancy Protocols

Any host's default router serves as the first router, or first hop, in the routing path from sender to receiver. However, IPv4 did not include high-availability and redundancy features related to the default router. IP hosts use a single setting with a single default router IP address. Also, IP did not define a backup or load-sharing mechanism for multiple routers connected to the same subnet.

First Hop Redundancy Protocols (FHRPs) add the function of redundancy and load sharing for the default router function in any subnet.

This chapter begins with the concepts central to all FHRPs. All FHRPs define how multiple routers work together to appear as a single default router, sharing responsibility. All the FHRPs hide their existence from the hosts, so there is no change to host routing logic. The second section examines the most popular FHRP: Hot Standby Router Protocol (HSRP). The final section compares HSRP with the other two FHRPs: Virtual Router Redundancy Protocol (VRRP) and Global Load Balancing Protocol (GLBP).

"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 16-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
First Hop Redundancy Protocols	1, 2
Hot Standby Router Protocol	3, 4
VRRP and GLBP Concepts	5, 6

1. R1 and R2 attach to the same Ethernet VLAN, with subnet 10.1.19.0/25, with addresses 10.1.19.1 and 10.1.19.2, respectively, configured with the **ip address** interface subcommand. Host A refers to 10.1.19.1 as its default router, and host B refers to 10.1.19.2 as its default router. The routers do not use an FHRP. Which of the following is a problem for this LAN?
   a. The design breaks IPv4 addressing rules because two routers cannot connect to the same LAN subnet.
   b. If one router fails, neither host can send packets off-subnet.
   c. If one router fails, both hosts will use the one remaining router as a default router.
   d. If one router fails, the host that uses that router as a default router cannot send packets off-subnet.
2. R1 and R2 attach to the same Ethernet VLAN, with subnet 10.1.19.0/25, with addresses 10.1.19.1 and 10.1.19.2, respectively, configured with the **ip address** interface subcommand. The routers use an FHRP. Host A and host B attach to the same LAN and have correct default router settings per the FHRP configuration. Which of the following statements is true for this LAN?
   a. The design breaks IPv4 addressing rules because two routers cannot connect to the same LAN subnet.
   b. If one router fails, neither host can send packets off-subnet.
   c. If one router fails, both hosts will use the one remaining router as a default router.
   d. If one router fails, only one of the two hosts will still be able to send packets off-subnet.
3. R1 and R2 attach to the same Ethernet VLAN, with subnet 10.1.19.0/25, with addresses 10.1.19.1 and 10.1.19.2, respectively, configured with the **ip address** interface subcommand. The routers use HSRP. The network engineer prefers to have R1 be the default router when both R1 and R2 are up. Which of the following is the likely default router setting for hosts in this subnet?
   a. 10.1.19.1
   b. 10.1.19.2
   c. Another IP address in subnet 10.1.19.0/25 other than 10.1.19.1 and 10.1.19.2
   d. A host name that the FHRP mini-DNS will initially point to 10.1.19.1
4. Routers R1, R2, and R3, with addresses 10.1.1.1, 10.1.1.2, and 10.1.1.3, respectively, are in HSRPv2 group 16, and use VIP 10.1.1.8. R2 is the current HSRP active router. Which statement is true about HSRP operation in the subnet?
   a. Traffic from hosts in the subnet balances across all routers (R1, R2, and R3).
   b. Traffic from hosts in the subnet flows into only router R2.
   c. Router R1 only replies to ARP requests for address 10.1.1.8.
   d. The HSRP group uses virtual MAC 0000.0C9F.F016.

5. Routers R1, R2, and R3, with addresses 10.1.1.1, 10.1.1.2, and 10.1.1.3, respectively, are in VRRPv3 group 32. R3 is the current VRRP active router. Which statements are true about VRRP operation in the subnet? (Choose two answers.)
   a. The current VIP may be 10.1.1.3.
   b. The current VIP must be 10.1.1.3.
   c. VRRP sends its group messages to multicast address 224.0.0.18.
   d. VRRP sends its group messages to multicast address 224.0.0.2.
6. Which answer best describes a mechanism that enables GLBP to achieve active/active load balancing, with all routers in the group forwarding packets as a default router?
   a. By configuring a VIP that matches one of the router's interface IP addresses
   b. By using a different VIP per router in the same group
   c. By using a separate GLBP group for each router
   d. By using a different virtual MAC address per router in the same group

Foundation Topics

First Hop Redundancy Protocols

When networks use a design that includes redundant routers, switches, LAN links, and WAN links, in some cases, other protocols are required to take advantage of that redundancy and prevent problems caused by it.

For instance, imagine a WAN with many remote branch offices. If each remote branch has two WAN links connecting it to the rest of the network, those routers can use an IP routing protocol to pick the best routes. The routing protocol learns routes over both WAN links, adding the best route into the routing table. When the better WAN link fails, the routing protocol adds the alternate route to the IP routing table, taking advantage of the redundant link.

As another example, consider a LAN with redundant links and switches. Those LANs have problems unless the switches use Spanning Tree Protocol (STP) or Rapid STP (RSTP). STP/RSTP prevents the problems created by frames that loop through those extra redundant paths in the LAN.

This section examines yet another protocol that helps when a network uses some redundancy, this time with redundant default routers. When two or more routers connect to the same LAN subnet, the hosts in that subnet could use any of the routers as their default router. However, another protocol is needed to use the redundant default routers best. The term **First Hop Redundancy Protocol (FHRP)** refers to the category of protocols that enable hosts to take advantage of redundant routers in a subnet.

This first major section of the chapter discusses the major concepts behind how different FHRPs work. This section begins by discussing a network's need for redundancy in general and the need for redundant default routers.

The Need for Redundancy in Networks

Networks need redundant links to improve the availability of those networks. Eventually, something in a network will fail. A router power supply might fail, or a link might break, or a switch might lose power. And those WAN links, shown as simple lines in most drawings in this book, represent the most complicated physical parts of the network, with many individual components that can fail as well.

Depending on the design of the network, the failure of a single component might mean an outage that affects at least some part of the user population. Network engineers refer to any one component that, if it fails, brings down that part of the network as a *single point of failure*. For instance, in Figure 16-1, the LANs appear to have some redundancy, whereas the WAN does not. If most of the traffic flows between sites, many single points of failure exist, as shown in the figure.

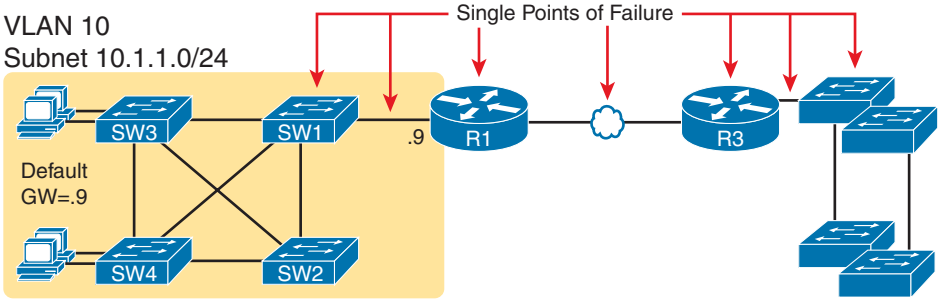


Figure 16-1 *R1 and the One WAN Link as Single Points of Failure*

The figure notes several components as a single point of failure. If any of the network's noted parts fail, packets cannot flow from the left side of the network to the right.

To improve availability, the network engineer first looks at a design and finds the single points of failure. Then the engineer chooses where to add to the network so that one (or more) single point of failure now has redundant options, increasing availability. In particular, the engineer

- Adds redundant devices and links
- Implements any necessary functions that take advantage of the redundant device or link

For instance, of all the single points of failure in Figure 16-1, the most expensive over the long term would likely be the WAN link because of the ongoing monthly charge. However, statistically, the WAN links are the most likely component to fail. So, a good upgrade from the network in Figure 16-1 would be to add a WAN link and possibly even connect to another router on the right side of the network, as shown in Figure 16-2.

Many real enterprise networks follow designs like Figure 16-2, with one router at each remote site, two WAN links connecting back to the main site, and redundant routers at the main site (on the right side of the figure). Compared to Figure 16-1, the design in Figure 16-2

has fewer single points of failure. Of the remaining single points of failure, a risk remains, but it is a calculated risk. For many outages, a reload of the router solves the problem, and the outage is short. But the risk still exists that the switch or router hardware will fail and require time to deliver a replacement device on-site before that site can work again.

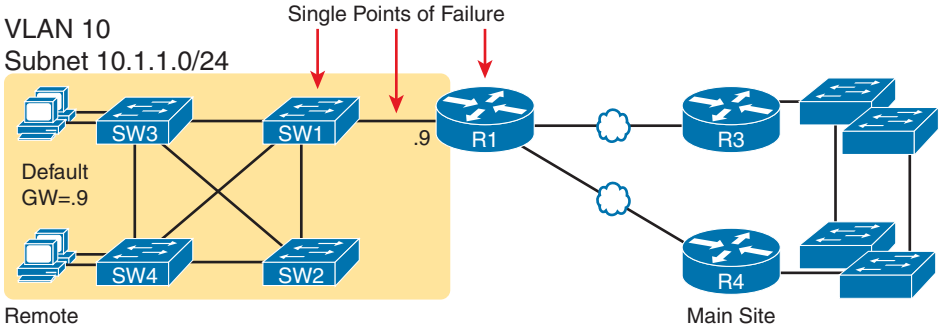


Figure 16-2 *Higher Availability but with R1 Still as a Single Point of Failure*

For enterprises that can justify more expense, the next step in higher availability for that remote site is to protect against those catastrophic router and switch failures. In this particular design, adding one router on the left side of the network in Figure 16-2 removes all the single points of failure noted earlier. Figure 16-3 shows the design with a second router, which connects to a different LAN switch so that SW1 is no longer a single point of failure.

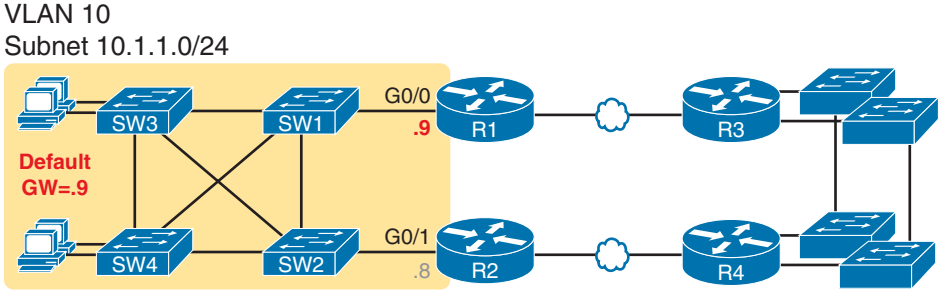


Figure 16-3 *Removing All Single Points of Failure from the Network Design*

NOTE Medium to large enterprise networks work hard to balance high-availability features versus the available budget dollars. Cisco.com has many design documents that discuss tradeoffs in high-availability design. If interested in learning more, search Cisco.com for the Cisco Design Zone section of the site.

The Need for a First Hop Redundancy Protocol

Of the designs shown so far in this chapter, only Figure 16-3's design has two routers to support the LAN on the left side of the figure, specifically the same VLAN and subnet.

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

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

While having the redundant routers on the same subnet helps, the network must use an FHRP when these redundant routers exist.

To see the need and benefit of using an FHRP, first think about how these redundant routers could be used as default routers by the hosts in VLAN 10/subnet 10.1.1.0/24, as shown in Figure 16-4. The host logic will remain unchanged, so each host has a single default router setting. So, some design options for default router settings include the following:

- All hosts in the subnet use R1 (10.1.1.9) as their default router, and they statically reconfigure their default router setting to R2's 10.1.1.8 if R1 fails.
- All hosts in the subnet use R2 (10.1.1.8) as their default router, and they statically reconfigure their default router setting to R1's 10.1.1.9 if R2 fails.
- Half the hosts use R1 and half use R2 as their default router, and if either router fails, half of the users statically reconfigure their default router setting.

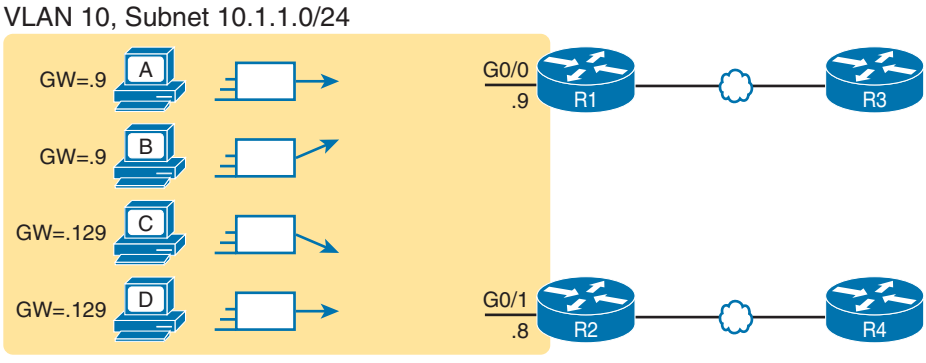


Figure 16-4 *Balancing Traffic by Assigning Different Default Routers to Different Clients*

To ensure the concept is clear, Figure 16-4 shows this third option, with half the hosts using R1 and the other half using R2. The figure removes all the LAN switches just to unclutter the figure. Hosts A and B use R1 as their default router, and hosts C and D use R2 as their default router.

All these options have a problem: the users must act. They have to know an outage occurred. They have to know how to reconfigure their default router setting. And they have to know when to change it back to the original setting.

FHRPs use the redundant default routers without the end users being aware of any changes. The two routers appear to be a single default router. The users never have to do anything: their default router setting remains the same, and their ARP tables remain the same.

To allow the hosts to remain unchanged, the routers must do more work, as defined by one of the FHRP protocols. Generically, each FHRP makes the following happen:

Key Topic

1. All hosts act like they always have, with one default router setting that never has to change.
2. The default routers share a virtual IP address in the subnet, defined by the FHRP.
3. Hosts use the FHRP virtual IP address as their default router address.

4. The routers exchange FHRP protocol messages so that both agree as to which router does what work at any point in time.
5. When a router fails or has some other problem, the routers use the FHRP to choose which router takes over responsibilities from the failed router.

The Three Solutions for First-Hop Redundancy

The term *First Hop Redundancy Protocol* does not name any one protocol. Instead, it names a family of protocols that fill the same role. For a given network, like the left side of Figure 16-4, the engineer would pick one of the protocols from the FHRP family.

NOTE *First Hop* refers to the default router being the first router, or first router hop, through which a packet must pass.

Table 16-2 lists the three FHRP protocols in chronological order as first used in the market. Cisco first introduced the proprietary **Hot Standby Router Protocol (HSRP)**, which worked well for many customers. Later, the IETF developed an RFC for a similar protocol, **Virtual Router Redundancy Protocol (VRRP)**. Finally, Cisco developed a more robust option, **Gateway Load Balancing Protocol (GLBP)**.

Key Topic

Table 16-2 Three FHRP Options

Acronym	Full Name	Origin	Redundancy Approach	Load Balancing Per…
HSRP	Hot Standby Router Protocol	Cisco	active/standby	subnet
VRRP	Virtual Router Redundancy Protocol	RFC 5798	active/standby	subnet
GLBP	Gateway Load Balancing Protocol	Cisco	active/active	host

The CCNA 200-301 version 1.1 blueprint requires you to know the purpose, functions, and concepts of an FHRP. To do that, the next section takes a deep look at HSRP concepts, while the final section of the chapter compares VRRP and GLBP to HSRP. (This chapter does not discuss FHRP configuration, but if you want to learn beyond the plain wording of the exam topics, note that Appendix D, "Topics from Previous Editions," contains a short section about HSRP and GLBP configuration, copied from an earlier edition of the book.)

Hot Standby Router Protocol

HSRP operates with an active/standby model (more generally called *active/passive*). HSRP allows two (or more) routers to cooperate, all willing to act as the default router. However, at any one time, only one router actively supports the end-user traffic. The packets sent by hosts to their default router flow to that one active router. Then the other routers sit there patiently waiting to take over should the active HSRP router have a problem.

This next section of the chapter discusses how HSRP achieves its goal of providing default router redundancy. It progresses briefly through the mechanisms of virtual IP and MAC addresses, failover, load balancing, object tracking, and HSRP versions.

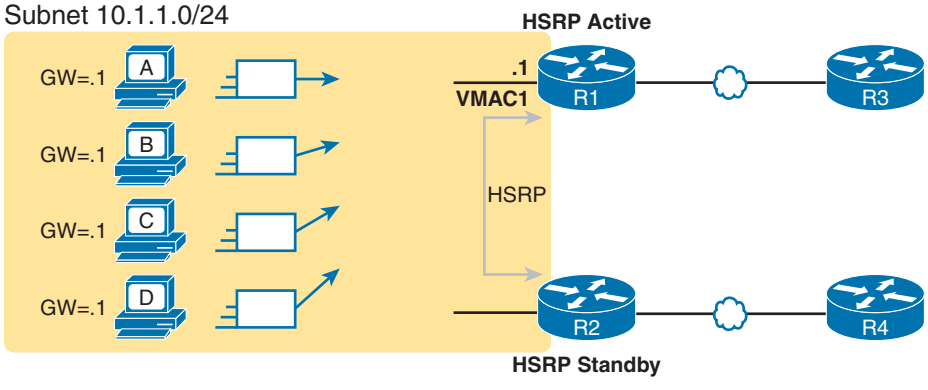
HSRP Virtual IP and MAC Addresses

The **HSRP active** router implements a **virtual IP address (VIP)** and matching **virtual MAC address**. This virtual IP address is part of the HSRP configuration, an additional configuration item compared to the usual **ip address** interface subcommand. This virtual IP address is in the same subnet as the interface IP address, but it is a different IP address. The router then automatically creates the virtual MAC address. All the cooperating HSRP routers know these virtual addresses, but only the HSRP active router uses these addresses at any one point in time.

Using HSRP protocol messages between the routers, the routers negotiate and settle in either the HSRP active or **HSRP standby** state. The router with the highest **HSRP priority** wins and becomes active, with the other router becoming the standby router. If the priorities tie, the router with the highest IP address wins and becomes active. (Also, note that while FHRPs often have only two routers in a group, if using three or more, HSRP uses only one standby router, with the other routers in a listen state, waiting to become the new standby router one day.)

The active router implements the virtual IP and MAC addresses on its interface in addition to its configured interface IP address. Hosts refer to the virtual IP address as their default router address instead of any router's interface IP address. For instance, in Figure 16-5, R1 and R2 use HSRP. The HSRP virtual IP address is 10.1.1.1, with the virtual MAC address referenced as VMAC1 for simplicity's sake.

Key Topic



Host ARP Table

IP	MAC
10.1.1.1	VMAC1

Figure 16-5 *All Traffic Goes to .1 (R1, Which Is Active); R2 Is Standby*

HSRP Failover

Under normal conditions, with all devices and interfaces working, one HSRP router is the default router, with another standing by. That might happen for months before the standby router needs to take over. However, so that the standby router knows when to act, the two routers continue to send HSRP messages to each other.

HSRP uses HSRP Hello messages to let the other HSRP routers in the same HSRP group know that the active router continues to work. HSRP defines a Hello timer, which dictates how often (in seconds) between successive Hello messages sent by the active router. HSRP also defines a Hold timer, typically more than three times the Hello timer. When the standby router fails to receive a Hello from the active router within the time defined by the hold time, the standby router believes the active router has failed, and begins taking over as the active router.

For example, Figure 16-6 shows the result when R1, the HSRP active router in Figure 16-5, loses power. R2 fails to receive additional HSRP Hellos from router R1 for hold time. At that point, R2, the new active router, starts using the virtual IP and MAC addresses.

Key Topic

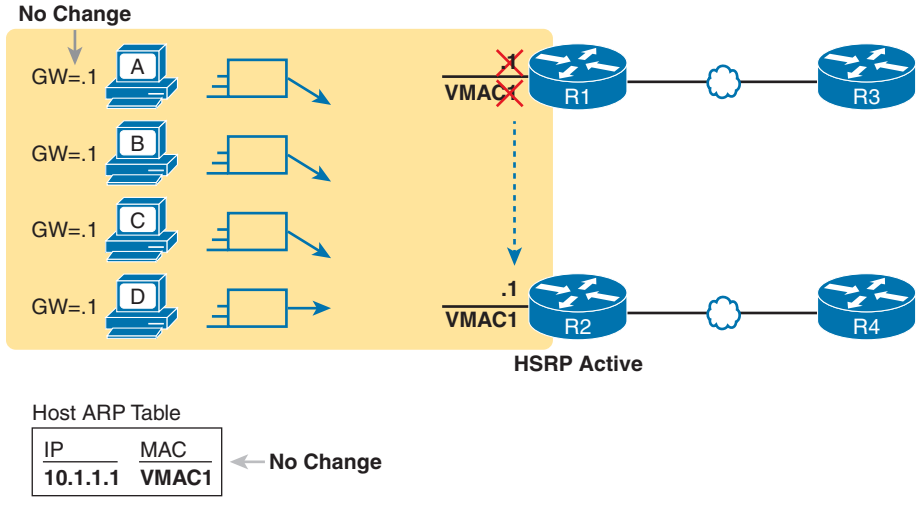


Figure 16-6 *Packets Sent Through R2 (New Active) After It Takes Over for Failed R1*

The figure shows packets flowing from the hosts toward router R2, with no changes on the hosts. The host keeps the same default router setting, referencing the virtual IP address (10.1.1.1). The host's ARP table does not have to change either, with the ARP entry for the default router listing the virtual MAC.

To direct the Ethernet frames that formerly flowed to router R1 to instead flow to router R2, changes occur on both the routers and the LAN switches. The new active router (R2) must be ready to receive packets (encapsulated inside frames) using the virtual IP and MAC addresses. The LAN switches, hidden in the last few figures, must also change their MAC address tables. Formerly, their MAC tables directed frames destined for VMAC1 to router R1, but now the switches must know to send the frames to the new active router, R2.

To make the switches change their MAC address table entries for VMAC1, R2 sends an Ethernet frame with VMAC1 as the source MAC address. The switches, as normal, learn the source MAC address (VMAC1) but with new ports that point toward R2. The frame is also a LAN broadcast, so all the switches learn a MAC table entry for VMAC1 that leads toward R2. (By the way, this Ethernet frame holds an ARP Reply message, called a gratuitous ARP, because the router sends it without first receiving an ARP Request.)

HSRP Load Balancing

The active/standby model of HSRP means that all hosts send their off-subnet packets through only one router. In other words, the routers do not share the workload; instead, one router forwards all the packets. For instance, back in Figure 16-5, R1 was the active router. All hosts in the subnet sent their packets through R1, and none of them sent their packets through R2.

HSRP does support load balancing by preferring different routers to be the active router in different subnets. Most sites that require a second router for redundancy also use several VLANs and subnets at the site. The two routers will likely connect to all the VLANs, acting as the default router in each subnet. The HSRP configuration settings can result in one router being active in one subnet and another router being active in another subnet, balancing the traffic. Or you can configure multiple instances of HSRP in the same subnet (called multiple HSRP groups), preferring one router to be active in one group and the other router to be selected as active in another.

For instance, Figure 16-7 shows a redesigned LAN with two hosts in VLAN 1 and two in VLAN 2. R1 and R2 connect to the LAN using a VLAN trunking and router-on-a-stick (ROAS) configuration. The two routers define two HSRP groups, one to support each of the two subnets. In this case, R1 wins and becomes active in Subnet 1, while router R2 becomes active in Subnet 2.

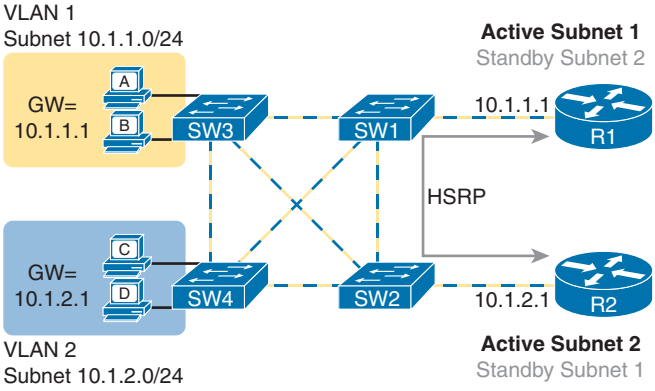


Figure 16-7 *Load Balancing with HSRP by Using Different Active Routers per Subnet*

Note that the design uses both routers and WAN links by having each router act as the HSRP active router in some subnets.

The example surrounding Figure 16-7 raises the question of where to consider using HSRP. You should consider an FHRP on any router or Layer 3 switch interface with an IP address that connects to hosts that rely on a default router setting. If only one router connects to the subnet, you do not need an FHRP, but if two or more connect to the subnet, you benefit from using an FHRP.

HSRP Interface Tracking

Another feature supported by all the FHRPs tracks the operational state of other router features. IOS allows for tracking of interface state, tracking routes in the IP routing table, and other types of objects. When the tracked interface or object fails, HSRP reduces that router's

HSRP priority. With well-chosen priority and tracking settings, you can arrange the HSRP configuration so that when everything works perfectly, one router is active. Later, when something fails related to that router, another router preempts and takes over as the active router.

Figure 16-8 shows one classic failure case that can occur without tracking. In this example, router R1 uses priority 110, with router R2 using 100 (the default), so R1 wins and becomes HSRP active. However, the one WAN link connected to R1 fails. R1 remains the HSRP active router. In this failure case, hosts forward packets to router R1, which has to forward them to router R2, which has the only working WAN link.

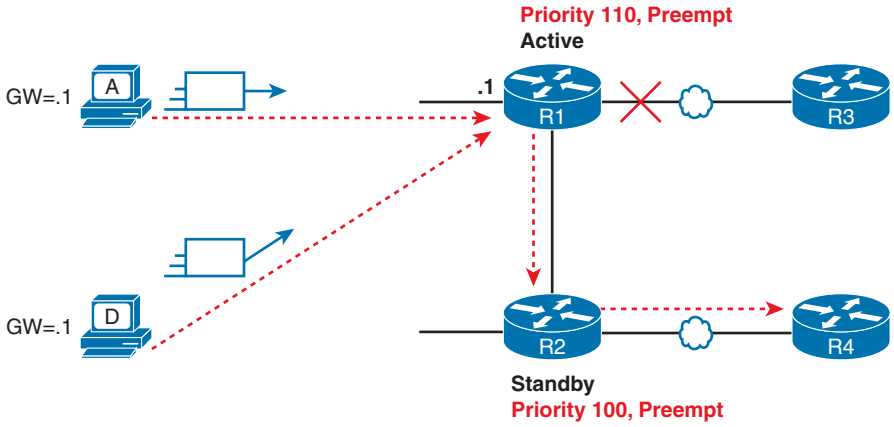


Figure 16-8 *Problem: Extra Routing Hop When the R1 WAN Link Fails*

A better plan links the HSRP role to the WAN link state. For instance, with interface tracking and preemption, you can configure HSRP as follows:

If R1's WAN link is up, make R1 HSRP active.

If R1's WAN link is down, make R2 HSRP active.

To do so, HSRP object tracking on R1 monitors the state of the R1 WAN interface. If the interface fails, HSRP lowers R1's HSRP priority, allowing R2 to preempt R1. For example:

1. R1 notices its WAN interface fails.
2. R1 lowers its HSRP priority by 20 points.
3. HSRP messages allow both R1 and R2 to realize that R2 has a better (higher) priority and has the right to preempt.
4. R2, using preemption, becomes the HSRP active router.

As a result, while router R1's WAN link is down, packets from the hosts on the left flow first to R2 and then out a WAN link. Later, when R1's WAN link recovers, it preempts router R2 and becomes active again.

HSRP Recovery and Preemption

The **HSRP preemption** also dictates what happens when a formerly active router recovers, independent of any HSRP tracking. HSRP disables preemption by default but supports it on any router.

First, consider the following scenario:

1. R1 has priority 110, and R2 has priority 100, so R1 wins and becomes active, while R2 becomes standby.
2. Later, R1 fails, so R2 becomes active.
3. When R1 recovers, what happens?

With the default setting of no preemption, R2 remains the active router. With only two routers in the HSRP group, when R1 recovers, it moves to a standby state, ready to take over from R2 when R2 next fails. In that case, the operations staff can choose when to make the failover happen, for instance, off-shift, when a minor outage has no impact.

If you prefer, you can enable preemption. With preemption, in this case, or any case in which a new router appears in the group that has a better (higher) priority than the active router, it takes over as the active router. The switch to a new active router is methodical but quick, without waiting for timers like the Hello and Hold timers to expire, but it might cause a disruption in packet flow for a second or two. (Note that preemption does not apply to cases where the priorities tie, but only when the new router has a higher priority.)

HSRP Versions

Cisco routers and Layer 3 switches support two versions of HSRP: versions 1 and 2. The versions have enough differences, like multicast IP addresses used and message formats, so routers in the same HSRP group must use the same version. Suppose two routers configured in the same HSRP group mistakenly use different versions. In that case, they will not understand each other and will ignore each other for the purposes of HSRP.

There are good reasons to use the more recent HSRP version 2 (HSRPv2). HSRPv2 added IPv6 support. It also supports faster convergence when changes happen using shorter Hello and Hold timers, while HSRPv1 typically had a minimum of a 1-second Hello timer. Table 16-3 lists the differences between HSRPv1 and HSRPv2.

Key Topic

Table 16-3 HSRPv1 Versus HSRPv2

Feature	Version 1	Version 2
IPv6 support	No	Yes
Smallest unit for Hello timer	Second	Millisecond
Range of group numbers	0..255	0..4095
Virtual MAC address used (*xx* or *xxx* is the hex group number)	0000.0C07.AC*xx*	0000.0C9F.F*xxx*
IPv4 multicast address used	224.0.0.2	224.0.0.102

Ensure you understand how a router chooses the virtual MAC shown in the table. HSRPv1 supports 256 groups per interface, while HSRPv2 supports 4096. You can represent decimal values 0..255 with two-digit hexadecimal equivalents of 00..FF, while decimal values 0..4095 require three hex digits from 000..FFF. The HSRP virtual MAC addresses use the hex equivalents of the configured decimal HSRP group number as the last two or three digits of the virtual MAC address as follows:

HSRPv1: 0000.0C07.AC*xx*, where *xx* is the hex group number

HSRPv2: 0000.0C9F.F*xxx*, where *xxx* is the hex group number

For example, an HSRPv1 group 1 would use virtual MAC address 0000.0C07.AC**01**, while an HSRPv2 group would use 0000.0C9F.F**001**. For group decimal 100 (hex 64), they would use 0000.0C07.AC**64** and 0000.0C9F.F**064**, respectively.

VRRP and GLBP Concepts

Now that you have a thorough understanding of the purpose, functions, and concepts of HSRP, this third major section of the chapter examines the two other FHRPs: VRRP and GLBP. Both provide the same primary functions as HSRP. VRRP has more similarities with HSRP, while GLBP goes beyond HSRP with better load-balancing features.

Virtual Router Redundancy Protocol (VRRP)

HSRP and VRRP emerged in the 1990s when TCP/IP and routers first became common in corporate networks. As is often the case, Cisco saw a need, but with no standards-based solution, so they defined HSRP as a proprietary solution for first hop router redundancy. Later, the IETF created VRRP, providing similar features. However, unlike many stories of Cisco-proprietary pre-standard features, HSRP has not faded into history; you will still find both HSRP and VRRP support in many Cisco product families.

NOTE While VRRP includes versions 1, 2, and 3, all references in this chapter refer to VRRPv3 (RFC 5798.)

For similarities, note that VRRP supports all the same functions as HSRP, as described earlier in this chapter. The purpose remains to provide a standby backup for the default router function, preemption if desired, and load balancing the default router role by using multiple VRRP groups.

The differences come with default settings, protocol details, and addresses used. Table 16-4 lists some comparison points between HSRP, VRRP, and GLBP (ignore GLBP for now.)

Key Topic

Table 16-4 Comparing Features of the Three FHRP Options

Acronym	HSRPv2	VRRPv3	GLBP
Cisco Proprietary	Yes	No	Yes
VIP must differ from the routers' interface IP addresses	Yes	No	Yes
Preemption off by default	Yes	No	Yes
Allows preemption (or not)	Yes	Yes	Yes
Default priority value (decimal)	100	100	100
Supports tracking to change the priority	Yes	Yes	Yes
Supports IPv4 and IPv6	Yes	Yes	Yes
Active/active load balancing with multiple active routers in one group	No	No	Yes
IPv4 multicast address used	224.0.0.102	224.0.0.18	224.0.0.102
Group numbers supported in IOS	0–4095	1–255	0–1023
Virtual MAC address pattern	0000.0c9f.fxxx	0000.5e00.01xx	0007.b40x.xxrr

You can configure VRRP so that it appears to work like HSRP. Two or more VRRP routers form a group within one subnet. VRRP routers define one VIP, use multicast messages to communicate with each other, use an active/standby approach, select the active router with the same logic as HSRP, allow tracking, and fail over when the master (active) router fails. (Note that VRRP uses the terms *master* and *backup* rather than *active* and *standby*.)

One difference comes in the choice of VIP. You can use the same IP address as one of the VRRP routers' interface addresses or, like HSRP, use another IP address in the subnet. For example, the HSRP discussion around Figures 16-5 and 16-6 used VIP 10.1.1.1, with router addresses 10.1.1.9 and 10.1.1.8. You could do the same with VRRP or use 10.1.1.9 (the same IP address as router R1's interface IP address).

VRRP has protocol differences as well. It uses a multicast IPv4 address (224.0.0.18) for its messages. While it uses a single virtual MAC per group, the MAC address follows a different pattern. VRRP configuration uses decimal group numbers from 1 to 255 decimal. The virtual MAC uses the equivalent two-digit hex group number at the end of the virtual MAC, with VRRP routers choosing their virtual MAC based on this pattern:

VRRPv3: 0000.5e00.01*xx*, where *xx* is the hex group number

GLBP Concepts

Cisco-proprietary GLBP, defined after HSRP and VRRP, provides the same benefits as HSRP and VRRP but with different implementation details. But it also includes different internals that allow much more effective load balancing. So, while used for redundancy (the *R* in FHRP), GLBP also adds robust load balancing, per its name.

This GLBP section begins with comparisons to the other FHRPs and then discusses its improved approach to load balancing.

Similarities of GLBP, HSRP, and VRRP

GLBP provides redundancy for the default router function while hiding that redundancy from the hosts using that default router address. But most of the core features follow a familiar theme:

- It uses a virtual IP address (VIP), which is the address used by endpoints as their default router.
- It identifies the best router in the group based on the highest priority.
- It allows for the preemption of the best router when a new router with a better (higher) priority joins the group.
- It supports tracking, which dynamically lowers one router's priority, allowing another router to preempt the first based on conditions like an interface failure.
- It sends messages using multicasts but uses a different address: 224.0.0.102.

GLBP uses virtual MAC addresses differently than the other FHRPs as part of the underlying support for load balancing. Like HSRP and VRRP, a GLBP group has one VIP. Unlike HSRP and VRRP, the routers in a group do not use one virtual MAC address whose function resides with the one active router. Instead, GLBP uses a unique virtual MAC address per GLBP router.

The MAC address value includes three hex digits to represent the decimal GLBP group number, with the unique last two digits (01, 02, 03, or 04) representing the four allowed GLBP routers in a group. The MAC address pattern is 0007.b40*x.xxrr*. For instance, for two routers in the same GLBP group:

Key Topic

Router R1: 0007:b400**:1401** (Decimal group 20, which is hex group 014, assigned router number 01)

Router R2: 0007:b400**:1402** (Decimal group 20, which is hex group 014, assigned router number 02)

GLBP Active/Active Load Balancing

With a name like Gateway Load Balancing Protocol, load balancing should be a key feature. The term *gateway* refers to the alternate term for default router (*default gateway*), so by name, GLBP claims to load balance across the default routers in a subnet—and it does.

GLBP manipulates the hosts' IP ARP tables in a subnet so that some hosts forward packets to one router and some to another. As usual, all the hosts use the same VIP as their default router address. Under normal conditions, with multiple GLBP routers working in the subnet, GLBP spreads the default router workload across all GLBP group members. When one of those routers fails, GLBP defines the methods by which the remaining router or routers take over the role of the failed router.

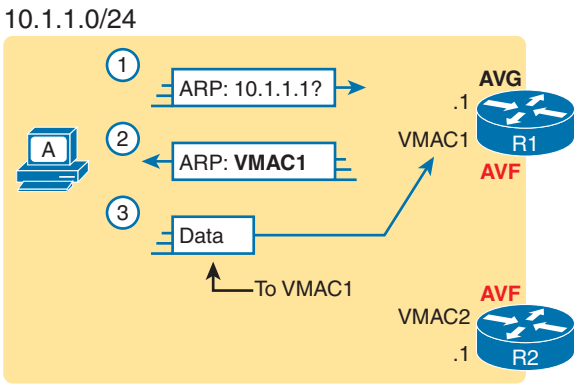
To achieve this active/active load balancing, one GLBP performs the role of **GLBP active virtual gateway (AVG)**. The AVG handles all ARP functions for the VIP. Knowing the virtual MAC addresses of all the routers in the group, the AVG replies to some ARP Requests with one virtual MAC and some with the other. As a result, some hosts in the subnet send frames to the Ethernet MAC address of one of the routers, with different hosts sending their frames to the MAC address of the second router.

All routers serve as a **GLBP active virtual forwarder (AVF)** to support load balancing. All the AVFs sit ready to receive Ethernet frames addressed to their unique virtual MAC address and to route the encapsulated packets as usual. Note that one router serves as both AVG and AVF.

Figures 16-9 and 16-10 show the results of two ARP Reply messages from AVG R1. First, Figure 16-9 shows how a GLBP balances traffic for host A based on the ARP Reply sent by the AVG (R1). The two AVF routers support virtual IP address 10.1.1.1, with the hosts using that address as their default router setting.

The figure shows three messages, top to bottom, with the following action:

1. Host A has no ARP table entry for its default router, 10.1.1.1, so host A sends an ARP Request to learn 10.1.1.1's MAC address.
2. The GLBP AVG, R1 in this case, sends back an ARP Reply. The AVG includes its virtual MAC address in the ARP Reply, VMAC1.
3. Host A encapsulates future IP packets in Ethernet frames destined for VMAC1, so they arrive at R1 (also an AVF).



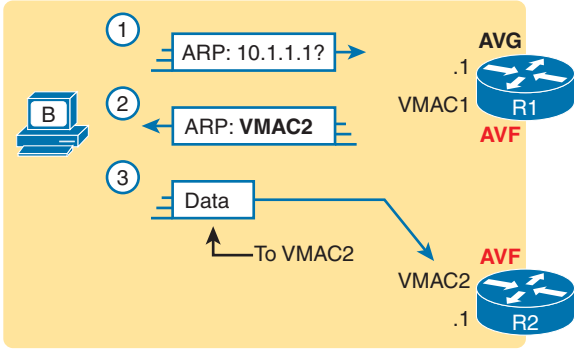
GLBP Table

Role	Router	Address
AVG	R1	10.1.1.1
Forwarder	R1	**VMAC1**
Forwarder	R2	VMAC2

Figure 16-9 *GLBP Directs Host A by Sending Back the ARP Reply with R1's VMAC1*

To balance the load, the AVG answers each new ARP Request with the MAC addresses of alternating routers. Figure 16-10 continues the load-balancing effect with host B's ARP Request for 10.1.1.1. The router acting as AVG (R1) still sends the ARP Reply, but this time with R2's virtual MAC (VMAC2).

Key Topic



GLBP Table

Role	Router	Address
AVG	R1	10.1.1.1
Forwarder	R1	VMAC1
Forwarder	R2	**VMAC2**

Figure 16-10 *GLBP Directs Host B by Sending Back the ARP Reply with R2's VMAC2*

Here are the steps in the figure:

1. Host B sends an ARP Request to learn 10.1.1.1's MAC address.
2. The GLBP AVG (R1) sends back an ARP Reply, listing VMAC2, R2's virtual MAC address.
3. Host B encapsulates future IP packets in Ethernet frames destined for VMAC2, so they arrive at R2.

Finally, to capture a few related points beyond this GLBP example, note that GLBP uses priority, preemption, and tracking. However, those rules apply to the AVG only; all GLBP routers serve as AVFs. So, if the AVG fails, the remaining routers in a GLBP group elect a new AVG.

That model requires additional logic to deal with AVF failures. When a router serving as only an AVF fails, the AVG recognizes the failure and causes a still-functional AVF to begin receiving frames sent to the failed AVF's virtual MAC address.

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 16-5 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 16-5 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 memory tables		Website

Review All the Key Topics

Key Topic

Table 16-6 Key Topics for Chapter 16

Key Topic Element	Description	Page Number
List	Common characteristics of all FHRPs	355
Table 16-2	Comparisons of HSRP, VRRP, GLBP	356
Figure 16-5	HSRP concepts	357
Figure 16-6	HSRP failover results	358
Table 16-3	Comparing HSRPv1 and HSRPv2	361
Table 16-4	Comparing HSRP, VRRP, and GLBP	362
List	GLBP virtual MAC addresses	364
Figure 16-10	GLBP AVG ARP Reply referring to a different GLBP router	365

Key Terms You Should Know

First Hop Redundancy Protocol (FHRP), Gateway Load Balancing Protocol (GLBP), GLBP active virtual forwarder (AVF), GLBP active virtual gateway (AVG), Hot Standby Router Protocol (HSRP), HSRP active, HSRP preemption, HSRP priority, HSRP standby, virtual IP address (VIP), virtual MAC address, Virtual Router Redundancy Protocol (VRRP)

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