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CCNA 200-301

Volume 1

WENDELL ODOM,
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CCNA 200-301

Official Cert Guide, Volume 1

WENDELL ODOM, CCIE No. 1624 Emeritus

Cisco Press
221 River St. (3D11C)
Hoboken, NJ 07030

CCNA 200-301 Official Cert Guide, Volume 1

Wendell Odom

Published by:
Cisco Press

ScoutAutomatedPrintCode

Library of Congress Control Number: 2019908180

ISBN-13: 978-0-13-579273-5
ISBN-10: 0-13-579273-8

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Wendell Odom, CCIE No. 1624 Emeritus, has been in the networking industry since 1981. He has worked as a network engineer, consultant, systems engineer, instructor, and course developer; he currently works writing and creating certification study tools. This book is his 28th edition of some product for Pearson, and he is the author of all editions of the CCNA Cert Guides about Routing and Switching from Cisco Press. He has written books about topics from networking basics, certification guides throughout the years for CCENT, CCNA R&S, CCNA DC, CCNP ROUTE, CCNP QoS, and CCIE R&S. He maintains study tools, links to his blogs, and other resources at www.certskills.com.

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Elan Beer, CCIE No. 1837, is a senior consultant and Cisco instructor specializing in data center architecture and multiprotocol network design. For the past 27 years, Elan has designed networks and trained thousands of industry experts in data center architecture, routing, and switching. Elan has been instrumental in large-scale professional service efforts designing and troubleshooting internetworks, performing data center and network audits, and assisting clients with their short- and long-term design objectives. Elan has a global perspective of network architectures via his international clientele. Elan has used his expertise to design and troubleshoot data centers and internetworks in Malaysia, North America, Europe, Australia, Africa, China, and the Middle East. Most recently, Elan has been focused on data center design, configuration, and troubleshooting as well as service provider technologies. In 1993, Elan was among the first to obtain the Cisco Certified System Instructor (CCSI) certification, and in 1996, he was among the first to attain the Cisco System highest technical certification, the Cisco Certified Internetworking Expert. Since then, Elan has been involved in numerous large-scale data center and telecommunications networking projects worldwide.

Acknowledgments

Brett Bartow and I have been a team for a few decades. His support and wisdom have been a big help through what is the most significant change to the Cisco CCNA and CCNP certifications since their beginnings back in 1998. He's always a great partner on working through big picture direction as well as features to make the books the best they can be for our readers. Once again he's the starting point of the team! (And one of the things he does is gather the rest of the team that you see below…)

I don't mean this to sound too melodramatic, but I am too psyched: I got Dave Hucaby to join my team as a coauthor for this edition of the book! Dave's been writing about LAN switching, wireless LANs, and security topics for Cisco Press almost as long as I have, and I've always loved the accuracy and style of his books. Cisco added more than a little wireless LAN content to CCNA this time around. One thing led to another, I wondered if Dave might be willing to join in, and now we get Dave on the wireless chapters! I hope you'll enjoy those chapters as much as I did when preparing the book.

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, the first question is whether Chris has time to develop the book. It's always a pleasure working with you, Chris, for what seems like the 20th time or so by now.

The second question for Brett when starting a new book is whether we might be able to get Elan Beer to do the tech editing. Elan has the right wiring, skills, and experience to do a great job for us with all aspects of the tech editing process. Fantastic job as usual; thanks, Elan.

Sometimes, with a short book timeline as with this book, I don't know who's working on the project for the production group until I've written these notes, but I heard Sandra's and Tonya's names early this time. Knowing they would be on the project again really did give me a chance to exhale, and I have to say that knowing they would be on the project gave me a great sense of calm going into the production phase of the book.

Thanks to Sandra Schroeder, Tonya Simpson, and all the production team for making the magic happen. Not to sound too much like a broken record, but getting to work with familiar people who have been a great help in the past really does help reduce the stress when writing, besides getting the highest-quality product out the door in print and e-book forms. 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. And Tonya got to juggle two books of mine at the same time (again)—thanks for managing the whole production process again.

Mike Tanamachi, illustrator and mind reader, did a great job on the figures again. I use a different process with the figures than most authors, with Mike drawing new figures as soon as I outline a new section or chapter. It means more edits when I change my mind and lots of mind reading of what Wendell really wanted versus what I drew poorly on my iPad. Mike came through again with some beautiful finished products.

I could not have made the timeline for this book without Chris Burns of Certskills Professional. Chris owns much of the PTP question support and administration process, works on the labs we put on my blog, and then catches anything I need to toss over my shoulder so I can focus on the books. Chris, you are the man!

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 (blog.certskills.com). Without question, the comments I receive directly and overhear by participating at CLN made this edition a better book.

Thanks to my wonderful wife, Kris, who helps make this sometimes challenging work lifestyle a breeze. I love walking this journey with you, doll. Thanks to my daughter Hannah, launching to college just as this book releases! And thanks to Jesus Christ, Lord of everything in my life.

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Online Appendixes

Reader Services

To access additional content for this book, simply register your product. To start the registration process, go to www.ciscopress.com/register and log in or create an account*. Enter the product ISBN 9780135792735 and click Submit. After the process is complete, you will find any available bonus content under Registered Products.

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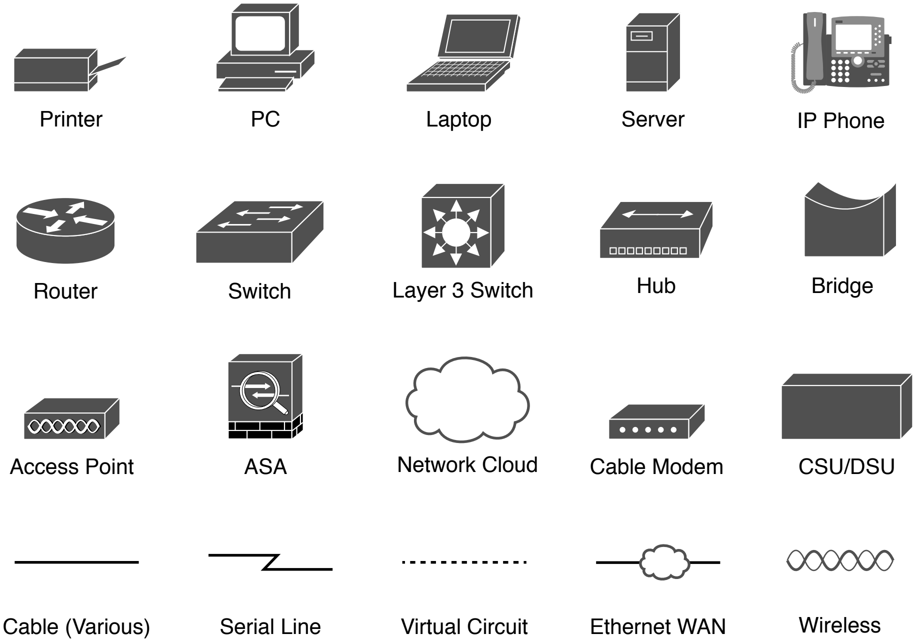


Command Syntax Conventions

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

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italic* indicates arguments for which you supply actual values.

- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

Introduction

About Cisco Certifications and 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, and the CCNA certification is the one place to begin that journey. If you want to succeed as a technical person in the networking industry at all, you need to know Cisco. Cisco has a ridiculously high market share in the router and switch marketplace, with more than 80 percent market share in some markets. In many geographies and markets around the world, networking equals Cisco. If you want to be taken seriously as a network engineer, Cisco certification makes perfect sense.

The first few pages of this Introduction explain the core features of Cisco's Career Certification program, of which the Cisco Certified Network Associate (CCNA) serves as the foundation for all the other certifications in the program. This section begins with a comparison of the old to the new certifications due to some huge program changes in 2019. It then gives the key features of CCNA, how to get it, and what's on the exam.

The Big Changes to Cisco Certifications in 2019

Cisco announced sweeping changes to its career certification program around mid-year 2019. Because so many of you will have read and heard about the old versions of the CCNA certification, this intro begins with a few comparisons between the old and new CCNA as well as some of the other Cisco career certifications.

First, consider Cisco's career certifications before 2019 as shown in Figure I-1. At that time, Cisco offered 10 separate CCNA certifications in different technology tracks. Cisco also had eight Professional-level (CCNP, or Cisco Certified Network Professional) certifications.

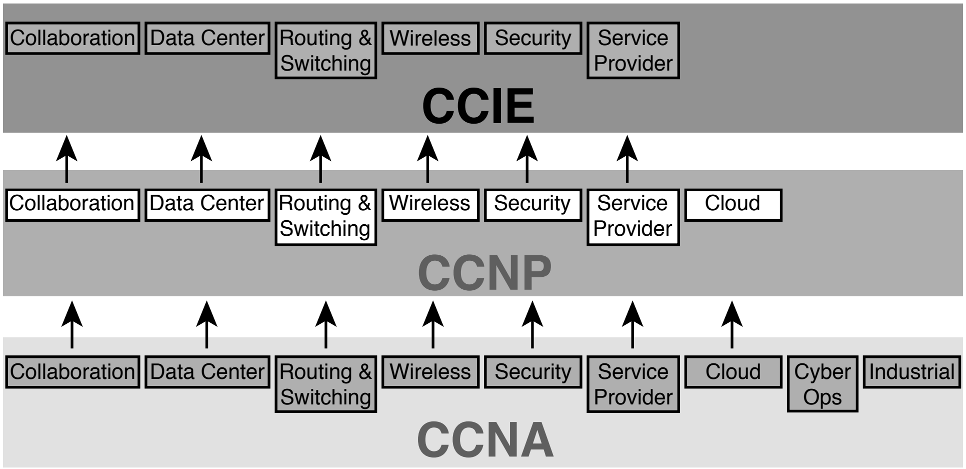


Figure I-1 *Old Cisco Certification Silo Concepts*

Why so many? Cisco began with one track—Routing and Switching—back in 1998. Over time, Cisco identified more and more technology areas that had grown to have enough content to justify another set of CCNA and CCNP certifications on those topics, so Cisco added more tracks. Many of those also grew to support expert level topics with CCIE (Cisco Certified Internetwork Expert).

In 2019, Cisco consolidated the tracks and moved the topics around quite a bit, as shown in Figure I-2.

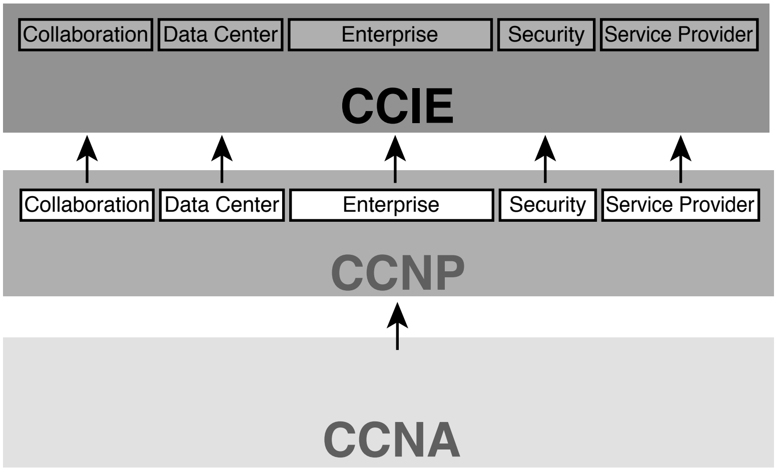


Figure I-2 *New Cisco Certification Tracks and Structure*

All the tracks now begin with the content in the one remaining CCNA certification. For CCNP, you now have a choice of five technology areas for your next steps, as shown in Figure I-2. (Note that Cisco replaced "Routing and Switching" with the term "Enterprise.")

Cisco made the following changes with the 2019 announcements:

CCENT: Retired the only Entry-level certification (CCENT, or Cisco Certified Entry Network Technician), with no replacement.

CCNA: Retired all the CCNA certifications except what was then known as "CCNA Routing and Switching," which became simply "CCNA."

CCNP: Consolidated the Professional level (CCNP) certifications to five tracks, including merging CCNP Routing and Switching and CCNP Wireless into CCNP Enterprise.

CCIE: Achieved better alignment with CCNP tracks through the consolidations.

Cisco needed to move many of the individual exam topics from one exam to another because of the number of changes. For instance, Cisco retired nine CCNA certifications plus the CCDA (Design Associate) certification—but those technologies didn't disappear! Cisco just moved the topics around to different exams in different certifications.

Consider wireless LANs as an example. The 2019 announcements retired both CCNA Wireless and CCNP Wireless as certifications. Some of the old CCNA Wireless topics landed in the new CCNA, while others landed in the two CCNP Enterprise exams about wireless LANs.

For those of you who want to learn more about the transition, check out my blog (blog.certskills.com) and look for posts in the News category from around June 2019. Now on to the details about CCNA as it exists starting in 2019!

How to Get Your CCNA Certification

As you saw in Figure I-2, all career certification paths now begin with CCNA. So how do you get it? 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 (vue.com). The process works something like this:

1. Establish a login at https://home.pearsonvue.com/ (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.
4. You will receive a notice of your score, and whether you passed, before you leave the testing center.

Types of Questions on CCNA 200-301 Exam

The Cisco CCNA and CCNP exams all follow the same general format, with these types of questions:

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

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

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

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

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

Before taking the test, learn the exam user interface by watching some videos Cisco provides about the exam user interface. To find the videos, just go to cisco.com and search for "Cisco Certification Exam Tutorial Videos."

CCNA 200-301 Exam Content, Per Cisco

Ever since I was in grade school, whenever the teacher announced that we were having a test soon, someone would always ask, "What's on the test?" We all want to know, and we all want to study what matters and avoid studying what doesn't matter.

Cisco tells the world the topics on each of its exams. Cisco wants the public to know the variety of topics and get an idea about the kinds of knowledge and skills required for each topic for every Cisco certification exam. To find the details, go to www.cisco.com/go/certifications, look for the CCNA page, and navigate until you see the exam topics.

This book also lists those same exam topics in several places. From one perspective, every chapter sets about to explain a small set of exam topics, so each chapter begins with the list of exam topics covered in that chapter. However, you might want to also see the exam topics in one place, so Appendix R, "Exam Topics Cross Reference," lists all the exam topics. You may want to download Appendix R in PDF form and keep it handy. The appendix lists the exam topics with two different cross references:

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

Exam Topic Verbs and Depth

Reading and understanding the exam topics, especially deciding the depth of skills required for each exam topic, require some thought. Each exam topic mentions the name of some technology, but it also lists a verb that implies the depth to which you must master the topic. The primary exam topics each list one or more verbs that describe the skill level required. For example, consider the following exam topic:

Configure and **verify** IPv4 addressing and subnetting

Note that this one exam topic has two verbs (*configure* and *verify*). Per this exam topic, you should be able to not only configure IPv4 addresses and subnets, but you should understand them well enough to verify that the configuration works. In contrast, the following exam topic asks you to describe a technology but does not ask you to configure it:

Describe the purpose of first hop redundancy protocol

The *describe* verb tells you to be ready to describe whatever a "first hop redundancy protocol" is. That exam topic also implies that you do not then need to be ready to configure or verify any first hop redundancy protocols (HSRP, VRRP, and GLBP).

Finally, note that the configure and verify exam topics imply that you should be able to describe and explain and otherwise master the concepts so that you understand what you have configured. The earlier "Configure and verify IPv4 addressing and subnetting" does not mean that you should know how to type commands but have no clue as to what you configured. You must first master the conceptual exam topic verbs. The progression runs something like this:

Describe, Identify, Explain, Compare/Contrast, Configure, Verify, Troubleshoot

For instance, an exam topic that lists "compare and contrast" means that you should be able to describe, identify, and explain the technology. Also, an exam topic with "configure and verify" tells you to also be ready to describe, explain, and compare/contrast.

The Context Surrounding the Exam Topics

Take a moment to navigate to www.cisco.com/go/certifications and find the list of exam topics for the CCNA 200-301 exam. Did your eyes go straight to the list of exam topics? Or did you take the time to read the paragraphs above the exam topics first?

That list of exam topics for the CCNA 200-301 exam includes a little over 50 primary exam topics and about 50 more secondary exam topics. The primary topics have those verbs as just discussed, which tell you something about the depth of skill required. The secondary topics list only the names of more technologies to know.

However, the top of the web page that lists the exam topics also lists some important information that tells us some important facts about the exam topics. In particular, that leading text, found at the beginning of Cisco exam topic pages of most every exam, tells us

- The guidelines may change over time.
- The exam topics are general guidelines about what may be on the exam.
- The actual exam may include "other related topics."

Interpreting these three facts in order, I would not expect to see a change to the published list of exam topics for the exam. I've been writing the Cisco Press CCNA Cert Guides since Cisco announced CCNA back in 1998, and I've never seen Cisco change the official exam topics in the middle of an exam—not even to fix typos. But the introductory words say that they might change the exam topics, so it's worth checking.

As for the second item in the preceding list, even before you know what the acronyms mean, you can see that the exam topics give you a general but not detailed idea about each topic. The exam topics do not attempt to clarify every nook and cranny or to list every command and parameter; however, this book serves as a great tool in that it acts as a much more detailed interpretation of the exam topics. We examine every exam topic, and if we think a concept or command is possibly within an exam topic, we put it into the book. So, the exam topics give us general guidance, and these books give us much more detailed guidance.

The third item in the list uses literal wording that runs something like this: "However, other related topics may also appear on any specific delivery of the exam." That one statement can be a bit jarring to test takers, but what does it really mean? Unpacking the statement, it says that such questions may appear on any one exam but may not; in other words, they don't set about to ask every test taker some questions that include concepts not mentioned in the exam topics. Second, the phrase "…other **related** topics…" emphasizes that any such questions would be related to some exam topic, rather than being far afield—a fact that helps us in how we respond to this particular program policy.

For instance, the CCNA 200-301 exam includes configuring and verifying the OSPF routing protocol, but it does not mention the EIGRP routing protocol. I personally would be unsurprised to see an OSPF question that required a term or fact not specifically mentioned in the exam topics. I would be surprised to see one that (in my opinion) ventures far away from the OSPF features in the exam topics. Also, I would not expect to see a question about how to configure and verify EIGRP.

And just as one final side point, note that Cisco does on occasion ask a test taker some unscored questions, and those may appear to be in this vein of questions from outside topics. When you sit down to take the exam, the small print mentions that you may see unscored questions and you won't know which ones are unscored. (These questions give Cisco a way to test possible new questions.) But some of these might be ones that fall into the "other related topics" category, but then not affect your score.

You should prepare a little differently for any Cisco exam, in comparison to say an exam back in school, in light of Cisco's "other related questions" policy:

- Do not approach an exam topic with an "I'll learn the core concepts and ignore the edges" approach.
- Instead, approach each exam topic with a "pick up all the points I can" approach by mastering each exam topic, both in breadth and in depth.
- Go beyond each exam topic when practicing configuration and verification by taking a little extra time to look for additional show commands and configuration options, and make sure you understand as much of the show command output that you can.

By mastering the known topics, and looking for places to go a little deeper, you will hopefully pick up the most points you can from questions about the exam topics. Then the extra practice you do with commands may happen to help you learn beyond the exam topics in a way that can help you pick up other points as well.

CCNA 200-301 Exam Content, Per This Book

When we created the Official Cert Guide content for the CCNA 200-301 exam, we considered a few options for how to package the content, and we landed on releasing a two-book set. Figure I-3 shows the setup of the content, with roughly 60 percent of the content in Volume 1 and the rest in Volume 2.

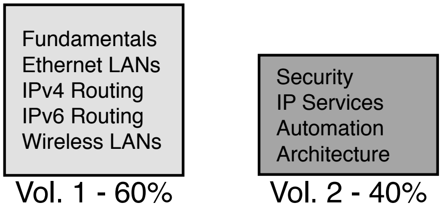


Figure I-3 *Two Books for CCNA 200-301*

The two books together cover all the exam topics in the CCNA 200-301 exam. Each chapter in each book develops the concepts and commands related to an exam topic, with clear and detailed explanations, frequent figures, and many examples that build your understanding of how Cisco networks work.

As for choosing what content to put into the books, note that we begin and finish with Cisco's exam topics, but with an eye toward predicting as many of the "other related topics" as we can. We start with the list of exam topics and apply a fair amount of experience, discussion, and other secret sauce to come up with an interpretation of what specific concepts and commands are worthy of being in the books or not. At the end of the writing process, the books should cover all the published exam topics, with additional depth and breadth that I choose based on the analysis of the exam. As we have done from the very first edition of the *CCNA Official Cert Guide*, we intend to cover each and every topic in depth. But as you would expect, we cannot predict every single fact on the exam given the nature of the exam policies, but we do our best to cover all known topics.

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.

Chapter Features and How to Use Each Chapter

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

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

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

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

Figure I-4 shows how each chapter uses these three key elements. You start with the DIKTA quiz. You can use the score to determine whether you already know a lot, or not so much, and determine how to approach reading the Foundation Topics (that is, the technology content in the chapter). When finished, use the Chapter Review tasks to start working on mastering your memory of the facts and skills with configuration, verification, and troubleshooting.

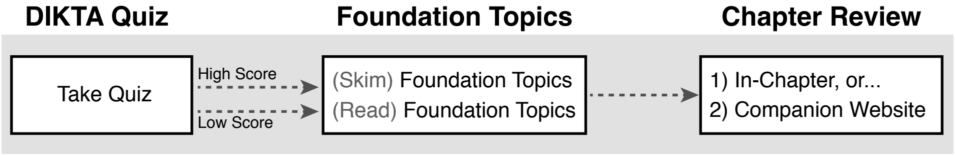


Figure I-4 *Three Primary Tasks for a First Pass Through Each Chapter*

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

- **Review Key Topics:** Inside the "Foundation Topics" section, the Key Topic icon appears next to the most important items, for the purpose of later review and mastery. While all content matters, some is, of course, more important to learn, or needs more review to master, so these items are noted as key topics. The Chapter Review lists the key topics in a table; scan the chapter for these items to review them. Or review the key topics interactively using the companion website.
- **Complete Tables from Memory:** Instead of just rereading an important table of information, you will find some tables have been turned into memory tables, an interactive exercise found on 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:** You do not need to be able to write a formal definition of all terms from scratch; however, you do need to understand each term well enough to understand exam questions and answers. The Chapter Review lists the key terminology from the chapter. Make sure you have a good understanding of each term and use the Glossary to cross-check your own mental definitions. You can also review key terms with the "Key Terms Flashcards" app on the companion website.
- **Labs:** Many exam topics use verbs such as *configure* and *verify*; all these refer to skills you should practice at the user interface (CLI) of a router or switch. The Chapter and Part Reviews refer you to these other tools. The upcoming section titled "About Building Hands-On Skills" discusses your options.
- **Command References:** Some book chapters cover a large number of router and switch commands. The Chapter Review includes reference tables for the commands used in that chapter, along with an explanation. Use these tables for reference, but also use them for study. Just cover one column of the table, and see how much you can remember and complete mentally.
- **Review DIKTA Questions:** Although you have already seen the DIKTA questions from the chapters, re-answering those questions can prove a useful way to review facts. The Part Review suggests that you repeat the DIKTA questions but using the Pearson Test Prep (PTP) exam.
- **Subnetting Exercises:** Chapters 12, 13, 14, 22, and 24 ask you to perform some math processes related to either IPv4 or IPv6 addressing. The Chapter Review asks you to do additional practice problems. The problems can be found in Appendices D through H, in PDF form, on the companion website. The website also includes interactive versions of most of the exercises from those appendices.

Part Features and How to Use the Part Review

The book organizes the chapters into parts for the purpose of helping you study for the exam. Each part groups a small number of related chapters together. Then the study process (described just before Chapter 1) suggests that you pause after each part to do a review of all chapters in the part. Figure I-5 lists the titles of the eight parts and the chapters in those parts (by chapter number) for this book.

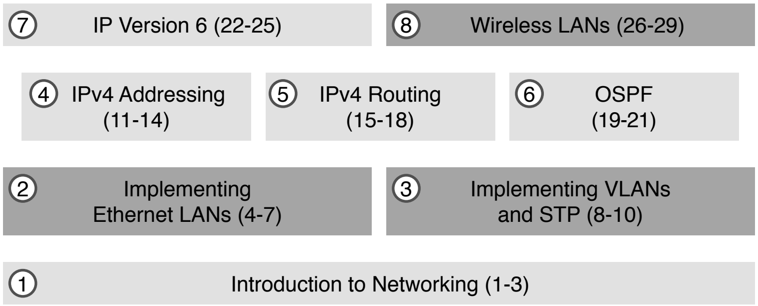

7 IP Version 6 (22-25)
8 Wireless LANs (26-29)
4 IPv4 Addressing (11-14)
5 IPv4 Routing (15-18)
6 OSPF (19-21)
2 Implementing Ethernet LANs (4-7)
3 Implementing VLANs and STP (8-10)
1 Introduction to Networking (1-3)

Figure I-5 *The Book Parts (by Title), and Chapter Numbers in Each Part*

The Part Review that ends each part acts as a tool to help you with spaced review sessions. Spaced reviews—that is, reviewing content several times over the course of your study—help improve retention. The Part Review activities include many of the same kinds of activities seen in the Chapter Review. Avoid skipping the Part Review, and take the time to do the review; it will help you in the long run.

The Companion Website for Online Content Review

We created an electronic version of every Chapter and Part Review task that could be improved though an interactive version of the 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 our testing software. As another example, when you want to review the key topics from a chapter, you can find all those in electronic form as well.

All the electronic review elements, as well as other electronic components of the book, exist on this book’s companion website. 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.
- **Untethered from the book:** You can access your review activities from anywhere—no need to have the book with you.
- **Good for tactile learners:** Sometimes looking at a static page after reading a chapter lets your mind wander. Tactile learners might do better by at least typing answers into an app, or clicking inside an app to navigate, to help keep you focused on the activity.

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 versions of the review elements also tend to do more of the Chapter and Part Review work. 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	Table with list; flip pages to find	Key Topics Table app
Config Checklist	Just one of many types of key topics	Config Checklist app
Key Terms	Listed in each "Chapter Review" section, with the Glossary in the back of the book	Glossary Flash Cards app
Subnetting Practice	Appendixes D–H, with practice problems and answers	A variety of apps, one per problem type

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

- Pearson Sim Lite Desktop App
- Pearson Test Prep (PT) Desktop App
- Pearson Test Prep (PT) Web App
- Videos as mentioned in book chapters

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: 9780135792735. 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:

- **Print book:** Look in the cardboard sleeve in the back of the book for a piece of paper with your book's unique PTP code.
- **Premium Edition:** 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 www.ciscopress.com, click **account** to see details of your account, and click the **digital purchases** tab.
- **Amazon Kindle:** For those who purchase a Kindle edition from Amazon, the access code will be supplied directly from Amazon.
- **Other Bookseller E-books:** Note that if you purchase an e-book version from any other source, the practice test is not included because other vendors to date have not chosen to vend the required unique access code.

NOTE Do not lose the activation code because it is the only means with which you can access the QA content with the book.

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 was 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 both for installing the desktop app and for using the web app.

Note that if you want to use the web app only at this point, just navigate to www.pearsontestprep.com, establish a free login if you do not already have one, and register this book's practice tests using the registration code you just found. The process should take only a couple of minutes.

NOTE Amazon eBook (Kindle) customers: It is easy to miss Amazon's email that lists your PTP access code. Soon after you purchase the Kindle eBook, Amazon should send an email. However, the email uses very generic text, and makes no specific mention of PTP or practice exams. To find your code, read every email from Amazon after you purchase the book. Also do the usual checks for ensuring your email arrives like checking your spam folder.

NOTE Other eBook customers: As of the time of publication, only the publisher and Amazon supply PTP access codes when you purchase their eBook editions of this book.

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 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).

- **E-book:** Pearson offers an e-book version of this book that includes extra practice tests. If interested, look for the special offer on a coupon card inserted in the sleeve in the back of the book. This offer enables you to purchase the *CCNA 200-301 Official Cert Guide, Volume 1, Premium Edition eBook and Practice Test* at a 70 percent discount off the list price. The product includes three versions of the e-book, PDF (for reading on your computer), EPUB (for reading on your tablet, mobile device, or Nook or other e-reader), and Mobi (the native Kindle version). It also includes additional practice test questions and enhanced practice test features.

- **Subnetting videos:** The companion website contains a series of videos that show you how to calculate various facts about IP addressing and subnetting (in particular, using the shortcuts described in this book).

- **Mentoring videos:** The companion website also includes a number of videos about other topics as mentioned in individual chapters.

- **Subnetting practice apps:** The companion website contains appendixes with a set of subnetting practice problems and answers. This is a great resource to practice building subnetting skills. You can also do these same practice problems with applications from the "Chapter and Part Review" section of the companion website.

- **CCNA 200-301 Network Simulator Lite:** This lite version of the best-selling CCNA Network Simulator from Pearson provides you with a means, right now, to experience the Cisco command-line interface (CLI). No need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the companion website.

- **CCNA Simulator:** If you are looking for more hands-on practice, you might want to consider purchasing the CCNA Network Simulator. You can purchase a copy of this software from Pearson at http://pearsonitcertification.com/networksimulator or other retail outlets. To help you with your studies, Pearson has created a mapping guide that maps each of the labs in the simulator to the specific sections in each volume of the CCNA Cert Guide. You can get this mapping guide free on the Extras tab on the book product page: www.ciscopress.com/title/9780135792735.

- **PearsonITCertification.com:** The website www.pearsonitcertification.com is a great resource for all things IT-certification related. Check out the great CCNA articles, videos, blogs, and other certification preparation tools from the industry's best authors and trainers.

- **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 blog.certskills.com.

Book Organization, Chapters, and Appendixes

This book contains 29 core chapters, with each chapter covering a subset of the topics on the CCNA exam. The book organizes the chapters into parts of three to five chapters. The core chapters cover the following topics:

- **Part I: Introduction to Networking**
  - **Chapter 1, "Introduction to TCP/IP Networking,"** introduces the central ideas and terms used by TCP/IP, and contrasts the TCP/IP networking model with the OSI model.
  - **Chapter 2, "Fundamentals of Ethernet LANs,"** introduces the concepts and terms used when building Ethernet LANs.
  - **Chapter 3, "Fundamentals of WANs and IP Routing,"** covers the basics of the data-link layer for WANs in the context of IP routing but emphasizes the main network layer protocol for TCP/IP. This chapter introduces the basics of IPv4, including IPv4 addressing and routing.
- **Part II: Implementing Ethernet LANs**
  - **Chapter 4, "Using the Command-Line Interface,"** explains how to access the text-based user interface of Cisco Catalyst LAN switches.
  - **Chapter 5, "Analyzing Ethernet LAN Switching,"** shows how to use the Cisco CLI to verify the current status of an Ethernet LAN and how it switches Ethernet frames.
  - **Chapter 6, "Configuring Basic Switch Management,"** explains how to configure Cisco switches for basic management features, such as remote access using Telnet and SSH.
  - **Chapter 7, "Configuring and Verifying Switch Interfaces,"** shows how to configure a variety of switch features that apply to interfaces, including duplex/speed.
- **Part III: Implementing VLANs and STP**
  - **Chapter 8, "Implementing Ethernet Virtual LANs,"** explains the concepts and configuration surrounding virtual LANs, including VLAN trunking.
  - **Chapter 9, "Spanning Tree Protocol Concepts,"** discusses the concepts behind IEEE Spanning Tree Protocol (STP), including Rapid STP (RSTP) and how they make some switch interfaces block frames to prevent frames from looping continuously around a redundant switched LAN.
  - **Chapter 10, "RSTP and EtherChannel Configuration,"** shows how to configure and verify RSTP and Layer 2 EtherChannels on Cisco switches.

- **Part IV: IPv4 Addressing**
  - **Chapter 11, "Perspectives on IPv4 Subnetting,"** walks you through the entire concept of subnetting, from starting with a Class A, B, or C network to a completed subnetting design as implemented in an enterprise IPv4 network.
  - **Chapter 12, "Analyzing Classful IPv4 Networks,"** explains how IPv4 addresses originally fell into several classes, with unicast IP addresses being in Class A, B, and C. This chapter explores all things related to address classes and the IP network concept created by those classes.
  - **Chapter 13, "Analyzing Subnet Masks,"** shows how an engineer can analyze the key facts about a subnetting design based on the subnet mask. This chapter shows how to look at the mask and IP network to determine the size of each subnet and the number of subnets.
  - **Chapter 14, "Analyzing Existing Subnets,"** describes how most troubleshooting of IP connectivity problems starts with an IP address and mask. This chapter shows how to take those two facts and find key facts about the IP subnet in which that host resides.
- **Part V: IPv4 Routing**
  - **Chapter 15, "Operating Cisco Routers,"** is like Chapter 8, focusing on basic device management, but it focuses on routers instead of switches.
  - **Chapter 16, "Configuring IPv4 Addressing and Static Routes,"** discusses how to add IPv4 address configuration to router interfaces and how to configure static IPv4 routes.
  - **Chapter 17, "IP Routing in the LAN,"** shows how to configure and troubleshoot different methods of routing between VLANs, including Router-on-a-Stick (ROAS), Layer 3 switching with SVIs, Layer 3 switching with routed ports, and using Layer 3 EtherChannels.
  - **Chapter 18, "Troubleshooting IPv4 Routing,"** focuses on how to use two key troubleshooting tools to find routing problems: the **ping** and **traceroute** commands.
- **Part VI: OSPF**
  - **Chapter 19, "Understanding OSPF Concepts,"** introduces the fundamental operation of the Open Shortest Path First (OSPF) protocol, focusing on link state fundamentals, neighbor relationships, flooding link state data, and calculating routes based on the lowest cost metric.
  - **Chapter 20, "Implementing OSPF,"** takes the concepts discussed in the previous chapter and shows how to configure and verify those same features.
  - **Chapter 21, "OSPF Network Types and Neighbors,"** takes the next steps in OSPF configuration and verification by looking in more depth at the concepts of how routers enable OSPF on interfaces, and the conditions that must be true before two routers will succeed in becoming OSPF neighbors.
- **Part VII: IP Version 6**
  - **Chapter 22, "Fundamentals of IP Version 6,"** discusses the most basic concepts of IP version 6, focusing on the rules for writing and interpreting IPv6 addresses.

- **Chapter 23, “IPv6 Addressing and Subnetting,”** works through the two branches of unicast IPv6 addresses—global unicast addresses and unique local addresses—that act somewhat like IPv4 public and private addresses, respectively.
- **Chapter 24, “Implementing IPv6 Addressing on Routers,”** shows how to configure IPv6 routing and addresses on routers, while discussing a variety of special IPv6 addresses.
- **Chapter 25, “Implementing IPv6 Routing,”** shows how to add static routes to an IPv6 router’s routing table.

- **Part VIII: Wireless LANs**
  - **Chapter 26, “Fundamentals of Wireless Networks,”** introduces the foundational concepts of wireless 802.11 LANs, including wireless topologies and basic wireless radio communications protocols.
  - **Chapter 27, “Analyzing Cisco Wireless Architectures,”** turns your attention to the questions related to systematic and architectural issues surrounding how to build wireless LANs and explains the primary options available for use.
  - **Chapter 28, “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 29, “Building a Wireless LAN,”** shows how to configure and secure a wireless LAN using a Wireless LAN Controller (WLC).
- **Part IX: 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, “CCNA 200-301, Volume 1 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.
  - **Appendix C, “Answers to the ‘Do I Know This Already?’ Quizzes,”** includes the explanations to all the “Do I Know This Already” quizzes.
  - The **Glossary** contains definitions for all the terms listed in the “Key Terms You Should Know” sections at the conclusion of the chapters.
- **Part X: Online Appendixes**
- **Practice Appendixes**

The following appendixes are available in digital format from the companion website. These appendixes provide additional practice for several networking processes that use some math.

- **Appendix D, “Practice for Chapter 12: Analyzing Classful IPv4 Networks”**
- **Appendix E, “Practice for Chapter 13: Analyzing Subnet Masks”**
- **Appendix F, “Practice for Chapter 14: Analyzing Existing Subnets”**
- **Appendix G, “Practice for Chapter 22: Fundamentals of IP Version 6”**

- **Appendix H, "Practice for Chapter 24: Implementing IPv6 Addressing on Routers"**
- **Content from Previous Editions**

Although the publisher restarts numbering at edition "1" each time, the name of the related exam changes in a significant way. In function, this book is in effect part of the 9th edition of the CCNA Cert Guide materials from Cisco Press. From edition to edition, some readers over the years have asked that we keep some select chapters with the book. Keeping content that Cisco removed from the exam, but that may still be useful, can help the average reader as well as instructors who use the materials to teach courses with this book. The following appendices hold this edition's content from previous editions:

- **Appendix J, "Topics from Previous Editions,"** is a collection of small topics from prior editions. None of the topics justify a complete appendix by themselves, so we collect the small topics into this single appendix.
- **Appendix K, "Analyzing Ethernet LAN Designs,"** examines various ways to design Ethernet LANs, discussing the pros and cons, and explains common design terminology.
- **Appendix L, "Subnet Design,"** takes a design approach to subnetting. This appendix begins with a classful IPv4 network and asks why a particular mask might be chosen, and if chosen, what subnet IDs exist.
- **Appendix M, "Practice for Appendix L: Subnet Design"**
- **Appendix N, "Variable-Length Subnet Masks,"** moves away from the assumption of one subnet mask per network to multiple subnet masks per network, which makes subnetting math and processes much more challenging. This appendix explains those challenges.
- **Appendix O, "Spanning Tree Protocol Implementation,"** shows how to configure and verify STP on Cisco switches.
- **Appendix P, "LAN Troubleshooting,"** examines the most common LAN switching issues and how to discover those issues when troubleshooting a network. The appendix includes troubleshooting topics for STP/RSTP, Layer 2 EtherChannel, LAN switching, VLANs, and VLAN trunking.
- **Appendix Q, "Troubleshooting IPv4 Routing Protocols,"** walks through the most common problems with IPv4 routing protocols, while alternating between OSPF examples and EIGRP examples.
- **Miscellaneous Appendixes**
    - **Appendix I, "Study Planner,"** is a spreadsheet with major study milestones, where you can track your progress through your study.
    - **Appendix R, "Exam Topics Cross Reference,"** provides some tables to help you find where each exam objective is covered in the book.

About Building Hands-On Skills

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

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

Config Lab Exercises

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

Each Config Lab lists details about a straightforward lab exercise for which you should create a small set of configuration commands for a few devices. Each lab presents a sample lab topology, with some requirements, and you have to decide what to configure on each device. The answer then shows a sample configuration. Your job is to create the configuration and then check your answer versus the supplied answer.

Config Lab content resides outside the book at the author's blog site (blog.certskills.com). You can navigate to the Config Lab in a couple of ways from the site, or just go directly to https://blog.certskills.com/category/hands-on/config-lab/ to reach a list of all Config Labs. Figure I-6 shows the logo that you will see with each Config Lab.

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

These Config Labs have several benefits, including the following:

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

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

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

Blog format: The format allows easy adds and changes by me and easy comments by you.

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

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

A Quick Start with Pearson Network Simulator Lite

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

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

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

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

The Pearson Network Simulator

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

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

Of course, you need to make a decision for yourself and consider all the options. Thankfully, you can get a great idea of how the full Simulator product works by using the Pearson Network Simulator Lite product included with the book. Both have the same base code, same user interface, and same types of labs. Try the Lite version to decide if you want to buy the full product.

Note that the Simulator and the books work on a different release schedule. For a time in 2019 (and probably into 2020), the Simulator will be the one created for the previous versions of the exams (ICND1 100-101, ICND2 200-101, and CCNA 200-120).

Interestingly, Cisco did not add a large number of new topics that require CLI skills to the CCNA 200-301 exam as compared with its predecessor, so the old Simulator covers most of the CLI topics. So, during the interim before the products based on the 200-301 exam come out, the old Simulator products should be quite useful.

On a practical note, when you want to do labs when reading a chapter or doing Part Review, the Simulator organizes the labs to match the book. Just look for the Sort by Chapter tab in the Simulator's user interface. However, during the months in 2019 for which the Simulator is the older edition listing the older exams in the title, you will need to refer to a PDF that lists those labs versus this book's organization. You can find that PDF on the book product page under the Downloads tab here: www.ciscopress.com/title/9780135792735.

More Lab Options

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

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

Cisco also makes a simulator that works very well as a learning tool: Cisco Packet Tracer. Cisco now makes Packet Tracer available for free. However, unlike the Pearson Network Simulator, it does not include lab exercises that direct you as to how to go about learning each topic. If interested in more information about Packet Tracer, check out my series about using Packet Tracer at my blog (blog.certskills.com); just search for "Packet Tracer."

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

You can even rent virtual Cisco router and switch lab pods from Cisco, in an offering called Cisco Learning Labs (https://learningnetworkstore.cisco.com/cisco-learning-labs).

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

For More Information

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

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

The *CCNA 200-301 Official Cert Guide, Volume 1*, 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.

CHAPTER 17

IP Routing in the LAN

This chapter covers the following exam topics:

1.0 Network Fundamentals

1.6 Configure and verify IPv4 addressing and subnetting

2.0 Network Access

2.4 Configure and verify (Layer 2/Layer 3) EtherChannel (LACP)

The preceding two chapters showed how to configure an IP address and mask on a router interface, making the router ready to route packets to/from the subnet implied by that address/mask combination. While true and useful, all the examples so far ignored the LAN switches and the possibility of VLANs. In fact, the examples so far show the simplest possible cases: the attached switches as Layer 2 switches, using only one VLAN, with the router configured with one **ip address** command on its physical interface. This chapter takes a detailed look at how to configure routers so that they route packets to/from the subnets that exist on each and every VLAN.

Because Layer 2 switches do not forward Layer 2 frames between VLANs, a network must use routers to route IP packets between subnets to allow those devices in different VLANs/subnets to communicate. To review, Ethernet defines the concept of a VLAN, while IP defines the concept of an IP subnet, so a VLAN is not equivalent to a subnet. However, the set of devices in one VLAN are typically also in one subnet. By the same reasoning, devices in two different VLANs are normally in two different subnets. For two devices in different VLANs to communicate with each other, routers must connect to the subnets that exist on each VLAN, and then the routers forward IP packets between the devices in those subnets.

This chapter discusses the configuration and verification steps related to three methods of routing between VLANs with three major sections:

- **VLAN Routing with Router 802.1Q Trunks:** The first section discusses how to configure a router to use VLAN trunking as connected to a Layer 2 switch. The router does the routing, with the switch creating the VLANs. The link between the router and switch use trunking so that the router has an interface connected to each VLAN/subnet. This feature is known as routing over a VLAN trunk and also known as router-on-a-stick (ROAS).
- **VLAN Routing with Layer 3 Switch SVIs:** The second section discusses using a LAN switch that supports both Layer 2 switching and Layer 3 routing (called a Layer 3 switch or multilayer switch). To route, the Layer 3 switch configuration uses interfaces called switched virtual interfaces (SVI), which are also called VLAN interfaces.
- **VLAN Routing with Layer 3 Switch Routed Ports:** The third major section of the chapter discusses an alternative to SVIs called routed ports, in which the physical switch ports are made to act like interfaces on a router. This third section also introduces the concept of an EtherChannel as used as a routed port in a feature called Layer 3 EtherChannel.

"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 17-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
VLAN Routing with Router 802.1Q Trunks	1, 2
VLAN Routing with Layer 3 Switch SVIs	3, 4
VLAN Routing with Layer 3 Switch Routed Ports	5, 6

1. Router 1 has a Fast Ethernet interface 0/0 with IP address 10.1.1.1. The interface is connected to a switch. This connection is then migrated to use 802.1Q trunking. Which of the following commands could be part of a valid configuration for Router 1's Fa0/0 interface? (Choose two answers.)

   a. **interface fastethernet 0/0.4**

   b. **dot1q enable**

   c. **dot1q enable 4**

   d. **trunking enable**

   e. **trunking enable 4**

   f. **encapsulation dot1q 4**

2. Router R1 has a router-on-a-stick (ROAS) configuration with two subinterfaces of interface G0/1: G0/1.1 and G0/1.2. Physical interface G0/1 is currently in a down/down state. The network engineer then configures a **shutdown** command when in interface configuration mode for G0/1.1 and a **no shutdown** command when in interface configuration mode for G0/1.2. Which answers are correct about the interface state for the subinterfaces? (Choose two answers.)

   a. G0/1.1 will be in a down/down state.

   b. G0/1.2 will be in a down/down state.

   c. G0/1.1 will be in an administratively down state.

   d. G0/1.2 will be in an up/up state.

3. A Layer 3 switch has been configured to route IP packets between VLANs 1, 2, and 3 using SVIs, which connect to subnets 172.20.1.0/25, 172.20.2.0/25, and 172.20.3.0/25, respectively. The engineer issues a **show ip route connected** command on the Layer 3 switch, listing the connected routes. Which of the following answers lists a piece of information that should be in at least one of the routes?

- **a.** Interface Gigabit Ethernet 0/0.3
- **b.** Next-hop router 172.20.2.1
- **c.** Interface VLAN 2
- **d.** Mask 255.255.255.0

4. An engineer has successfully configured a Layer 3 switch with SVIs for VLANs 2 and 3. Hosts in the subnets using VLANs 2 and 3 can ping each other with the Layer 3 switch routing the packets. The next week, the network engineer receives a call that those same users can no longer ping each other. If the problem is with the Layer 3 switching function, which of the following could have caused the problem? (Choose two answers.)

- **a.** Six (or more) out of 10 working VLAN 2 access ports failing due to physical problems
- **b.** A **shutdown** command issued from interface VLAN 4 configuration mode
- **c.** VTP on the switch removing VLAN 3 from the switch's VLAN list
- **d.** A **shutdown** command issued from VLAN 2 configuration mode

5. A LAN design uses a Layer 3 EtherChannel between two switches SW1 and SW2, with port-channel interface 1 used on both switches. SW1 uses ports G0/1, G0/2, and G0/3 in the channel. Which of the following are true about SW1's configuration to make the channel be able to route IPv4 packets correctly? (Choose two answers.)

- **a.** The **ip address** command must be on the port-channel 1 interface.
- **b.** The **ip address** command must be on interface G0/1 (lowest numbered port).
- **c.** The port-channel 1 interface must be configured with the **no switchport** command.
- **d.** Interface G0/1 must be configured with the **routedport** command.

6. A LAN design uses a Layer 3 EtherChannel between two switches SW1 and SW2, with port-channel interface 1 used on both switches. SW1 uses ports G0/1 and G0/2 in the channel. However, only interface G0/1 is bundled into the channel and working. Think about the configuration settings on port G0/2 that could have existed before adding G0/2 to the EtherChannel. Which answers identify a setting that could prevent IOS from adding G0/2 to the Layer 3 EtherChannel? (Choose two answers.)

- **a.** A different STP cost (**spanning-tree cost** *value*)
- **b.** A different speed (**speed** *value*)
- **c.** A default setting for switchport (**switchport**)
- **d.** A different access VLAN (**switchport access vlan** *vlan-id*)

Foundation Topics

VLAN Routing with Router 802.1Q Trunks

Almost all enterprise networks use VLANs. To route IP packets in and out of those VLANs, some devices (either routers or Layer 3 switches) need to have an IP address in each subnet and have a connected route to each of those subnets. Then the IP addresses on those routers or Layer 3 switches can serve as the default gateways in those subnets.

This chapter breaks down the LAN routing options into four categories:

- Use a router, with one router LAN interface and cable connected to the switch for each and every VLAN (typically not used)
- Use a router, with a VLAN trunk connecting to a LAN switch (known as router-on-a-stick, or ROAS)
- Use a Layer 3 switch with switched virtual interfaces (SVI)
- Use a Layer 3 switch with routed interfaces (which may or may not be Layer 3 EtherChannels)

Of the items in the list, the first option works, but to be practical, it requires far too many interfaces. It is mentioned here only to make the list complete.

As for the other three options, this chapter discusses each in turn as the main focus of one of the three major sections in this chapter. Each feature is used in real networks today, with the choice to use one or the other driven by the design and needs for a particular part of the network. Figure 17-1 shows cases in which these options could be used.

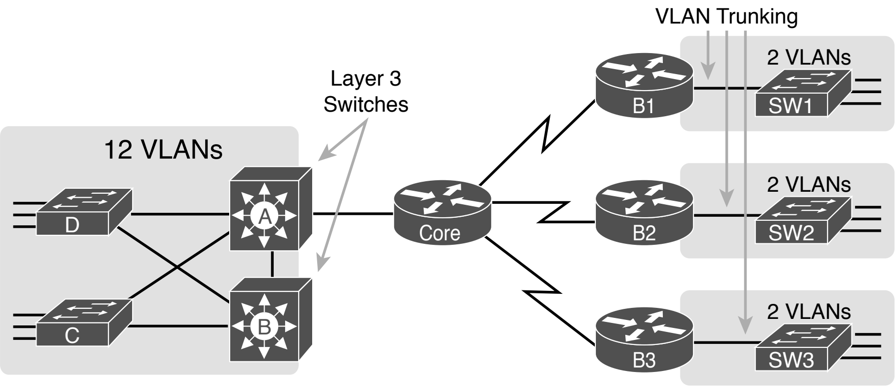


Figure 17-1 *Layer 3 Switching at the Central Site*

Figure 17-1 shows two switches, labeled A and B, which could act as Layer 3 switches—both with SVIs and routed interfaces. The figure shows a central site campus LAN on the left, with 12 VLANs. Switches A and B act as Layer 3 switches, combining the functions of a router and a switch, routing between all 12 subnets/VLANs, as well as routing to/from the Core router. Those Layer 3 switches could use SVIs, routed interfaces, or both.

Figure 17-1 also shows a classic case for using a router with a VLAN trunk. Sites like the remote sites on the right side of the figure may have a WAN-connected router and a LAN switch. These sites might use ROAS to take advantage of the router's ability to route over an 802.1Q trunk.

Note that Figure 17-1 just shows an example. The engineer could use Layer 3 switching at each site or routers with VLAN trunking at each site.

Configuring ROAS

This next topic discusses how routers route packets to subnets associated with VLANs connected to a router 802.1Q trunk. That long description can be a bit of a chore to repeat each time someone wants to discuss this feature, so over time, the networking world has instead settled on a shorter and more interesting name for this feature: router-on-a-stick (ROAS).

ROAS uses router VLAN trunking configuration to give the router a logical router interface connected to each VLAN. Because the router then has an interface connected to each VLAN, the router can also be configured with an IP address in the subnet that exists on each VLAN.

Routers use subinterfaces as the means to have an interface connected to a VLAN. The router needs to have an IP address/mask associated with each VLAN on the trunk. However, the router has only one physical interface for the link connected to the trunk. Cisco solves this problem by creating multiple virtual router interfaces, one associated with each VLAN on that trunk (at least for each VLAN that you want the trunk to support). Cisco calls these virtual interfaces *subinterfaces*. The configuration can then include an **ip address** command for each subinterface.

Figure 17-2 shows the concept with Router B1, one of the branch routers from Figure 17-1. Because this router needs to route between only two VLANs, the figure also shows two subinterfaces, named G0/0.10 and G0/0.20, which create a new place in the configuration where the per-VLAN configuration settings can be made. The router treats frames tagged with VLAN 10 as if they came in or out of G0/0.10 and frames tagged with VLAN 20 as if they came in or out G0/0.20.

Key Topic

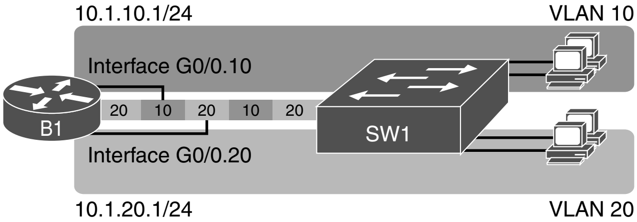


Figure 17-2 *Subinterfaces on Router B1*

In addition, note that most Cisco routers do not attempt to negotiate trunking, so both the router and switch need to manually configure trunking. This chapter discusses the router side of that trunking configuration; the matching switch interface would need to be configured with the **switchport mode trunk** command.

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

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

Example 17-1 shows a full example of the 802.1Q trunking configuration required on Router B1 in Figure 17-2. More generally, these steps detail how to configure 802.1Q trunking on a router:

Config Checklist

Step 1. Use the **interface** *type number.subint* command in global configuration mode to create a unique subinterface for each VLAN that needs to be routed.

Step 2. Use the **encapsulation dot1q** *vlan_id* command in subinterface configuration mode to enable 802.1Q and associate one specific VLAN with the subinterface.

Step 3. Use the **ip address** *address mask* command in subinterface configuration mode to configure IP settings (address and mask).

Example 17-1 *Router Configuration for the 802.1Q Encapsulation Shown in Figure 17-2*

```
B1# show running-config
! Only pertinent lines shown
interface gigabitethernet 0/0
! No IP address up here! No encapsulation up here!
!
interface gigabitethernet 0/0.10
 encapsulation dot1q 10
 ip address 10.1.10.1 255.255.255.0
!
interface gigabitethernet 0/0.20
 encapsulation dot1q 20
 ip address 10.1.20.1 255.255.255.0
```

First, look at the subinterface numbers. The subinterface number begins with the period, like .10 and .20 in this case. These numbers can be any number from 1 up through a very large number (over 4 billion). The number just needs to be unique among all subinterfaces associated with this one physical interface. In fact, the subinterface number does not even have to match the associated VLAN ID. (The **encapsulation** command, and not the subinterface number, defines the VLAN ID associated with the subinterface.)

NOTE Although not required, most sites do choose to make the subinterface number match the VLAN ID, as shown in Example 17-1, just to avoid confusion.

Each subinterface configuration lists two subcommands. One command (**encapsulation**) enables trunking and defines the VLAN whose frames are considered to be coming in and out of the subinterface. The **ip address** command works the same way it does on any other interface. Note that if the physical Ethernet interface reaches an up/up state, the subinterface should as well, which would then let the router add the connected routes shown at the bottom of the example.

Now that the router has a working interface, with IPv4 addresses configured, the router can route IPv4 packets on these subinterfaces. That is, the router treats these subinterfaces like any physical interface in terms of adding connected routes, matching those routes, and forwarding packets to/from those connected subnets.

The configuration and use of the native VLAN on the trunk require a little extra thought. The native VLAN can be configured on a subinterface, or on the physical interface, or ignored as in Example 17-1. Each 802.1Q trunk has one native VLAN, and if the router needs to route packets for a subnet that exists in the native VLAN, then the router needs some configuration to support that subnet. The two options to define a router interface for the native VLAN are

- Configure the **ip address** command on the physical interface, but without an **encapsulation** command; the router considers this physical interface to be using the native VLAN.
- Configure the **ip address** command on a subinterface and use the **encapsulation dot1q** *vlan-id* **native** subcommand to tell the router both the VLAN ID and the fact that it is the native VLAN.

Example 17-2 shows both native VLAN configuration options with a small change to the same configuration in Example 17-1. In this case, VLAN 10 becomes the native VLAN. The top part of the example shows the option to configure the router physical interface to use native VLAN 10. The second half of the example shows how to configure that same native VLAN on a subinterface. In both cases, the switch configuration also needs to be changed to make VLAN 10 the native VLAN.

Example 17-2 *Router Configuration Using Native VLAN 10 on Router B1*

```
! First option: put the native VLAN IP address on the physical interface
interface gigabitethernet 0/0
 ip address 10.1.10.1 255.255.255.0
!
interface gigabitethernet 0/0.20
 encapsulation dot1q 20
 ip address 10.1.20.1 255.255.255.0
```

```
! Second option: like Example 17-1, but add the native keyword
interface gigabitethernet 0/0.10
 encapsulation dot1q 10 native
 ip address 10.1.10.1 255.255.255.0
!
interface gigabitethernet 0/0.20
 encapsulation dot1q 20
 ip address 10.1.20.1 255.255.255.0
```

Verifying ROAS

Beyond using the **show running-config** command, ROAS configuration on a router can be best verified with two commands: **show ip route** [**connected**] and **show vlans**. As with any router interface, as long as the interface is in an up/up state and has an IPv4 address configured, IOS will put a connected (and local) route in the IPv4 routing table. So, a first and obvious check would be to see if all the expected connected routes exist. Example 17-3 lists the connected routes per the configuration shown in Example 17-1.

Example 17-3 *Connected Routes Based on Example 17-1 Configuration*

```
B1# show ip route connected
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
! Legend omitted for brevity

      10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C        10.1.10.0/24 is directly connected, GigabitEthernet0/0.10
L        10.1.10.1/32 is directly connected, GigabitEthernet0/0.10
C        10.1.20.0/24 is directly connected, GigabitEthernet0/0.20
L        10.1.20.1/32 is directly connected, GigabitEthernet0/0.20
```

As for interface and subinterface state, note that the ROAS subinterface state does depend to some degree on the physical interface state. In particular, the subinterface state cannot be better than the state of the matching physical interface. For instance, on Router B1 in the examples so far, physical interface G0/0 is in an up/up state, and the subinterfaces are in an up/up state. But if you unplugged the cable from that port, the physical port would fail to a down/down state, and the subinterfaces would also fail to a down/down state. Example 17-4 shows another example, with the physical interface being shut down, with the subinterfaces then automatically changed to an administratively down state as a result.

Example 17-4 *Subinterface State Tied to Physical Interface State*

```
B1# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
B1(config)# interface g0/0
B1(config-if)# shutdown
B1(config-if)# ^Z
B1# show ip interface brief | include 0/0
GigabitEthernet0/0         unassigned      YES manual administratively down down
GigabitEthernet0/0.10      10.1.10.1       YES manual administratively down down
GigabitEthernet0/0.20      10.1.20.1       YES manual administratively down down
```

Additionally, the subinterface state can also be enabled and disabled independently from the physical interface, using the **no shutdown** and **shutdown** commands in subinterface configuration mode.

Another useful ROAS verification command, **show vlans**, spells out which router trunk interfaces use which VLANs, which VLAN is the native VLAN, plus some packet statistics. The fact that the packet counters are increasing can be useful when verifying whether traffic is happening or not. Example 17-5 shows a sample, based on the Router B1 configuration in Example 17-2 (bottom half), in which native VLAN 10 is configured on subinterface G0/0.10. Note that the output identifies VLAN 1 associated with the physical interface, VLAN 10 as the native VLAN associated with G0/0.10, and VLAN 20 associated with G0/0.20. It also lists the IP addresses assigned to each interface/subinterface.

Example 17-5 *Sample* **show vlans** *Command to Match Sample Router Trunking Configuration*

```
R1# show vlans
Virtual LAN ID: 1 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface: GigabitEthernet0/0

   Protocols Configured:  Address:        Received:    Transmitted:
        Other                                    0              83

   69 packets, 20914 bytes input
   147 packets, 11841 bytes output

Virtual LAN ID:   10 (IEEE 802.1Q Encapsulation)

    vLAN Trunk Interface:   GigabitEthernet0/0.10

 This is configured as native Vlan for the following interface(s) :
GigabitEthernet0/0      Native-vlan Tx-type: Untagged

      Protocols Configured:   Address:     Received:    Transmitted:
              IP              10.1.10.1           2               3
           Other                                  0               1

   3 packets, 722 bytes input
   4 packets, 264 bytes output

Virtual LAN ID:   20 (IEEE 802.1Q Encapsulation)

    vLAN Trunk Interface:   GigabitEthernet0/0.20

    Protocols Configured:  Address:        Received:  Transmitted:
            IP             10.1.20.1              0          134
         Other                                    0             1

    0 packets, 0 bytes input
    135 packets, 10498 bytes output
```

Troubleshooting ROAS

The biggest challenge when troubleshooting ROAS has to do with the fact that if you misconfigure only the router or misconfigure only the switch, the other device on the trunk has no way to know that the other side is misconfigured. That is, if you check the **show ip route** and **show vlans** commands on a router, and the output looks like it matches the intended configuration, and the connected routes for the correct subinterfaces show up, routing may still fail because of problems on the attached switch. So, troubleshooting ROAS often begins with checking the configuration on both the router and switch because there is no status output on either device that tells you where the problem might be.

First, to check ROAS on the router, you need to start with the intended configuration and ask questions about the configuration:

Key Topic

1. Is each non-native VLAN configured on the router with an **encapsulation dot1q** *vlan-id* command on a subinterface?
2. Do those same VLANs exist on the trunk on the neighboring switch (**show interfaces trunk**), and are they in the allowed list, not VTP pruned, and not STP blocked?
3. Does each router ROAS subinterface have an IP address/mask configured per the planned configuration?
4. If using the native VLAN, is it configured correctly on the router either on a subinterface (with an **encapsulation dot1q** *vlan-id* **native** command) or implied on the physical interface?
5. Is the same native VLAN configured on the neighboring switch's trunk in comparison to the native VLAN configured on the router?
6. Are the router physical or ROAS subinterfaces configured with a **shutdown** command?

For some of these steps, you need to be ready to investigate possible VLAN trunking issues on the LAN switch. The reason is that on many Cisco routers, router interfaces do not negotiate trunking. As a result, ROAS relies on static trunk configuration on both the router and switch. If the switch has any problems with VLANs or the VLAN trunking configuration on its side of the trunk, the router has no way to realize that the problem exists.

For example, imagine you configured ROAS on a router just like in Example 17-1 or Example 17-2. However, the switch on the other end of the link had no matching configuration. For instance, maybe the switch did not even define VLANs 10 and 20. Maybe the switch did not configure trunking on the port connected to the router. Even with blatant misconfiguration or missing configuration on the switch, the router still shows up/up ROAS interfaces and subinterfaces, IP routes in the output of **show ip route**, and meaningful configuration information in the output of the **show vlans** command.

VLAN Routing with Layer 3 Switch SVIs

Using a router with ROAS to route packets makes sense in some cases, particularly at small remote sites. In sites with a larger LAN, network designers choose to use Layer 3 switches for most inter-VLAN routing.

A Layer 3 switch (also called a multilayer switch) is one device, but it executes logic at two layers: Layer 2 LAN switching and Layer 3 IP routing. The Layer 2 switch function forwards frames inside each VLAN, but it will not forward frames between VLANs. The Layer 3 forwarding (routing) logic forwards IP packets between VLANs.

Layer 3 switches typically support two configuration options to enable IPv4 routing inside the switch, specifically to enable IPv4 on switch interfaces. This section explains one option, an option that uses switched virtual interfaces (SVI). The final major section of the chapter deals with the other option for configuring IPv4 addresses on Layer 3 switches: routed interfaces.

Configuring Routing Using Switch SVIs

The configuration of a Layer 3 switch mostly looks like the Layer 2 switching configuration shown back in Parts II and III of this book, with a small bit of configuration added for the Layer 3 functions. The Layer 3 switching function needs a virtual interface connected to each VLAN internal to the switch. These *VLAN interfaces* act like router interfaces, with an IP address and mask. The Layer 3 switch has an IP routing table, with connected routes off each of these VLAN interfaces. (These interfaces are also referred to as *switched virtual interfaces* [SVI].)

To show the concept of Layer 3 switching with SVIs, the following example uses the same branch office with two VLANs shown in the earlier examples, but now the design will use Layer 3 switching in the LAN switch. Figure 17-3 shows the design changes and configuration concept for the Layer 3 switch function with a router icon inside the switch, to emphasize that the switch routes the packets.

Key Topic

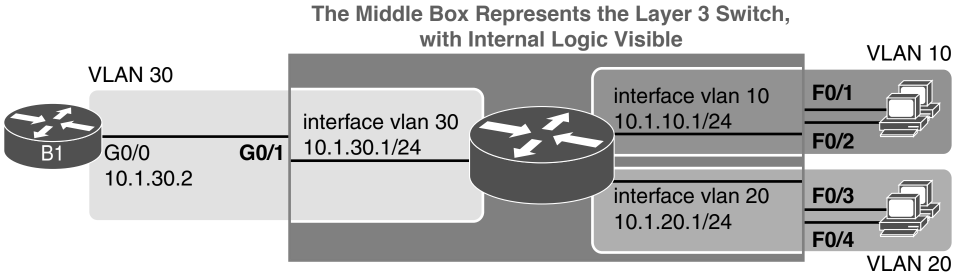


Figure 17-3 *Routing on VLAN Interfaces in a Layer 3 Switch*

Note that the figure represents the internals of the Layer 3 switch within the box in the middle of the figure. The branch still has two user VLANs (10 and 20), so the Layer 3 switch needs one VLAN interface for each VLAN. The figure shows a router icon inside the gray box to represent the Layer 3 switching function, with two VLAN interfaces on the right side of that icon. In addition, the traffic still needs to get to router B1 (a physical router) to access the WAN, so the switch uses a third VLAN (VLAN 30 in this case) for the link to Router B1. The physical link between the Layer 3 switch and router B1 would not be a trunk, but instead be an access link.

The following steps show how to configure Layer 3 switching using SVIs. Note that on some switches, like the 2960 and 2960-XR switches used for the examples in this book, the ability to route IPv4 packets must be enabled first, with a **reload** of the switch required to enable the feature. The steps that occur after the reload would apply to all models of Cisco switches that are capable of doing Layer 3 switching.

Config Checklist

Step 1. Enable IP routing on the switch, as needed:

A. Use the **sdm prefer lanbase-routing** command (or similar) in global configuration mode to change the switch forwarding ASIC settings to make space for IPv4 routes at the next reload of the switch.

B. Use the **reload** EXEC command in enable mode to reload (reboot) the switch to pick up the new **sdm prefer** command setting.

C. Once reloaded, use the **ip routing** command in global configuration mode to enable the IPv4 routing function in IOS software and to enable key commands like **show ip route.**

Step 2. Configure each SVI interface, one per VLAN for which routing should be done by this Layer 3 switch:

A. Use the **interface vlan** *vlan_id* command in global configuration mode to create a VLAN interface and to give the switch's routing logic a Layer 3 interface connected into the VLAN of the same number.

B. Use the **ip address** *address mask* command in VLAN interface configuration mode to configure an IP address and mask on the VLAN interface, enabling IPv4 routing on that VLAN interface.

C. (As needed) Use the **no shutdown** command in interface configuration mode to enable the VLAN interface (if it is currently in a shutdown state).

Example 17-6 shows the configuration to match Figure 17-3. In this case, switch SW1 has already used the **sdm prefer** global command to change to a setting that supports IPv4 routing, and the switch has been reloaded. The example shows the related configuration on all three VLAN interfaces.

Example 17-6 *VLAN Interface Configuration for Layer 3 Switching*

```
ip routing
!
interface vlan 10
 ip address 10.1.10.1 255.255.255.0
!
interface vlan 20
 ip address 10.1.20.1 255.255.255.0
!
interface vlan 30
 ip address 10.1.30.1 255.255.255.0
```

Verifying Routing with SVIs

With the VLAN configuration shown in the previous section, the switch is ready to route packets between the VLANs as shown in Figure 17-3. To support the routing of packets, the switch adds connected IP routes as shown in Example 17-7; note that each route is listed as being connected to a different VLAN interface.

Example 17-7 *Connected Routes on a Layer 3 Switch*

```
SW1# show ip route
! legend omitted for brevity

       10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C         10.1.10.0/24 is directly connected, Vlan10
L         10.1.10.1/32 is directly connected, Vlan10
C         10.1.20.0/24 is directly connected, Vlan20
L         10.1.20.1/32 is directly connected, Vlan20
C         10.1.30.0/24 is directly connected, Vlan30
L         10.1.30.1/32 is directly connected, Vlan30
```

The switch would also need additional routes to the rest of the network (not shown in the figures in this chapter). The Layer 3 switch could use static routes or a routing protocol, depending on the capabilities of the switch. For instance, if you then enabled OSPF on the Layer 3 switch, the configuration and verification would work the same as it does on a router, as discussed in Chapter 20, “Implementing OSPF.” The routes that IOS adds to the Layer 3 switch’s IP routing table would list the VLAN interfaces as outgoing interfaces.

NOTE Some models of Cisco enterprise switches, based on model, IOS version, and IOS feature set, support different capabilities for IP routing and routing protocols, so for real networks, check the capabilities of the switch model by browsing at Cisco.com. In particular, check the Cisco Feature Navigator (CFN) tool at http://www.cisco.com/go/cfn.

Troubleshooting Routing with SVIs

There are two big topics to investigate when troubleshooting routing over LANs with SVIs. First, you have to make sure the switch has been enabled to support IP routing. Second, the VLAN associated with each VLAN interface must be known and active on the local switch; otherwise, the VLAN interfaces do not come up.

First, about enabling IP routing, note that some models of Cisco switches default to enable Layer 3 switching, and some do not. So, to make sure your switch supports Layer 3 routing, look to those first few configuration commands listed in the configuration checklist found in the earlier section “Configuring Routing Using Switch SVIs.” Those commands are **sdm prefer** (followed by a **reload**) and then **ip routing** (after the **reload**).

The **sdm prefer** command changes how the switch forwarding chips allocate memory for different forwarding tables, and changes to those tables require a reload of the switch. By default, many access switches that support Layer 3 switching still have an SDM default that does not allocate space for an IP routing table. Once changed and reloaded, the **ip routing** command then enables IPv4 routing in IOS software. Both are necessary before some Cisco switches will act as a Layer 3 switch.

Example 17-8 shows some symptoms on a router for which Layer 3 switching had not yet been enabled by the **sdm prefer** command. As you can see, both the **show ip route** EXEC command and the **ip routing** config command are rejected because they do not exist to IOS until the **sdm prefer** command has been used (followed by a **reload** of the switch).

Example 17-8 *Evidence That a Switch Has Not Yet Enabled IPv4 Routing*

```
SW1# show ip route
             ^
% Invalid input detected at '^' marker.


SW3# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
SW3(config)# ip routing
                ^
% Invalid input detected at '^' marker.
```

The second big area to investigate when troubleshooting SVIs relates to the SVI state, a state that ties to the state of the associated VLANs. Each VLAN interface has a matching VLAN of the same number, and the VLAN interface's state is tied to the state of the VLAN in certain ways. In particular, for a VLAN interface to be in an up/up state:

Key Topic

Step 1. The VLAN must be defined on the local switch (either explicitly or learned with VTP).

Step 2. The switch must have at least one up/up interface using the VLAN, either/both:

- **A.** An up/up access interface assigned to that VLAN
- **B.** A trunk interface for which the VLAN is in the allowed list, is STP forwarding, and is not VTP pruned

Step 3. The VLAN (not the VLAN interface) must be administratively enabled (that is, not **shutdown**).

Step 4. The VLAN interface (not the VLAN) must be administratively enabled (that is, not **shutdown**).

When working through the steps in the list, keep in mind that the VLAN and the VLAN interface are related but separate ideas, and the configuration items are separate in the CLI. The VLAN interface is a switch's Layer 3 interface connected to the VLAN. If you want to route packets for the subnets on VLANs 11, 12, and 13, the matching VLAN interfaces must be numbered 11, 12, and 13. And both the VLANs and the VLAN interfaces can be disabled and enabled with the **shutdown** and **no shutdown** commands (as mentioned in Steps 3 and 4 in the previous list), so you have to check for both.

Example 17-9 shows three scenarios, each of which leads to one of the VLAN interfaces in the previous configuration example (Figure 17-3, Example 17-6) to fail. At the beginning of the example, all three VLAN interfaces are up/up. VLANs 10, 20, and 30 each have at least one access interface up and working. The example works through three scenarios:

- **Scenario 1:** The last access interface in VLAN 10 is shut down (F0/1), so IOS shuts down the VLAN 10 interface.
- **Scenario 2:** VLAN 20 (not VLAN interface 20, but VLAN 20) is deleted, which results in IOS then bringing down (not shutting down) the VLAN 20 interface.
- **Scenario 3:** VLAN 30 (not VLAN interface 30, but VLAN 30) is shut down, which results in IOS then bringing down (not shutting down) the VLAN 30 interface.

Example 17-9 *Three Examples That Cause VLAN Interfaces to Fail*

```
SW1# show interfaces status
! Only ports related to the example are shown
Port      Name               Status       Vlan       Duplex  Speed Type
Fa0/1                        connected    10         a-full  a-100 10/100BaseTX
Fa0/2                        notconnect   10           auto   auto 10/100BaseTX
Fa0/3                        connected    20         a-full  a-100 10/100BaseTX
Fa0/4                        connected    20         a-full  a-100 10/100BaseTX
Gi0/1                        connected    30         a-full a-1000 10/100/1000BaseTX
```

```
SW1# configure terminal
Enter configuration commands, one per line. End with CNTL/Z.

! Case 1: Interface F0/1, the last up/up access interface in VLAN 10, is shutdown
SW1(config)# interface fastEthernet 0/1
SW1(config-if)# shutdown
SW1(config-if)#
*Apr 2 19:54:08.784: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan10, changed
state to down
SW1(config-if)#
*Apr 2 19:54:10.772: %LINK-5-CHANGED: Interface FastEthernet0/1, changed state to
administratively down
*Apr 2 19:54:11.779: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/1,
changed state to down

! Case 2: VLAN 20 is deleted
SW1(config)# no vlan 20
SW1(config)#
*Apr 2 19:54:39.688: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan20, changed
state to down

! Case 3: VLAN 30, the VLAN from the switch to the router, is shutdown
SW1(config)# vlan 30
SW1(config-vlan)# shutdown
SW1(config-vlan)# exit
SW1(config)#
*Apr 2 19:55:25.204: %LINEPROTO-5-UPDOWN: Line protocol on Interface Vlan30, changed
state to down

! Final status of all three VLAN interfaces are below
SW1# show ip interface brief | include Vlan
Vlan1                  unassigned      YES manual administratively down down
Vlan10                 10.1.10.1       YES manual up                    down
Vlan20                 10.1.20.1       YES manual up                    down
Vlan30                 10.1.30.1       YES manual up                    down
```

Note that the example ends with the three VLAN interfaces in an up/down state per the **show ip interface brief** command.

VLAN Routing with Layer 3 Switch Routed Ports

When Layer 3 switches use SVIs, the physical interfaces on the switches act like they always have: as Layer 2 interfaces. That is, the physical interfaces receive Ethernet frames. The switch learns the source MAC address of the frame, and the switch forwards the frame based on the destination MAC address. To perform routing, any Ethernet frames destined for any of the SVI interface MAC addresses trigger the processing of the Layer 2 switching logic, resulting in normal routing actions like stripping data-link headers, making a routing decision, and so on.

Alternately, the Layer 3 switch configuration can make a physical port act like a router interface instead of a switch interface. To do so, the switch configuration makes that port a routed port. On a *routed* port, the switch does not perform Layer 2 switching logic on that frame. Instead, frames arriving in a routed port trigger the Layer 3 routing logic, including

1. Stripping off the incoming frame's Ethernet data-link header/trailer
2. Making a Layer 3 forwarding decision by comparing the destination IP address to the IP routing table
3. Adding a new Ethernet data-link header/trailer to the packet
4. Forwarding the packet, encapsulated in a new frame

This third major section of the chapter examines routed interfaces as configured on Cisco Layer 3 switches, but with a particular goal in mind: to also discuss Layer 3 EtherChannels. The exam topics do not mention routed interfaces specifically, but the exam topics do mention L3 EtherChannels, meaning Layer 3 EtherChannels.

You might recall that Chapter 10, "RSTP and EtherChannel Configuration," discussed Layer 2 EtherChannels. Like Layer 2 EtherChannels, Layer 3 EtherChannels also treat multiple links as one link. Unlike Layer 2 EtherChannels, however, Layer 3 EtherChannels treat the channel as a *routed* port instead of *switched* port. So this section first looks at routed ports on Cisco Layer 3 switches and then discusses Layer 3 EtherChannels.

Implementing Routed Interfaces on Switches

When a Layer 3 switch needs a Layer 3 interface connected to a subnet, and only one physical interface connects to that subnet, the network engineer can choose to use a routed port instead of an SVI. Conversely, when the Layer 3 switch needs a Layer 3 interface connected to a subnet, and many physical interfaces on the switch connect to that subnet, an SVI needs to be used. (SVIs forward traffic internally into the VLAN, so that then the Layer 2 logic can forward the frame out any of the ports in the VLAN. Routed ports cannot.)

To see why, consider the design in Figure 17-4, which repeats the same design from Figure 17-3 (used in the SVI examples). In that design, the gray rectangle on the right represents the switch and its internals. On the right of the switch, at least two access ports sit in both VLAN 10 and VLAN 20. However, that figure shows a single link from the switch to Router B1. The switch could configure the port as an access port in a separate VLAN, as shown with VLAN 30 in Examples 17-6 and 17-7. However, with only one switch port needed, the switch could configure that link as a routed port, as shown in the figure.

Key Topic

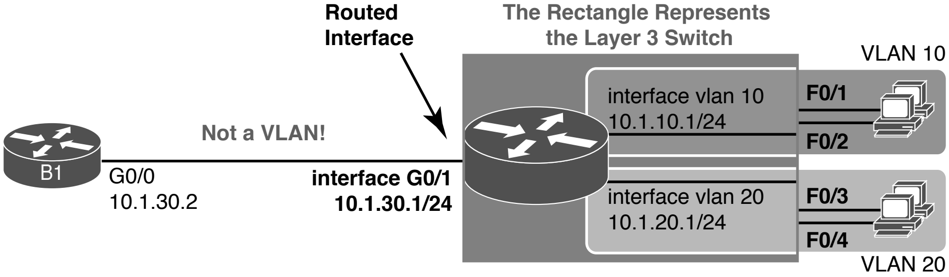


Figure 17-4 *Routing on a Routed Interface on a Switch*

Enabling a switch interface to be a routed interface instead of a switched interface is simple: just use the **no switchport** subcommand on the physical interface. Cisco switches capable of being a Layer 3 switch use a default of the **switchport** command to each switch physical interface. Think about the word *switchport* for a moment. With that term, Cisco tells the switch to treat the port like it is a port on a switch—that is, a Layer 2 port on a switch. To make the port stop acting like a switch port and instead act like a router port, use the **no switchport** command on the interface.

Once the port is acting as a routed port, think of it like a router interface. That is, configure the IP address on the physical port, as implied in Figure 17-4. Example 17-10 shows a completed configuration for the interfaces configured on the switch in Figure 17-4. Note that the design uses the exact same IP subnets as the example that showed SVI configuration in Example 17-6, but now, the port connected to subnet 10.1.30.0 has been converted to a routed port. All you have to do is add the **no switchport** command to the physical interface and configure the IP address on the physical interface.

Example 17-10 *Configuring Interface G0/1 on Switch SW1 as a Routed Port*

```
ip routing
!
interface vlan 10
 ip address 10.1.10.1 255.255.255.0
!
interface vlan 20
 ip address 10.1.20.1 255.255.255.0
!
interface gigabitethernet 0/1
 no switchport
 ip address 10.1.30.1 255.255.255.0
```

Once configured, the routed interface will show up differently in command output in the switch. In particular, for an interface configured as a routed port with an IP address, like interface GigabitEthernet0/1 in the previous example:

Key Topic

- **show interfaces:** Similar to the same command on a router, the output will display the IP address of the interface. (Conversely, for switch ports, this command does not list an IP address.)
- **show interfaces status:** Under the "VLAN" heading, instead of listing the access VLAN or the word *trunk*, the output lists the word *routed*, meaning that it is a routed port.
- **show ip route:** Lists the routed port as an outgoing interface in routes.
- **show interfaces** *type number* **switchport:** If a routed port, the output is short and confirms that the port is not a switch port. (If the port is a Layer 2 port, this command lists many configuration and status details.)

Example 17-11 shows samples of all four of these commands as taken from the switch as configured in Example 17-10.

Example 17-11 *Verification Commands for Routed Ports on Switches*

```
SW11# show interfaces g0/1
GigabitEthernet0/1 is up, line protocol is up (connected)
 Hardware is Gigabit Ethernet, address is bcc4.938b.e541 (bia bcc4.938b.e541)
 Internet address is 10.1.30.1/24
! lines omitted for brevity

SW1# show interfaces status
! Only ports related to the example are shown; the command lists physical only
Port      Name               Status       Vlan       Duplex  Speed Type
Fa0/1                        connected    10         a-full  a-100 10/100BaseTX
Fa0/2                        notconnect   10           auto   auto 10/100BaseTX
Fa0/3                        connected    20         a-full  a-100 10/100BaseTX
Fa0/4                        connected    20         a-full  a-100 10/100BaseTX
Gi0/1                        connected    routed     a-full a-1000 10/100/1000BaseTX

SW1# show ip route
! legend omitted for brevity

       10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C         10.1.10.0/24 is directly connected, Vlan10
L         10.1.10.1/32 is directly connected, Vlan10
C         10.1.20.0/24 is directly connected, Vlan20
L         10.1.20.1/32 is directly connected, Vlan20
C         10.1.30.0/24 is directly connected, GigabitEthernet0/1
L         10.1.30.1/32 is directly connected, GigabitEthernet0/1

SW1# show interfaces g0/1 switchport
Name: Gi0/1
Switchport: Disabled
```

So, with two options—SVI and routed ports—where should you use each?

> For any topologies with a point-to-point link between two devices that do routing, a routed interface works well.

Figure 17-5 shows an example of where to use SVIs and where to use routed ports in a typical core/distribution/access design. In this design, the core (Core1, Core2) and distribution (D11 through D14) switches perform Layer 3 switching. All the ports that are links directly between the Layer 3 switches can be routed interfaces. For VLANs for which many interfaces (access and trunk) connect to the VLAN, SVIs make sense because the SVIs can send and receive traffic out multiple ports on the same switch. In this design, all the ports on Core1 and Core2 will be routed ports, while the four distribution switches will use some routed ports and some SVIs.

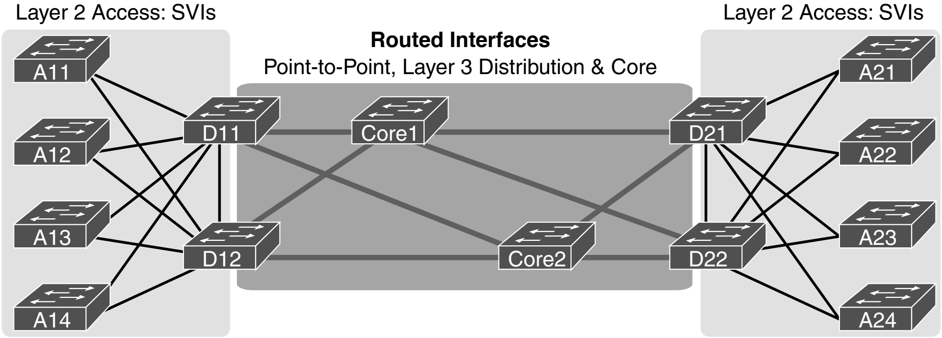


Figure 17-5 *Using Routed Interfaces for Core and Distribution Layer 3 Links*

Implementing Layer 3 EtherChannels

So far, this section has stated that routed interfaces can be used with a single point-to-point link between pairs of Layer 3 switches, or between a Layer 3 switch and a router. However, in most designs, the network engineers use at least two links between each pair of distribution and core switches, as shown in Figure 17-6.

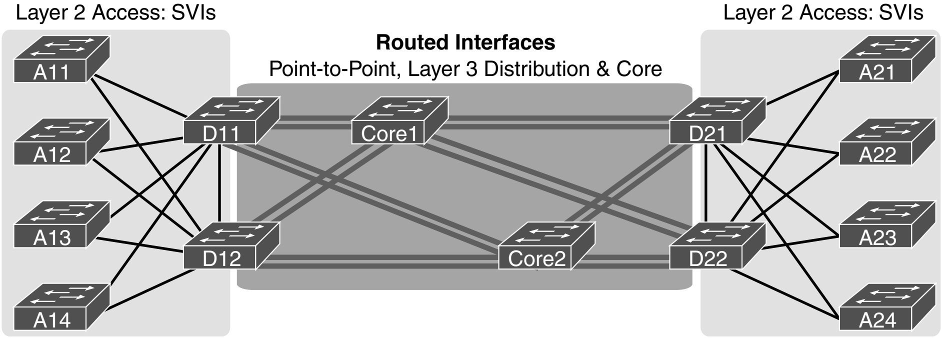


Figure 17-6 *Two Links Between Each Distribution and Core Switch*

While each individual port in the distribution and core could be treated as a separate routed port, it is better to combine each pair of parallel links into a Layer 3 EtherChannel. Without using EtherChannel, you can still make each port on each switch in the center of the figure be a routed port. It works. However, once you enable a routing protocol but don’t use EtherChannels, each Layer 3 switch will now learn two IP routes with the same neighboring switch as the next hop—one route over one link, another route over the other link.

Using a Layer 3 EtherChannel makes more sense with multiple parallel links between two switches. By doing so, each pair of links acts as one Layer 3 link. So, each pair of switches has one routing protocol neighbor relationship with the neighbor, and not two. Each switch learns one route per destination per pair of links, and not two. IOS then balances the traffic, often with better balancing than the balancing that occurs with the use of multiple IP routes to the same subnet. Overall, the Layer 3 EtherChannel approach works much better than leaving each link as a separate routed port and using Layer 3 balancing.

Compared to what you have already learned, configuring a Layer 3 EtherChannel takes only a little more work. Chapter 10 already showed you how to configure an EtherChannel. This chapter has already shown how to make a port a Layer 3 routed port. Next, you have to combine the two ideas by combining both the EtherChannel and routed port configuration. The following checklist shows the steps, assuming a static definition.

Config Checklist

Step 1. Configure the physical interfaces as follows, in interface configuration mode:

A. Add the **channel-group** *number* **mode on** command to add it to the channel. Use the same number for all physical interfaces on the same switch, but the number used (the channel-group number) can differ on the two neighboring switches.

B. Add the **no switchport** command to make each physical port a routed port.

Step 2. Configure the PortChannel interface:

A. Use the **interface port-channel** *number* command to move to port-channel configuration mode for the same channel number configured on the physical interfaces.

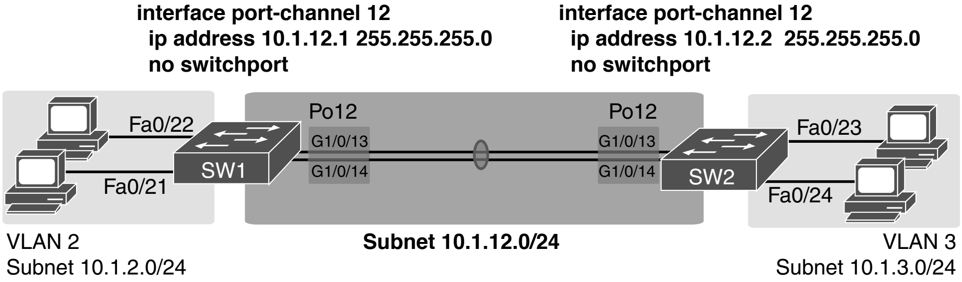
B. Add the **no switchport** command to make sure that the port-channel interface acts as a routed port. (IOS may have already added this command.)

C. Use the **ip address** *address mask* command to configure the address and mask.

NOTE Cisco uses the term *EtherChannel* in concepts discussed in this section and then uses the term *PortChannel*, with command keyword **port-channel**, when verifying and configuring EtherChannels. For the purposes of understanding the technology, you may treat these terms as synonyms. However, it helps to pay close attention to the use of the terms *PortChannel* and *EtherChannel* as you work through the examples in this section because IOS uses both.

Example 17-12 shows an example of the configuration for a Layer 3 EtherChannel for switch SW1 in Figure 17-7. The EtherChannel defines port-channel interface 12 and uses subnet 10.1.12.0/24.

Key Topic



```
interface port-channel 12
 ip address 10.1.12.1 255.255.255.0
 no switchport
```

```
interface port-channel 12
 ip address 10.1.12.2  255.255.255.0
 no switchport
```

Figure 17-7 *Design Used in EtherChannel Configuration Examples*

Example 17-12 *Layer 3 EtherChannel Configuration on Switch SW1*

```
interface GigabitEthernet1/0/13
 no switchport
 no ip address
 channel-group 12 mode on
!
interface GigabitEthernet1/0/14
 no switchport
 no ip address
 channel-group 12 mode on
!
interface Port-channel12
 no switchport
 ip address 10.1.12.1 255.255.255.0
```

Of particular importance, note that although the physical interfaces and PortChannel interface are all routed ports, the IP address should be placed on the PortChannel interface only. In fact, when the **no switchport** command is configured on an interface, IOS adds the **no ip address** command to the interface. Then configure the IP address on the PortChannel interface only.

Once configured, the PortChannel interface appears in several commands, as shown in Example 17-13. The commands that list IP addresses and routes refer to the PortChannel interface. Also, note that the **show interfaces status** command lists the fact that the physical ports and the port-channel 12 interface are all routed ports.

Example 17-13 *Verification Commands Listing Interface Port-Channel 12 from Switch SW1*

```
SW1# show interfaces port-channel 12
Port-channel12 is up, line protocol is up (connected)
  Hardware is EtherChannel, address is bcc4.938b.e543 (bia bcc4.938b.e543)
  Internet address is 10.1.12.1/24
! lines omitted for brevity

SW1# show interfaces status
! Only ports related to the example are shown.
Port      Name               Status       Vlan       Duplex  Speed Type
Gi1/0/13                     connected    routed     a-full a-1000 10/100/1000BaseTX
Gi1/0/14                     connected    routed     a-full a-1000 10/100/1000BaseTX
Po12                         connected    routed     a-full a-1000

SW1# show ip route
! legend omitted for brevity
       10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C         10.1.2.0/24 is directly connected, Vlan2
L         10.1.2.1/32 is directly connected, Vlan2
C         10.1.12.0/24 is directly connected, Port-channel12
L         10.1.12.1/32 is directly connected, Port-channel12
```

For a final bit of verification, you can examine the EtherChannel directly with the **show etherchannel summary** command as listed in Example 17-14. Note in particular that it lists a flag legend for characters that identify key operational states, such as whether a port is bundled (included) in the PortChannel (P) and whether it is acting as a routed (R) or switched (S) port.

Example 17-14 *Verifying the EtherChannel*

```
SW1# show etherchannel 12 summary
Flags: D - down        P - bundled in port-channel
       I - stand-alone s - suspended
       H - Hot-standby (LACP only)
       R - Layer3      S - Layer2
       U - in use      f - failed to allocate aggregator

       M - not in use, minimum links not met
       u - unsuitable for bundling
       w - waiting to be aggregated
       d - default port



Number of channel-groups in use: 1
Number of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+-----------------------------------------------
12     Po12(RU)         -        Gi1/0/13(P) Gi1/0/14(P)
```

Troubleshooting Layer 3 EtherChannels

When you are troubleshooting a Layer 3 EtherChannel, there are two main areas to consider. First, you need to look at the configuration of the **channel-group** command, which enables an interface for an EtherChannel. Second, you should check a list of settings that must match on the interfaces for a Layer 3 EtherChannel to work correctly.

As for the **channel-group** interface subcommand, this command can enable EtherChannel statically or dynamically. If dynamic, this command's keywords imply either Port Aggregation Protocol (PaGP) or Link Aggregation Control Protocol (LACP) as the protocol to negotiate between the neighboring switches whether they put the link into the EtherChannel.

If all this sounds vaguely familiar, it is the exact same configuration covered way back in the Chapter 10 section "Configuring Dynamic EtherChannels." The configuration of the **channel-group** subcommand is exactly the same, with the same requirements, whether configuring Layer 2 or Layer 3 EtherChannels. So, it might be a good time to review those EtherChannel configuration details from Chapter 10. However, regardless of when you review and master those commands, note that the configuration of the EtherChannel (with the **channel-group** subcommand) is the same, whether Layer 2 or Layer 3.

Additionally, you must do more than just configure the **channel-group** command correctly for all the physical ports to be bundled into the EtherChannel. Layer 2 EtherChannels have a longer list of requirements, but Layer 3 EtherChannels also require a few consistency checks between the ports before they can be added to the EtherChannel. The following is the list of requirements for Layer 3 EtherChannels:

no switchport: The PortChannel interface must be configured with the **no switchport** command, and so must the physical interfaces. If a physical interface is not also configured with the **no switchport** command, it will not become operational in the EtherChannel.

Speed: The physical ports in the channel must use the same speed.

duplex: The physical ports in the channel must use the same duplex.

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 17-2 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 17-2 Chapter Review Tracking

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

Review All the Key Topics

Table 17-3 Key Topics for Chapter 17

Key Topic Element	Description	Page Number
Figure 17-2	Concept of VLAN subinterfaces on a router	396
List	Two alternative methods to configure the native VLAN in a ROAS configuration	398
List	Troubleshooting suggestions for ROAS configuration	401
Figure 17-3	Layer 3 switching with SVIs concept and configuration	402

Key Topic Element	Description	Page Number
List	Troubleshooting suggestions for correct operation of a Layer 3 switch that uses SVIs	405
Figure 17-4	Layer 3 switching with routed ports concept and configuration	407
List	**show** commands that list Layer 3 routed ports in their output	408
Figure 17-7	Layer 3 EtherChannel concept and configuration	411
List	List of configuration settings that must be consistent before IOS will bundle a link with an existing Layer 3 EtherChannel	414

Key Terms You Should Know

router-on-a-stick (ROAS), switched virtual interface (SVI), VLAN interface, Layer 3 EtherChannel (L3 EtherChannel), routed port, Layer 3 switch, multilayer switch, subinterfaces

Command References

Tables 17-4 and 17-5 list configuration and verification commands used in this chapter. As an easy review exercise, cover the left column in a table, read the right column, and try to recall the command without looking. Then repeat the exercise, covering the right column, and try to recall what the command does.

Table 17-4 Chapter 17 Configuration Command Reference

Command	Description
interface *type number.subint*	Router global command to create a subinterface and to enter configuration mode for that subinterface
encapsulation dot1q *vlan-id* [**native**]	Router subinterface subcommand that tells the router to use 802.1Q trunking, for a particular VLAN, and with the **native** keyword, to not encapsulate in a trunking header
[**no**] **ip routing**	Global command that enables (**ip routing**) or disables (**no ip routing**) the routing of IPv4 packets on a router or Layer 3 switch
interface vlan *vlan-id*	A switch global command on a Layer 3 switch to create a VLAN interface and to enter configuration mode for that VLAN interface
sdm prefer lanbase-routing	Command on some Cisco switches that reallocates forwarding chip memory to allow for an IPv4 routing table
[**no**] **switchport**	Layer 3 switch subcommand that makes the port act as a Layer 2 port (**switchport**) or Layer 3 routed port (**no switchport**)

Command	Description
interface port-channel *channel-number*	A switch command to enter PortChannel configuration mode and also to create the PortChannel if not already created
channel-group *channel-number* **mode** {**auto** | **desirable** | **active** | **passive** | **on**}	Interface subcommand that enables EtherChannel on the interface

Table 17-5 Chapter 17 EXEC Command Reference

Command	Description
show ip route	Lists the router's entire routing table
show ip route [**connected**]	Lists a subset of the IP routing table
show vlans	Lists VLAN configuration and statistics for VLAN trunks configured on routers
show interfaces [**interface** *type number*]	Lists detailed status and statistical information, including IP address and mask, about all interfaces (or the listed interface only)
show interfaces [**interface** *type number*] **status**	Among other facts, for switch ports, lists the access VLAN or the fact that the interface is a trunk; or, for routed ports, lists "routed"
show interfaces *interface-id* **switchport**	For switch ports, lists information about any interface regarding administrative settings and operational state; for routed ports, the output simply confirms the port is a routed (not switched) port
show interfaces vlan *number*	Lists the interface status, the switch's IPv4 address and mask, and much more
show etherchannel [*channel-group-number*] **summary**	Lists information about the state of EtherChannels on this switch, including whether the channel is a Layer 2 or Layer 3 EtherChannel

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