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CCNA 200-301

Volume 1

WENDELL ODOM,
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CCNA 200-301, Volume 1
Official Cert Guide

In addition to the wealth of updated content, this new edition includes a series of free hands-on exercises to help you master several real-world configuration and troubleshooting activities. These exercises can be performed on the CCNA 200-301 Network Simulator Lite, Volume 1 software included for free on the companion website that accompanies this book. This software, which simulates the experience of working on actual Cisco routers and switches, contains the following 21 free lab exercises, covering topics in Part II and Part III, the first hands-on configuration sections of the book:

1. Configuring Local Usernames
2. Configuring Hostnames
3. Interface Status I
4. Interface Status II
5. Interface Status III
6. Interface Status IV
7. Configuring Switch IP Settings
8. Switch IP Address
9. Switch IP Connectivity I
10. Switch CLI Configuration Process I
11. Switch CLI Configuration Process II
12. Switch CLI Exec Mode
13. Setting Switch Passwords
14. Interface Settings I
15. Interface Settings II
16. Interface Settings III
17. Switch Forwarding I
18. Switch Security I
19. Switch Interfaces and Forwarding Configuration Scenario
20. Configuring VLANs Configuration Scenario
21. VLAN Troubleshooting

If you are interested in exploring more hands-on labs and practice configuration and troubleshooting with more router and switch commands, go to **www.pearsonitcertification.com/networksimulator** for demos and to review the latest products for sale.

CCNA
200-301

Official Cert Guide, Volume 1

WENDELL ODOM, CCIE No. 1624 Emeritus

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CCNA 200-301 Official Cert Guide, Volume 1

Wendell Odom

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About the Technical Reviewer

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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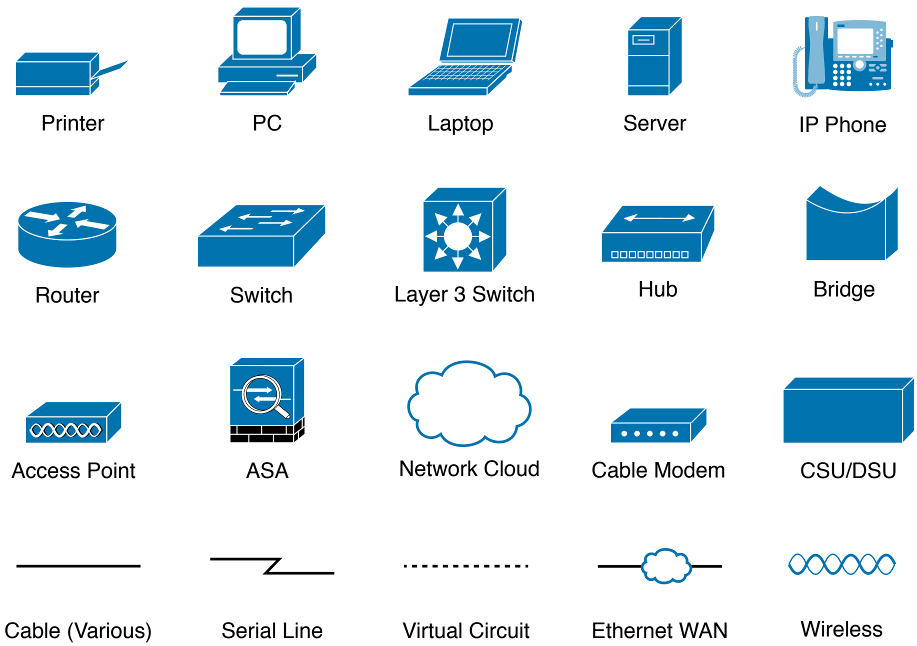

Command Syntax Conventions

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.

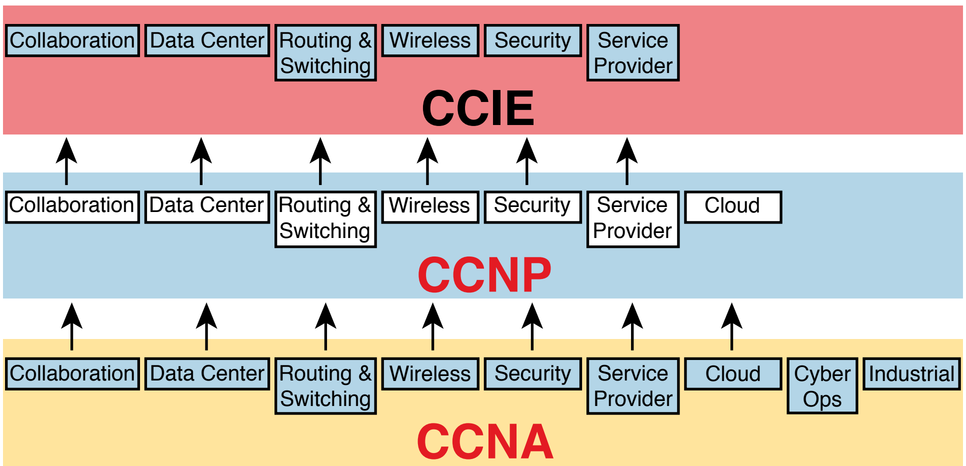

Figure I-1 *Old Cisco Certification Silo Concepts*

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.

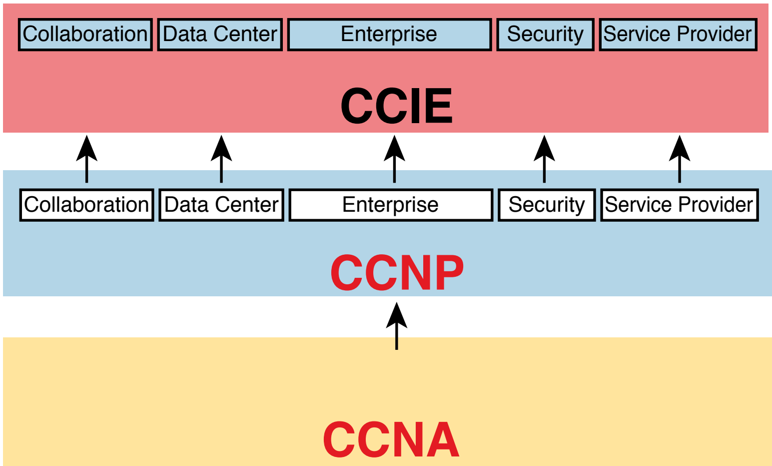

Figure I-2 *New Cisco Certification Tracks and Structure*

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.

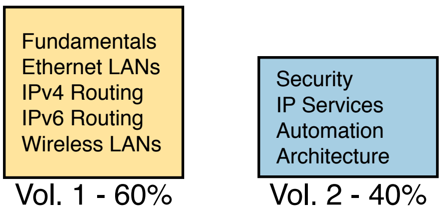

Figure I-3 *Two Books for CCNA 200-301*

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.

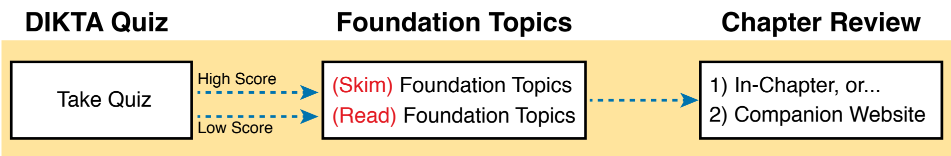

Figure I-4 *Three Primary Tasks for a First Pass Through Each Chapter*

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.

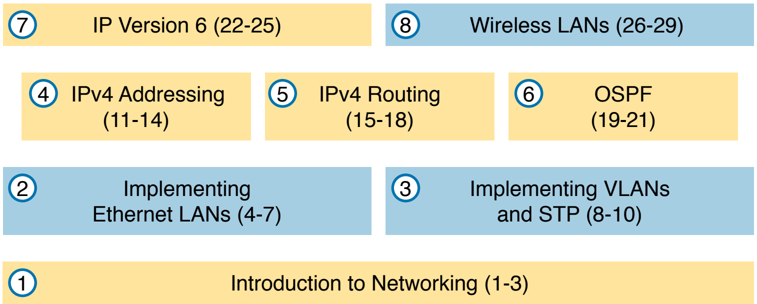

Figure I-5 *The Book Parts (by Title), and Chapter Numbers in Each Part*

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.

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Your Study Plan

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

Stop to read this section about how to create your own study plan for the CCNA 200-301 exam. Your study will go much better if you take time (maybe 15 minutes) to think about a few key points about how to study before starting on this journey. That is what this section will help you do.

A Brief Perspective on Cisco Certification Exams

Cisco sets the bar pretty high for passing the CCNA 200-301 exam. Most anyone can study and pass the exam, but it takes more than just a quick read through the book and the cash to pay for the exam.

The challenge of the exam comes from many angles. First, the exam covers a lot of concepts and many commands specific to Cisco devices. Beyond knowledge, all these Cisco exams also require deep skills. You must be able to analyze and predict what really happens in a network, and you must be able to configure Cisco devices to work correctly in those networks.

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

For instance, you might encounter a question that asks you why two routers cannot exchange routing information using the OSPF routing protocol. The question would supply some of the information, like some pieces of the jigsaw puzzle, as represented with the white pieces in Figure 1. You have to apply your knowledge of IPv4 routing, IPv4 addressing, and the OSPF protocol to the scenario in the question to come up with some of the other pieces of the puzzle. For a given question, some pieces of the puzzle might remain a mystery, but with enough of the puzzle filled in, you should be able to answer the question. And some pieces will just remain unknown for a given question.

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

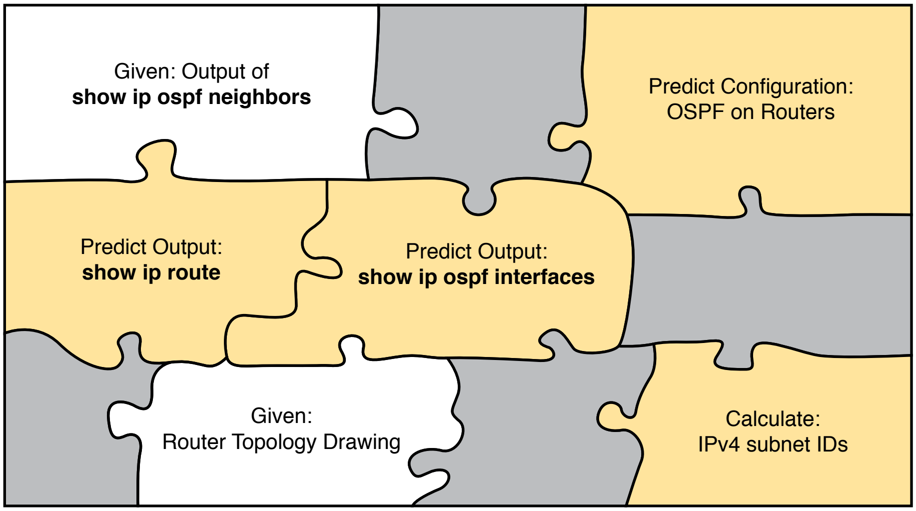

Figure 1 *Filling In Puzzle Pieces with Your Analysis Skills*

Five Study Plan Steps

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

Step 1: Think in Terms of Parts and Chapters

The first step in your study plan is to get the right mindset about the size and nature of the task you have set out to accomplish. This is a large book, and to be ready for the CCNA 200-301 exam, you need to complete it and then the *CCNA 200-301 Official Cert Guide, Volume 2*. You cannot think about these two books as one huge task, or you might get discouraged. So break the task down into smaller tasks.

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

The first step in your study plan is to visualize this book not as one large book but as components. First, visualize the book as eight smaller parts. Then, within each part, visualize each part as three or four chapters. Your study plan has you working through the chapters in each part and then reviewing the material in that part before moving on, as shown in Figure 2.

Now your plan has the following:

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

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

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

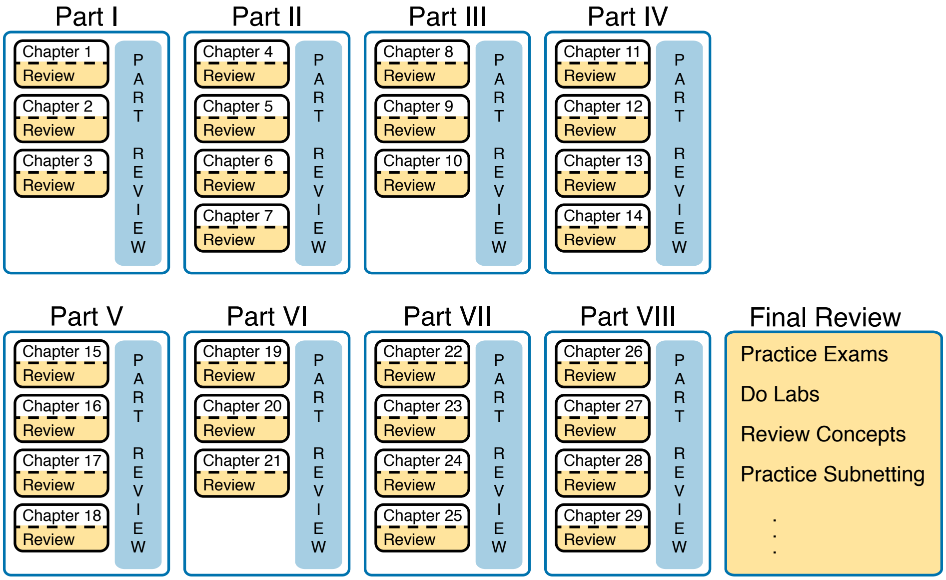

Figure 2 *Eight Parts, with an Average of Four Chapters Each, with Part Reviews*

Step 2: Build Your Study Habits Around the Chapter

For your second step, possibly the most important step, approach each chapter with the same process as shown in Figure 3. The chapter pre-quiz (called a DIKTA quiz, or "Do I Know This Already?" quiz) helps you decide how much time to spend reading versus skimming the core of the chapter, called the "Foundation Topics." The "Chapter Review" section then gives you instructions about how to study and review what you just read.

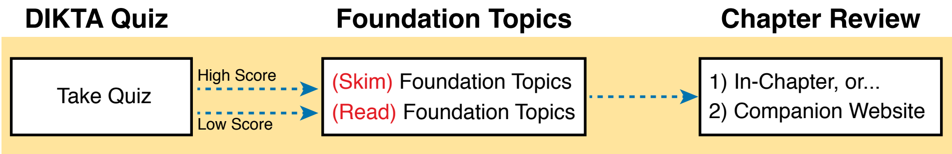

Figure 3 *Suggested Approach to Each Chapter*

The book has no long chapters, on purpose. They average about 20 pages for the Foundation Topics (which is the part of the chapter with new content). Because we kept the size reasonable, you can complete all of a chapter in one or two short study sessions. For instance, when you begin a new chapter, if you have an hour or an hour and a half, you should be able to complete a first reading of the chapter and at least make a great start on it. And even if you do not have enough time to read the entire chapter, look for the major headings inside the chapter; each chapter has two to three major headings, and those make a great place to stop reading when you need to wait to complete the reading in the next study sessions.

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

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

Step 3: Use Book Parts for Major Milestones

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

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

Figure 4 lists the names of the parts in this book, with some color coding. Note that Parts II and III are related (Ethernet), and Parts IV through VII are also related (IP version 4 and IP Version 6). Each part ends with a Part Review section of two to four pages, with notes about what tools and activities to use.

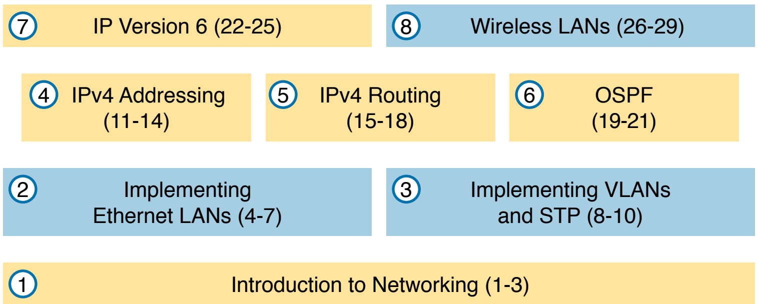

Figure 4 *Parts as Major Milestones*

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

Step 4: Use Volume 2's Final Review Chapter

Your fourth step has one overall task: perform the details outlined in the "Final Exam Review" chapter at the end of the *CCNA 200-301 Official Cert Guide, Volume 2*. Note that you have no exam to take at the end of this Volume 1 book, so keep working with Volume 2 when you complete this book. Once you're finished with both books, Volume 2's "Final Exam Review" will direct you.

Step 5: Set Goals and Track Your Progress

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

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

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

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

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

Table 1 Sample Excerpt from a Planning Table

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

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

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

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

Things to Do Before Starting the First Chapter

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

Bookmark the Companion Website

The companion website contains links to all the tools you need for chapter and part review. In fact, it includes a chapter-by-chapter and part-by-part breakdown of all the review activities. Before you finish the first chapter, make sure and follow the instructions in the Introduction's section titled "The Companion Website for Online Content Review," get access, and bookmark the page.

Also, if you did not yet read about the companion website in the Introduction or explore the site, take a few minutes to look at the resources available on the site.

Bookmark/Install Pearson Test Prep

This book, like many other Cisco Press books, includes the rights to use the Pearson Test Prep (PTP) software, along with rights to use some exam questions related to this book. PTP has many useful study features:

- Both a web and desktop version for your convenience and choice
- History tracking of your simulated exam attempts, synchronized between web and desktop
- Study mode, which lets you see the correct answers with each question and the related explanations
- Practice exam mode, which simulates exam conditions, hiding answers/explanations and timing the exam event
- Filters to let you choose questions based on chapter(s) and/or part(s)

You should take a few minutes to set up your PTP installation. Refer to the section titled "How to Access the Pearson Test Prep (PTP) App" in the Introduction for details.

Understand This Book's PTP Databases and Modes

When you activate a product in PTP, you gain the rights to that product's exams. Understanding those exams helps you choose when to use them and when to delay using different exams to save those questions for later. The retail version of this book comes with four exams, as shown in Figure 5; the premium edition adds exams 3 and 4, which are similar in purpose to exams 1 and 2.

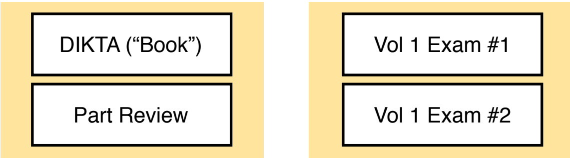

Figure 5 *PTP Exams/Exam Databases and When to Use Them*

When using PTP, you can choose to use any of these exam databases at any time, both in study mode and practice exam mode. However, many people find it best to avoid using some exams until you do your final exam review at the end of reading the *CCNA 200-301 Official Cert Guide, Volume 2*. So, consider using this plan:

- During Chapter Review, use PTP to review the DIKTA questions for that chapter, using study mode.
- During Part Review, use the questions built specifically for Part Review (the Part Review questions) for that part of the book, using study mode.
- Save the remaining exams to use with the "Final Review" chapter at the end of the Volume 2 book.

Alternatively, use exams 1 and 2 at any time during your study, and consider buying the premium edition of the book to add two more exams. For instance, you could review each chapter by answering the questions from that chapter in exams 1 and 2, and wait to use exams 3 and 4 until your final exam review at the end of Volume 2.

> **NOTE** The *CCNA 200-301 Official Cert Guide, Volume 2*, includes several CCNA exams as well—exams that include questions from Volume 1 and Volume 2. You can use those exams during final review to practice simulated CCNA 200-301 exams.

Additionally, take the time to experiment with the study modes in the PTP applications:

Study mode: Study mode works best when you are still working on understanding and learning the content. In study mode, you can see the answers immediately, so you can study the topics more easily.

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

Practice Viewing Per-Chapter DIKTA Questions

Take a few minutes to experiment with and understand how to use PTP to answer questions from a single chapter's DIKTA quiz, as follows:

Step 1. Start the PTP web or desktop app.

Step 2. From the main (home) menu, select the item for this product, with a name like *CCNA 200-301 Official Cert Guide, Volume 1*, and click **Open Exam**.

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

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

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

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

Practice Viewing Per-Part Review Questions

Your PTP access also includes a Part Review exam created solely for study during the Part Review process. To view these questions, follow the same process as you did with DIKTA/book questions, but select the Part Review database rather than the book database. PTP has a clear name for this database: Part Review Questions.

Join the Cisco Learning Network CCNA Study Group

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

Getting Started: Now

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

This first part of the book introduces the fundamentals of the most important topics in TCP/IP networking. Chapter 1 provides a broad look at TCP/IP, introducing the common terms, big concepts, and major protocols for TCP/IP. Chapter 2 then examines local-area networks (LAN), which are networks that connect devices that are located near each other; for instance, in the same building. Chapter 3 then shows how to connect those LANs across long distances with wide-area networks (WAN) with a focus on how routers connect LANs and WANs to forward data between any two devices in the network.

Part I

Introduction to Networking

CHAPTER 1

Introduction to TCP/IP Networking

This chapter covers the following exam topics:

1.0 Network Fundamentals

1.3 Compare physical interface and cabling types

1.3.a Single-mode fiber, multimode fiber, copper

1.3.b Connections (Ethernet shared media and point-to-point)

Welcome to the first chapter in your study for CCNA! This chapter begins Part I, which focuses on the basics of networking.

Networks work correctly because the various devices and software follow the rules. Those rules come in the form of standards and protocols, which are agreements of a particular part of how a network should work. However, the sheer number of standards and protocols available can make it difficult for the average network engineer to think about and work with networks—so the world of networking has used several networking models over time. Networking models define a structure and different categories (layers) of standards and protocols. As new standards and protocols emerge over time, networkers can think of those new details in the context of a working model.

You can think of a networking model as you think of a set of architectural plans for building a house. A lot of different people work on building your house, such as framers, electricians, bricklayers, painters, and so on. The blueprint helps ensure that all the different pieces of the house work together as a whole. Similarly, the people who make networking products, and the people who use those products to build their own computer networks, follow a particular networking model. That networking model defines rules about how each part of the network should work, as well as how the parts should work together so that the entire network functions correctly.

Today, TCP/IP rules as the most pervasive networking model in use. You can find support for TCP/IP on practically every computer operating system (OS) in existence today, from mobile phones to mainframe computers. Every network built using Cisco products today supports TCP/IP. And not surprisingly, the CCNA exam focuses heavily on TCP/IP. This chapter uses TCP/IP for one of its main purposes: to present various concepts about networking using the context of the different roles and functions in the TCP/IP model.

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

Foundation Topics Section	Questions
Perspectives on Networking	None
TCP/IP Networking Model	1–4
Data Encapsulation Terminology	5–7

1. Which of the following protocols are examples of TCP/IP transport layer protocols? (Choose two answers.)
   a. Ethernet
   b. HTTP
   c. IP
   d. UDP
   e. SMTP
   f. TCP
2. Which of the following protocols are examples of TCP/IP data-link layer protocols? (Choose two answers.)
   a. Ethernet
   b. HTTP
   c. IP
   d. UDP
   e. SMTP
   f. TCP
   g. PPP
3. The process of HTTP asking TCP to send some data and making sure that it is received correctly is an example of what?
   a. Same-layer interaction
   b. Adjacent-layer interaction
   c. OSI model
   d. All of these answers are correct.
4. The process of TCP on one computer marking a TCP segment as segment 1, and the receiving computer then acknowledging the receipt of TCP segment 1 is an example of what?
   a. Data encapsulation
   b. Same-layer interaction
   c. Adjacent-layer interaction
   d. OSI model
   e. All of these answers are correct.

5. The process of a web server adding a TCP header to the contents of a web page, followed by adding an IP header and then adding a data-link header and trailer, is an example of what?

   a. Data encapsulation

   b. Same-layer interaction

   c. OSI model

   d. All of these answers are correct.

6. Which of the following terms is used specifically to identify the entity created when encapsulating data inside data-link layer headers and trailers?

   a. Data

   b. Chunk

   c. Segment

   d. Frame

   e. Packet

7. Which OSI encapsulation term can be used instead of the term frame?

   a. Layer 1 PDU

   b. Layer 2 PDU

   c. Layer 3 PDU

   d. Layer 5 PDU

   e. Layer 7 PDU

Foundation Topics

Perspectives on Networking

So, you are new to networking. Like many people, your perspective about networks might be that of a user of the network, as opposed to the network engineer who builds networks. For some, your view of networking might be based on how you use the Internet, from home, using a high-speed Internet connection like digital subscriber line (DSL) or cable TV, as shown in Figure 1-1.

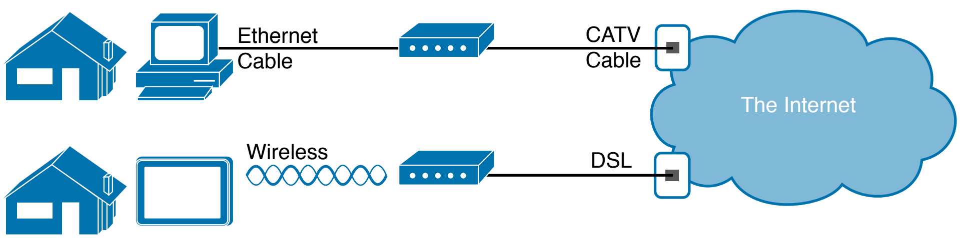

Figure 1-1 *End-User Perspective on High-Speed Internet Connections*

The top part of the figure shows a typical high-speed cable Internet user. The PC connects to a cable modem using an Ethernet cable. The cable modem then connects to a cable TV (CATV) outlet in the wall using a round coaxial cable—the same kind of cable used to connect your TV to the CATV wall outlet. Because cable Internet services provide service continuously, the user can just sit down at the PC and start sending email, browsing websites, making Internet phone calls, and using other tools and applications.

The lower part of the figure uses two different technologies. First, the tablet computer uses wireless technology that goes by the name wireless local-area network (wireless LAN), or Wi-Fi, instead of using an Ethernet cable. In this example, the router uses a different technology, DSL, to communicate with the Internet.

Both home-based networks and networks built for use by a company make use of similar networking technologies. The Information Technology (IT) world refers to a network created by one corporation, or enterprise, for the purpose of allowing its employees to communicate, as an *enterprise network*. The smaller networks at home, when used for business purposes, often go by the name small office/home office (SOHO) networks.

Users of enterprise networks have some idea about the enterprise network at their company or school. People realize that they use a network for many tasks. PC users might realize that their PC connects through an Ethernet cable to a matching wall outlet, as shown at the top of Figure 1-2. Those same users might use wireless LANs with their laptop when going to a meeting in the conference room as well. Figure 1-2 shows these two end-user perspectives on an enterprise network.

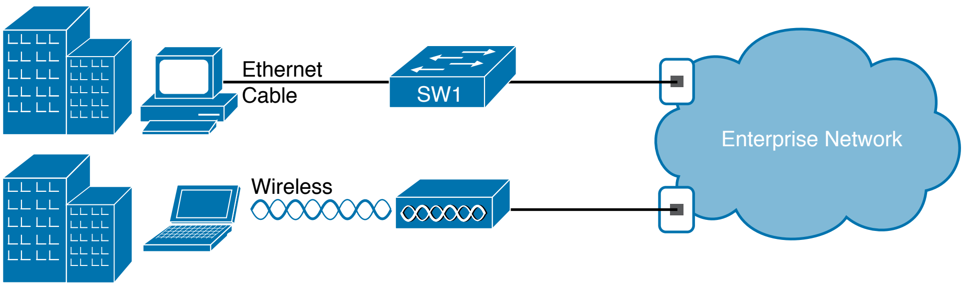

Figure 1-2 *Example Representation of an Enterprise Network*

NOTE In networking diagrams, a cloud represents a part of a network whose details are not important to the purpose of the diagram. In this case, Figure 1-2 ignores the details of how to create an enterprise network.

Some users might not even have a concept of the network at all. Instead, these users just enjoy the functions of the network—the ability to post messages to social media sites, make phone calls, search for information on the Internet, listen to music, and download countless apps to their phones—without caring about how it works or how their favorite device connects to the network.

Regardless of how much you already know about how networks work, this book and the related certification help you learn how networks do their job. That job is simply this: moving data from one device to another. The rest of this chapter, and the rest of this first part of the book, reveals the basics of how to build enterprise networks so that they can deliver data between two devices.

TCP/IP Networking Model

A *networking model*, sometimes also called either a *networking architecture* or *networking blueprint*, refers to a comprehensive set of documents. Individually, each document describes one small function required for a network; collectively, these documents define everything that should happen for a computer network to work. Some documents define a *protocol*, which is a set of logical rules that devices must follow to communicate. Other documents define some physical requirements for networking. For example, a document could define the voltage and current levels used on a particular cable when transmitting data.

You can think of a networking model as you think of an architectural blueprint for building a house. Sure, you can build a house without the blueprint. However, the blueprint can ensure that the house has the right foundation and structure so that it will not fall down, and it has the correct hidden spaces to accommodate the plumbing, electrical, gas, and so on. Also, the many different people that build the house using the blueprint—such as framers, electricians, bricklayers, painters, and so on—know that if they follow the blueprint, their part of the work should not cause problems for the other workers.

Similarly, you could build your own network—write your own software, build your own networking cards, and so on—to create a network. However, it is much easier to simply buy and use products that already conform to some well-known networking model or blueprint. Because the networking product vendors build their products with some networking model in mind, their products should work well together.

History Leading to TCP/IP

Today, the world of computer networking uses one networking model: TCP/IP. However, the world has not always been so simple. Once upon a time, networking protocols didn't exist, including TCP/IP. Vendors created the first networking protocols; these protocols supported only that vendor's computers.

For example, IBM, the computer company with the largest market share in many markets back in the 1970s and 1980s, published its Systems Network Architecture (SNA) networking model in 1974. Other vendors also created their own proprietary networking models. As a result, if your company bought computers from three vendors, network engineers often had to create three different networks based on the networking models created by each company, and then somehow connect those networks, making the combined networks much more complex. The left side of Figure 1-3 shows the general idea of what a company's enterprise network might have looked like back in the 1980s, before TCP/IP became common in enterprise internetworks.

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

1 D and F **2** A and G **3** B **4** B **5** A **6** D **7** B

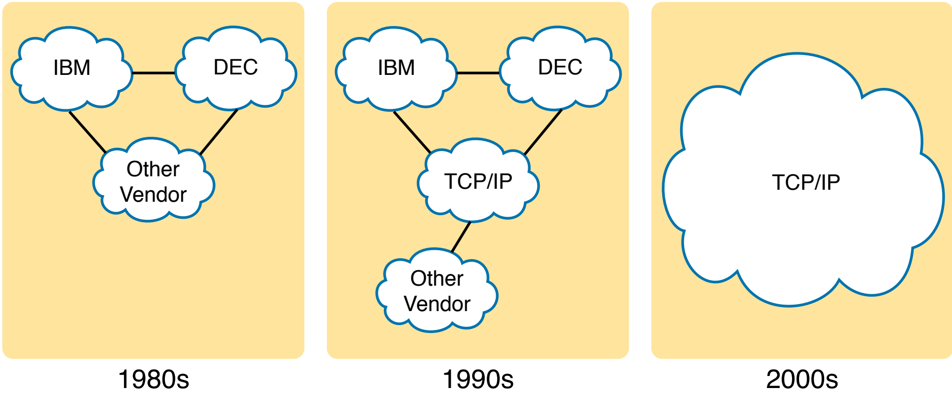

Figure 1-3 *Historical Progression: Proprietary Models to the Open TCP/IP Model*

Although vendor-defined proprietary networking models often worked well, having an open, vendor-neutral networking model would aid competition and reduce complexity. The International Organization for Standardization (ISO) took on the task to create such a model, starting as early as the late 1970s, beginning work on what would become known as the Open Systems Interconnection (OSI) networking model. ISO had a noble goal for the OSI model: to standardize data networking protocols to allow communication among all computers across the entire planet. ISO worked toward this ambitious and noble goal, with participants from most of the technologically developed nations on Earth participating in the process.

A second, less-formal effort to create an open, vendor-neutral, public networking model sprouted forth from a U.S. Department of Defense (DoD) contract. Researchers at various universities volunteered to help further develop the protocols surrounding the original DoD work. These efforts resulted in a competing open networking model called TCP/IP.

During the 1990s, companies began adding OSI, TCP/IP, or both to their enterprise networks. However, by the end of the 1990s, TCP/IP had become the common choice, and OSI fell away. The center part of Figure 1-3 shows the general idea behind enterprise networks in that decade—still with networks built upon multiple networking models but including TCP/IP.

Here in the twenty-first century, TCP/IP dominates. Proprietary networking models still exist, but they have mostly been discarded in favor of TCP/IP. The OSI model, whose development suffered in part because of a slower formal standardization process as compared with TCP/IP, never succeeded in the marketplace. And TCP/IP, the networking model originally created almost entirely by a bunch of volunteers, has become the most prolific network model ever, as shown on the right side of Figure 1-3.

In this chapter, you will read about some of the basics of TCP/IP. Although you will learn some interesting facts about TCP/IP, the true goal of this chapter is to help you understand what a networking model or networking architecture really is and how it works.

Also in this chapter, you will learn about some of the jargon used with OSI. Will any of you ever work on a computer that is using the full OSI protocols instead of TCP/IP? Probably not. However, you will often use terms relating to OSI.

Overview of the TCP/IP Networking Model

The TCP/IP model both defines and references a large collection of protocols that allow computers to communicate. To define a protocol, TCP/IP uses documents called *Requests For Comments* (RFC). (You can find these RFCs using any online search engine.) The TCP/IP model also avoids repeating work already done by some other standards body or vendor consortium by simply referring to standards or protocols created by those groups. For example, the Institute of Electrical and Electronic Engineers (IEEE) defines Ethernet LANs; the TCP/IP model does not define Ethernet in RFCs, but refers to IEEE Ethernet as an option.

The TCP/IP model creates a set of rules that allows us all to take a computer (or mobile device) out of the box, plug in all the right cables, turn it on, and connect to and use the network. You can use a web browser to connect to your favorite website, use most any app, and it all works. How? Well, the OS on the computer implements parts of the TCP/IP model. The Ethernet card, or wireless LAN card, built in to the computer implements some LAN standards referenced by the TCP/IP model. In short, the vendors that created the hardware and software implemented TCP/IP.

To help people understand a networking model, each model breaks the functions into a small number of categories called *layers*. Each layer includes protocols and standards that relate to that category of functions, as shown in Figure 1-4.

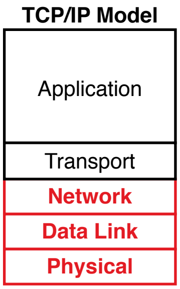

Figure 1-4 *The TCP/IP Networking Models*

The TCP/IP model shows the more common terms and layers used when people talk about TCP/IP today. The bottom layer focuses on how to transmit bits over each individual link. The data-link layer focuses on sending data over one type of physical link: for instance, networks use different data-link protocols for Ethernet LANs versus wireless LANs. The network layer focuses on delivering data over the entire path from the original sending computer to the final destination computer. And the top two layers focus more on the applications that need to send and receive data.

NOTE A slightly different four-layer original version of the TCP/IP model exists in RFC 1122, but for the purposes of both real networking and for today's CCNA, use the five-layer model shown here in Figure 1-4.

Many of you will have already heard of several TCP/IP protocols, like the examples listed in Table 1-2. Most of the protocols and standards in this table will be explained in more detail as you work through this book. Following the table, this section takes a closer look at the layers of the TCP/IP model.

Table 1-2 TCP/IP Architectural Model and Example Protocols

TCP/IP Architecture Layer	Example Protocols
Application	HTTP, POP3, SMTP
Transport	TCP, UDP
Internet	IP, ICMP
Data Link & Physical	Ethernet, 802.11 (Wi-Fi)

TCP/IP Application Layer

TCP/IP application layer protocols provide services to the application software running on a computer. The application layer does not define the application itself, but it defines services that applications need. For example, application protocol HTTP defines how web browsers can pull the contents of a web page from a web server. In short, the application layer provides an interface between software running on a computer and the network itself.

Arguably, the most popular TCP/IP application today is the web browser. Many major software vendors either have already changed or are changing their application software to support access from a web browser. And thankfully, using a web browser is easy: You start a web browser on your computer and select a website by typing the name of the website, and the web page appears.

HTTP Overview

What really happens to allow that web page to appear on your web browser?

Imagine that Bob opens his browser. His browser has been configured to automatically ask for web server Larry's default web page, or *home page*. The general logic looks like Figure 1-5.

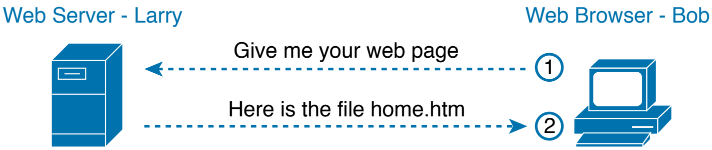

Figure 1-5 *Basic Application Logic to Get a Web Page*

So, what really happened? Bob's initial request actually asks Larry to send his home page back to Bob. Larry's web server software has been configured to know that the default web page is contained in a file called home.htm. Bob receives the file from Larry and displays the contents of the file in Bob's web browser window.

HTTP Protocol Mechanisms

Taking a closer look, this example shows how applications on each endpoint computer—specifically, the web browser application and web server application—use a TCP/IP application layer protocol. To make the request for a web page and return the contents of the web page, the applications use the Hypertext Transfer Protocol (HTTP).

HTTP did not exist until Tim Berners-Lee created the first web browser and web server in the early 1990s. Berners-Lee gave HTTP functionality to ask for the contents of web pages, specifically by giving the web browser the ability to request files from the server and giving the server a way to return the content of those files. The overall logic matches what was shown in Figure 1-5; Figure 1-6 shows the same idea, but with details specific to HTTP.

NOTE The full version of most web addresses—also called Uniform Resource Locators (URL) or Universal Resource Identifiers (URI)—begins with the letters *http*, which means that HTTP is used to transfer the web pages.

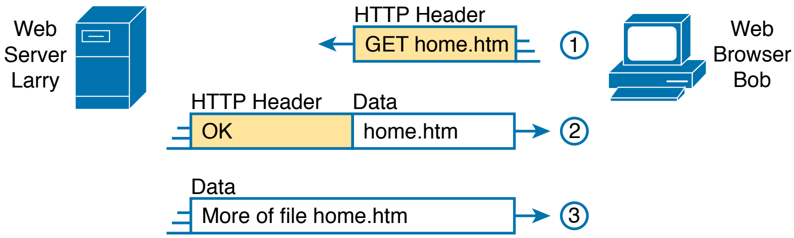

Figure 1-6 *HTTP GET Request, HTTP Reply, and One Data-Only Message*

To get the web page from Larry, at Step 1, Bob sends a message with an HTTP header. Generally, protocols use headers as a place to put information used by that protocol. This HTTP header includes the request to "get" a file. The request typically contains the name of the file (home.htm, in this case), or if no filename is mentioned, the web server assumes that Bob wants the default web page.

Step 2 in Figure 1-6 shows the response from web server Larry. The message begins with an HTTP header, with a return code (200), which means something as simple as "OK" returned in the header. HTTP also defines other return codes so that the server can tell the browser whether the request worked. (Here is another example: If you ever looked for a web page that was not found, and then received an HTTP 404 "not found" error, you received an HTTP return code of 404.) The second message also includes the first part of the requested file.

Step 3 in Figure 1-6 shows another message from web server Larry to web browser Bob, but this time without an HTTP header. HTTP transfers the data by sending multiple messages, each with a part of the file. Rather than wasting space by sending repeated HTTP headers that list the same information, these additional messages simply omit the header.

TCP/IP Transport Layer

Although many TCP/IP application layer protocols exist, the TCP/IP transport layer includes a smaller number of protocols. The two most commonly used transport layer protocols are the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP).

Transport layer protocols provide services to the application layer protocols that reside one layer higher in the TCP/IP model. How does a transport layer protocol provide a service to a higher-layer protocol? This section introduces that general concept by focusing on a single service provided by TCP: error recovery. The *CCNA 200-301 Official Cert Guide*, Volume 2, includes a chapter, "Introduction to TCP/IP Transport and Applications," which examines the transport layer.

TCP Error Recovery Basics

To appreciate what the transport layer protocols do, you must think about the layer above the transport layer, the application layer. Why? Well, each layer provides a service to the layer above it, like the error-recovery service provided to application layer protocols by TCP.

For example, in Figure 1-5, Bob and Larry used HTTP to transfer the home page from web server Larry to Bob's web browser. But what would have happened if Bob's HTTP GET request had been lost in transit through the TCP/IP network? Or, what would have happened if Larry's response, which included the contents of the home page, had been lost? Well, as you might expect, in either case, the page would not have shown up in Bob's browser.

TCP/IP needs a mechanism to guarantee delivery of data across a network. Because many application layer protocols probably want a way to guarantee delivery of data across a network, the creators of TCP included an error-recovery feature. To recover from errors, TCP uses the concept of acknowledgments. Figure 1-7 outlines the basic idea behind how TCP notices lost data and asks the sender to try again.

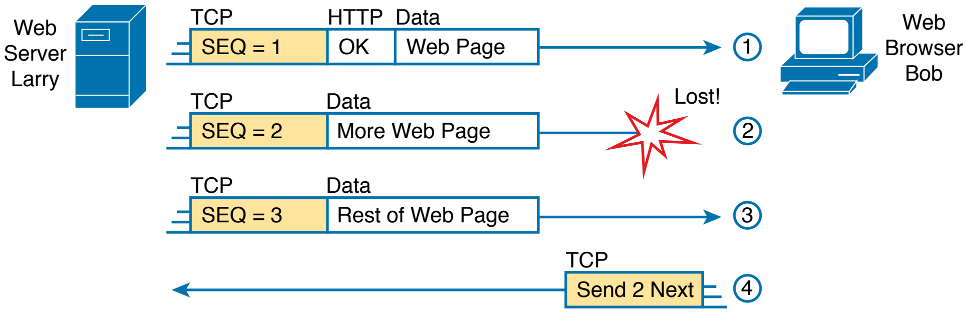

Figure 1-7 *TCP Error-Recovery Services as Provided to HTTP*

Figure 1-7 shows web server Larry sending a web page to web browser Bob, using three separate messages. Note that this figure shows the same HTTP headers as Figure 1-6, but it also shows a TCP header. The TCP header shows a sequence number (SEQ) with each message. In this example, the network has a problem, and the network fails to deliver the TCP message (called a segment) with sequence number 2. When Bob receives messages with sequence numbers 1 and 3, but does not receive a message with sequence number 2, Bob realizes that message 2 was lost. That realization by Bob's TCP logic causes Bob to send a TCP segment back to Larry, asking Larry to send message 2 again.

Same-Layer and Adjacent-Layer Interactions

Figure 1-7 also demonstrates a function called *adjacent-layer interaction*, which refers to the concepts of how adjacent layers in a networking model, on the same computer, work together. In this example, the higher-layer protocol (HTTP) wants error recovery, so it uses the next lower-layer protocol (TCP) to perform the service of error recovery; the lower layer provides a service to the layer above it.

Figure 1-7 also shows an example of a similar function called *same-layer interaction*. When a particular layer on one computer wants to communicate with the same layer on another computer, the two computers use headers to hold the information that they want to communicate. For example, in Figure 1-7, Larry set the sequence numbers to 1, 2, and 3 so that Bob could notice when some of the data did not arrive. Larry's TCP process created that TCP header with the sequence number; Bob's TCP process received and reacted to the TCP segments.

Table 1-3 summarizes the key points about how adjacent layers work together on a single computer and how one layer on one computer works with the same networking layer on another computer.

Key Topic

Table 1-3 Summary: Same-Layer and Adjacent-Layer Interactions

Concept	Description
Same-layer interaction on different computers	The two computers use a protocol to communicate with the same layer on another computer. The protocol defines a header that communicates what each computer wants to do.
Adjacent-layer interaction on the same computer	On a single computer, one lower layer provides a service to the layer just above. The software or hardware that implements the higher layer requests that the next lower layer perform the needed function.

TCP/IP Network Layer

The application layer includes many protocols. The transport layer includes fewer protocols, most notably, TCP and UDP. The TCP/IP network layer includes a small number of protocols, but only one major protocol: the Internet Protocol (IP). In fact, the name TCP/IP is simply the names of the two most common protocols (TCP and IP) separated by a /.

IP provides several features, most importantly, addressing and routing. This section begins by comparing IP's addressing and routing with another commonly known system that uses addressing and routing: the postal service. Following that, this section introduces IP addressing and routing. (More details follow in Chapter 3, "Fundamentals of WANs and IP Routing.")

Internet Protocol and the Postal Service

Imagine that you just wrote two letters: one to a friend on the other side of the country and one to a friend on the other side of town. You addressed the envelopes and put on the stamps, so both are ready to give to the postal service. Is there much difference in how you treat each letter? Not really. Typically, you would just put them in the same mailbox and expect the postal service to deliver both letters.

The postal service, however, must think about each letter separately, and then make a decision of where to send each letter so that it is delivered. For the letter sent across town, the people in the local post office probably just need to put the letter on another truck.

For the letter that needs to go across the country, the postal service sends the letter to another post office, then another, and so on, until the letter gets delivered across the country. At each post office, the postal service must process the letter and choose where to send it next.

To make it all work, the postal service has regular routes for small trucks, large trucks, planes, boats, and so on, to move letters between postal service sites. The service must be able to receive and forward the letters, and it must make good decisions about where to send each letter next, as shown in Figure 1-8.

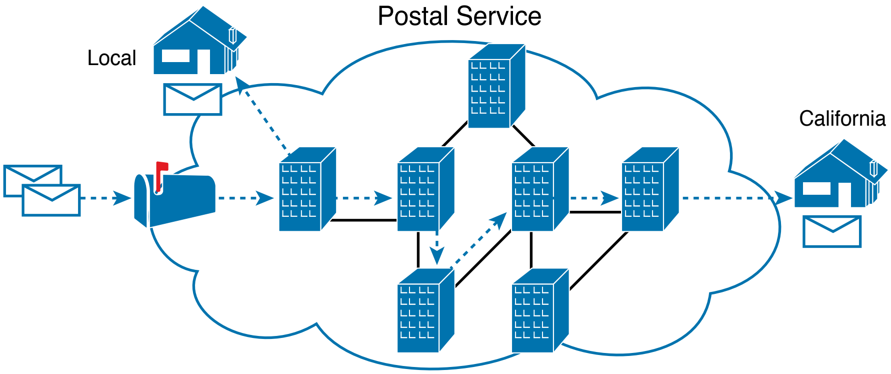

Figure 1-8 *Postal Service Forwarding (Routing) Letters*

Still thinking about the postal service, consider the difference between the person sending the letter and the work that the postal service does. The person sending the letters expects that the postal service will deliver the letter most of the time. However, the person sending the letter does not need to know the details of exactly what path the letters take. In contrast, the postal service does not create the letter, but it accepts the letter from the customer. Then, the postal service must know the details about addresses and postal codes that group addresses into larger groups, and it must have the ability to deliver the letters.

The TCP/IP application and transport layers act like the person sending letters through the postal service. These upper layers work the same way regardless of whether the endpoint host computers are on the same LAN or are separated by the entire Internet. To send a message, these upper layers ask the layer below them, the network layer, to deliver the message.

The lower layers of the TCP/IP model act more like the postal service to deliver those messages to the correct destinations. To do so, these lower layers must understand the underlying physical network because they must choose how to best deliver the data from one host to another.

So, what does this all matter to networking? Well, the network layer of the TCP/IP networking model, primarily defined by the Internet Protocol (IP), works much like the postal service. IP defines that each host computer should have a different IP address, just as the postal service defines addressing that allows unique addresses for each house, apartment, and business. Similarly, IP defines the process of routing so that devices called routers can work like the post office, forwarding packets of data so that they are delivered to the correct destinations. Just as the postal service created the necessary infrastructure to deliver letters—post offices, sorting machines, trucks, planes, and personnel—the network layer defines the details of how a network infrastructure should be created so that the network can deliver data to all computers in the network.

Internet Protocol Addressing Basics

IP defines addresses for several important reasons. First, each device that uses TCP/IP—each TCP/IP *host*—needs a unique address so that it can be identified in the network. IP also defines how to group addresses together, just like the postal system groups addresses based on postal codes (like ZIP codes in the United States).

To understand the basics, examine Figure 1-9, which shows the familiar web server Larry and web browser Bob; but now, instead of ignoring the network between these two computers, part of the network infrastructure is included.

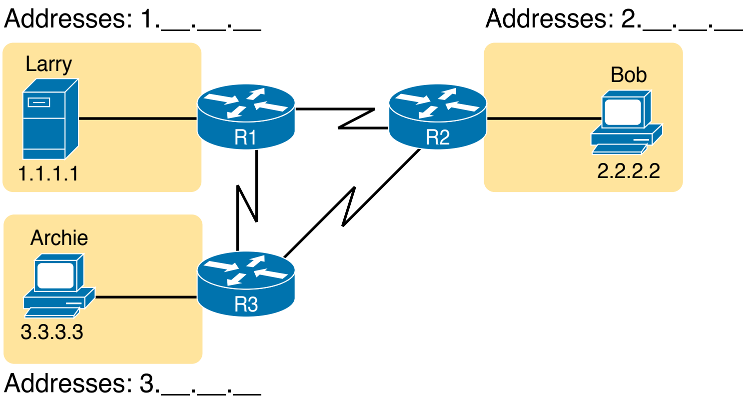

Figure 1-9 *Simple TCP/IP Network: Three Routers with IP Addresses Grouped*

First, note that Figure 1-9 shows some sample IP addresses. Each IP address has four numbers, separated by periods. In this case, Larry uses IP address 1.1.1.1, and Bob uses 2.2.2.2. This style of number is called a dotted-decimal notation (DDN).

Figure 1-9 also shows three groups of addresses. In this example, all IP addresses that begin with 1 must be on the upper left, as shown in shorthand in the figure as 1.__.__.__. All addresses that begin with 2 must be on the right, as shown in shorthand as 2.__.__.__. Finally, all IP addresses that begin with 3 must be at the bottom of the figure.

In addition, Figure 1-9 introduces icons that represent IP routers. Routers are networking devices that connect the parts of the TCP/IP network together for the purpose of routing (forwarding) IP packets to the correct destination. Routers do the equivalent of the work done by each post office site: They receive IP packets on various physical interfaces, make decisions based on the IP address included with the packet, and then physically forward the packet out some other network interface.

IP Routing Basics

The TCP/IP network layer, using the IP protocol, provides a service of forwarding IP packets from one device to another. Any device with an IP address can connect to the TCP/IP network and send packets. This section shows a basic IP routing example for perspective.

NOTE The term *IP host* refers to any device, regardless of size or power, that has an IP address and connects to any TCP/IP network.

Figure 1-10 repeats the familiar case in which web server Larry wants to send part of a web page to Bob, but now with details related to IP. On the lower left, note that server Larry has the familiar application data, HTTP header, and TCP header ready to send. In addition, the message now contains an IP header. The IP header includes a source IP address of Larry's IP address (1.1.1.1) and a destination IP address of Bob's IP address (2.2.2.2).

Key Topic

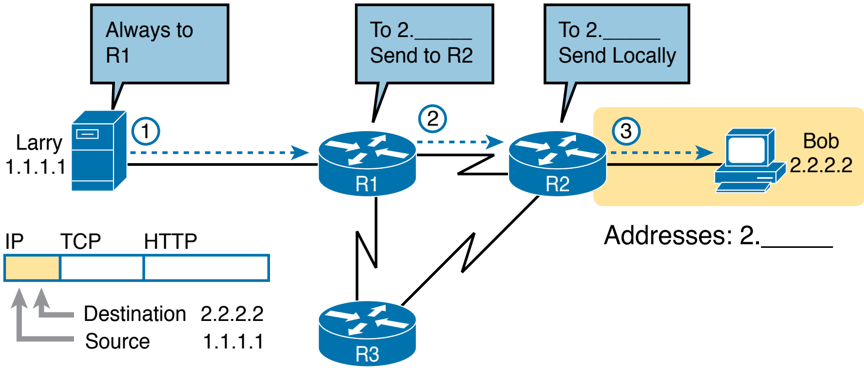

Figure 1-10 *Basic Routing Example*

Step 1, on the left of Figure 1-10, begins with Larry being ready to send an IP packet. Larry's IP process chooses to send the packet to some router—a nearby router on the same LAN—with the expectation that the router will know how to forward the packet. (This logic is much like you or me sending all our letters by putting them in a nearby mailbox.) Larry doesn't need to know anything more about the topology or the other routers.

At Step 2, Router R1 receives the IP packet, and R1's IP process makes a decision. R1 looks at the destination address (2.2.2.2), compares that address to its known IP routes, and chooses to forward the packet to Router R2. This process of forwarding the IP packet is called *IP routing* (or simply *routing*).

At Step 3, Router R2 repeats the same kind of logic used by Router R1. R2's IP process will compare the packet's destination IP address (2.2.2.2) to R2's known IP routes and make a choice to forward the packet to the right, on to Bob.

You will learn IP in more depth than any other protocol while preparing for CCNA. More than half the chapters in this book discuss some feature that relates to addressing, IP routing, and how routers perform routing.

TCP/IP Data-Link and Physical Layers

The TCP/IP model's data-link and physical layers define the protocols and hardware required to deliver data across some physical network. The two work together quite closely; in fact, some standards define both the data-link and physical layer functions. The physical layer defines the cabling and energy (for example, electrical signals) that flow over the cables. Some rules and conventions exist when sending data over the cable; however, those rules exist in the data-link layer of the TCP/IP model.

Focusing on the data-link layer for a moment, just like every layer in any networking model, the TCP/IP data-link layer provides services to the layer above it in the model (the network layer). When a host's or router's IP process chooses to send an IP packet to another router or host, that host or router then uses link-layer details to send that packet to the next host/router.

Because each layer provides a service to the layer above it, take a moment to think about the IP logic related to Figure 1-10. In that example, host Larry's IP logic chooses to send the IP packet to a nearby router (R1). However, while Figure 1-10 shows a simple line between Larry and router R1, that drawing means that some Ethernet LAN sits between the two. Figure 1-11 shows four steps of what occurs at the link layer to allow Larry to send the IP packet to R1.

Key Topic

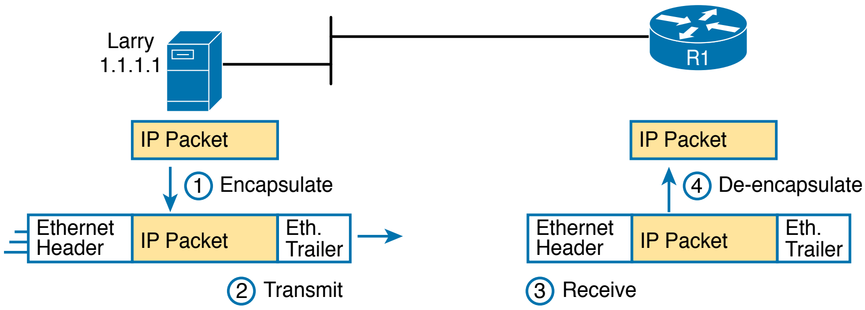

Figure 1-11 *Larry Using Ethernet to Forward an IP Packet to Router R1*

NOTE Figure 1-11 depicts the Ethernet as a series of lines. Networking diagrams often use this convention when drawing Ethernet LANs, in cases where the actual LAN cabling and LAN devices are not important to some discussion, as is the case here. The LAN would have cables and devices, like LAN switches, which are not shown in this figure.

Figure 1-11 shows four steps. The first two occur on Larry, and the last two occur on Router R1, as follows:

Step 1. Larry encapsulates the IP packet between an Ethernet header and Ethernet trailer, creating an Ethernet *frame*.

Step 2. Larry physically transmits the bits of this Ethernet frame, using electricity flowing over the Ethernet cabling.

Step 3. Router R1 physically receives the electrical signal over a cable and re-creates the same bits by interpreting the meaning of the electrical signals.

Step 4. Router R1 de-encapsulates the IP packet from the Ethernet frame by removing and discarding the Ethernet header and trailer.

By the end of this process, Larry and R1 have worked together to deliver the packet from Larry to Router R1.

NOTE Protocols define both headers and trailers for the same general reason, but headers exist at the beginning of the message and trailers exist at the end.

The data-link and physical layers include a large number of protocols and standards. For example, the link layer includes all the variations of Ethernet protocols and wireless LAN protocols discussed throughout this book.

In short, the TCP/IP physical and data-link layers include two distinct functions, respectively: functions related to the physical transmission of the data, plus the protocols and rules that control the use of the physical media.

Data Encapsulation Terminology

As you can see from the explanations of how HTTP, TCP, IP, and Ethernet do their jobs, when sending data, each layer adds its own header (and for data-link protocols, also a trailer) to the data supplied by the higher layer. The term *encapsulation* refers to the process of putting headers (and sometimes trailers) around some data.

Many of the examples in this chapter show the encapsulation process. For example, web server Larry encapsulated the contents of the home page inside an HTTP header in Figure 1-6. The TCP layer encapsulated the HTTP headers and data inside a TCP header in Figure 1-7. IP encapsulated the TCP headers and the data inside an IP header in Figure 1-10. Finally, the Ethernet link layer encapsulated the IP packets inside both a header and a trailer in Figure 1-11.

The process by which a TCP/IP host sends data can be viewed as a five-step process. The first four steps relate to the encapsulation performed by the four TCP/IP layers, and the last step is the actual physical transmission of the data by the host. In fact, if you use the five-layer TCP/IP model, one step corresponds to the role of each layer. The steps are summarized in the following list:

Step 1. **Create and encapsulate the application data with any required application layer headers.** For example, the HTTP OK message can be returned in an HTTP header, followed by part of the contents of a web page.

Step 2. **Encapsulate the data supplied by the application layer inside a transport layer header.** For end-user applications, a TCP or UDP header is typically used.

Step 3. **Encapsulate the data supplied by the transport layer inside a network layer (IP) header.** IP defines the IP addresses that uniquely identify each computer.

Step 4. **Encapsulate the data supplied by the network layer inside a data-link layer header and trailer.** This layer uses both a header and a trailer.

Step 5. **Transmit the bits.** The physical layer encodes a signal onto the medium to transmit the frame.

The numbers in Figure 1-12 correspond to the five steps in this list, graphically showing the same concepts. Note that because the application layer often does not need to add a header, the figure does not show a specific application layer header, but the application layer will also at times add a header as well.

Key Topic

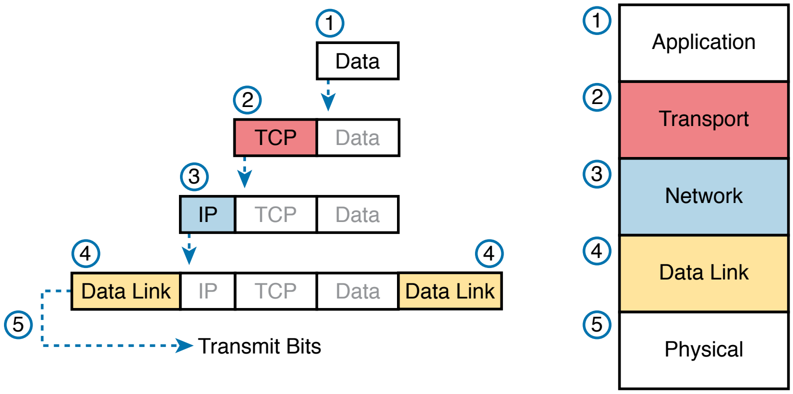

Figure 1-12 *Five Steps of Data Encapsulation: TCP/IP*

Names of TCP/IP Messages

One reason this chapter takes the time to show the encapsulation steps in detail has to do with terminology. When talking and writing about networking, people use *segment*, *packet*, and *frame* to refer to the messages shown in Figure 1-13 and the related list. Each term has a specific meaning, referring to the headers (and possibly trailers) defined by a particular layer and the data encapsulated following that header. Each term, however, refers to a different layer: segment for the transport layer, packet for the network layer, and frame for the link layer. Figure 1-13 shows each layer along with the associated term.

Key Topic

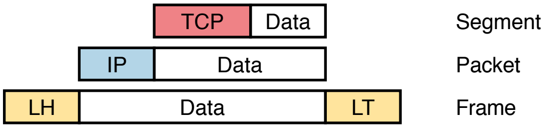

Figure 1-13 *Perspectives on Encapsulation and "Data"**

* The letters LH and LT stand for link header and link trailer, respectively, and refer to the data-link layer header and trailer.

Figure 1-13 also shows the encapsulated data as simply "data." When focusing on the work done by a particular layer, the encapsulated data typically is unimportant. For example, an IP packet can indeed have a TCP header after the IP header, an HTTP header after the TCP header, and data for a web page after the HTTP header. However, when discussing IP, you probably just care about the IP header, so everything after the IP header is just called data. So, when drawing IP packets, everything after the IP header is typically shown simply as data.

OSI Networking Model and Terminology

At one point in the history of the OSI model, many people thought that OSI would win the battle of the networking models discussed earlier. If that had occurred, instead of running TCP/IP on every computer in the world, those computers would be running with OSI.

However, OSI did not win that battle. In fact, OSI no longer exists as a networking model that could be used instead of TCP/IP, although some of the original protocols referenced by the OSI model still exist.

So, why is OSI even in this book? Terminology. During those years in which many people thought the OSI model would become commonplace in the world of networking (mostly in the late 1980s and early 1990s), many vendors and protocol documents started using terminology from the OSI model. That terminology remains today. So, while you will never need to work with a computer that uses OSI, to understand modern networking terminology, you need to understand something about OSI.

Comparing OSI and TCP/IP Layer Names and Numbers

The OSI model has many similarities to the TCP/IP model from a basic conceptual perspective. It has layers, and each layer defines a set of typical networking functions. As with TCP/IP, the OSI layers each refer to multiple protocols and standards that implement the functions specified by each layer. In other cases, just as for TCP/IP, the OSI committees did not create new protocols or standards, but instead referenced other protocols that were already defined. For example, the IEEE defines Ethernet standards, so the OSI committees did not waste time specifying a new type of Ethernet; it simply referred to the IEEE Ethernet standards.

Today, the OSI model can be used as a standard of comparison to other networking models. Figure 1-14 compares the seven-layer OSI model with both the four-layer and five-layer TCP/IP models.

Key Topic

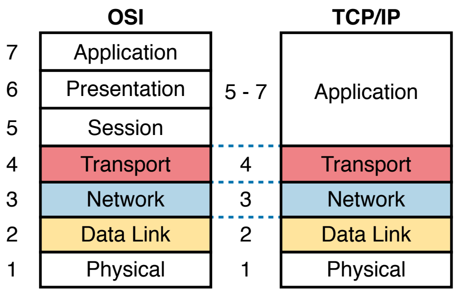

Figure 1-14 *OSI Model Compared to the Two TCP/IP Models*

Note that the TCP/IP model in use today, on the right side of the figure, uses the exact same layer names as OSI at the lower layers. The functions generally match as well, so for the purpose of discussing networking, and reading networking documentation, think of the bottom four layers as equivalent, in name, in number, and in meaning.

Even though the world uses TCP/IP today rather than OSI, we tend to use the numbering from the OSI layer. For instance, when referring to an application layer protocol in a TCP/IP network, the world still refers to the protocol as a "Layer 7 protocol." Also, while TCP/IP includes more functions at its application layer, OSI breaks those intro session, presentation, and application layers. Most of the time, no one cares much about the distinction, so you will see references like "Layer 5–7 protocol," again using OSI numbering.

For the purposes of this book, know the mapping between the five-layer TCP/IP model and the seven-layer OSI model shown in Figure 1-14, and know that layer number references to Layer 7 really do match the application layer of TCP/IP as well.

OSI Data Encapsulation Terminology

Like TCP/IP, each OSI layer asks for services from the next lower layer. To provide the services, each layer makes use of a header and possibly a trailer. The lower layer encapsulates the higher layer's data behind a header.

OSI uses a more generic term to refer to messages, rather than frame, packet, and segment. OSI uses the term *protocol data unit* (PDU). A PDU represents the bits that include the headers and trailers for that layer, as well as the encapsulated data. For example, an IP packet, as shown in Figure 1-13, using OSI terminology, is a PDU, more specifically a *Layer 3 PDU* (abbreviated L3PDU) because IP is a Layer 3 protocol. OSI simply refers to the Layer *x* PDU (LxPDU), with *x* referring to the number of the layer being discussed, as shown in Figure 1-15.

Key Topic

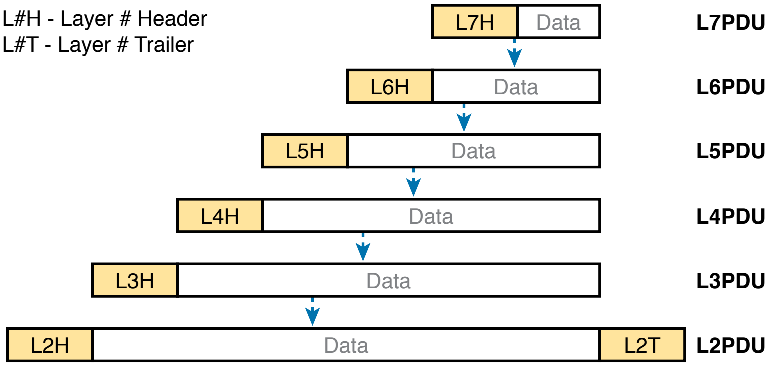

Figure 1-15 *OSI Encapsulation and Protocol Data Units*

Chapter Review

The "Your Study Plan" element, just before Chapter 1, discusses how you should study and practice the content and skills for each chapter before moving on to the next chapter. That element introduces the tools used here at the end of each chapter. If you haven't already done so, take a few minutes to read that section. Then come back here and do the useful work of reviewing the chapter to help lock into memory what you just read.

Review this chapter's material using either the tools in the book or the interactive tools for the same material found on the book's companion website. Table 1-4 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.

1

Table 1-4 Chapter Review Tracking

Review Element	Review Date(s)	Resource Used
Review key topics		Book, website
Review key terms		Book, website
Answer DIKTA questions		Book, PTP Online

Review All the Key Topics

Key Topic

Table 1-5 Key Topics for Chapter 1

Key Topic Elements	Description	Page Number
Table 1-3	Provides definitions of same-layer and adjacent-layer interaction	22
Figure 1-10	Shows the general concept of IP routing	25
Figure 1-11	Depicts the data-link services provided to IP for the purpose of delivering IP packets from host to host	26
Figure 1-12	Five steps to encapsulate data on the sending host	28
Figure 1-13	Shows the meaning of the terms *segment*, *packet*, and *frame*	28
Figure 1-14	Compares the OSI and TCP/IP network models	29
Figure 1-15	Terminology related to encapsulation	30

Key Terms You Should Know

adjacent-layer interaction, de-encapsulation, encapsulation, frame, networking model, packet, protocol data unit (PDU), same-layer interaction, segment

CHAPTER 2

Fundamentals of Ethernet LANs

This chapter covers the following exam topics:

1.0 Network Fundamentals

1.1 Explain the role and function of network components

1.1.b L2 and L3 Switches

1.2 Describe characteristics of network topology architectures

1.2.e Small office/home office (SOHO)

1.3 Compare physical interface and cabling types

1.3.a Single-mode fiber, multimode fiber, copper

1.3.b Connections (Ethernet shared media and point-to-point)

Most enterprise computer networks can be separated into two general types of technology: local-area networks (LANs) and wide-area networks (WANs). LANs typically connect nearby devices: devices in the same room, in the same building, or in a campus of buildings. In contrast, WANs connect devices that are typically relatively far apart. Together, LANs and WANs create a complete enterprise computer network, working together to do the job of a computer network: delivering data from one device to another.

Many types of LANs have existed over the years, but today's networks use two general types of LANs: Ethernet LANs and wireless LANs. Ethernet LANs happen to use cables for the links between nodes, and because many types of cables use copper wires, Ethernet LANs are often called *wired LANs*. Ethernet LANs also make use of fiber-optic cabling, which includes a fiberglass core that devices use to send data using light. In comparison to Ethernet, wireless LANs do not use wires or cables, instead using radio waves for the links between nodes; Part V of this book discusses Wireless LANs at length.

This chapter introduces Ethernet LANs, with more detailed coverage in Parts II and III of this book.

"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 2-1 “Do I Know This Already?” Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
An Overview of LANs	1–2
Building Physical Ethernet LANs with UTP	3–4
Building Physical Ethernet LANs with Fiber	5
Sending Data in Ethernet Networks	6–9

1. In the LAN for a small office, some user devices connect to the LAN using a cable, while others connect using wireless technology (and no cable). Which of the following is true regarding the use of Ethernet in this LAN?
   a. Only the devices that use cables are using Ethernet.
   b. Only the devices that use wireless are using Ethernet.
   c. Both the devices using cables and those using wireless are using Ethernet.
   d. None of the devices are using Ethernet.
2. Which of the following Ethernet standards defines Gigabit Ethernet over UTP cabling?
   a. 10GBASE-T
   b. 100BASE-T
   c. 1000BASE-T
   d. None of the other answers is correct.
3. Which of the following is true about Ethernet crossover cables for Fast Ethernet?
   a. Pins 1 and 2 are reversed on the other end of the cable.
   b. Pins 1 and 2 on one end of the cable connect to pins 3 and 6 on the other end of the cable.
   c. Pins 1 and 2 on one end of the cable connect to pins 3 and 4 on the other end of the cable.
   d. The cable can be up to 1000 meters long to cross over between buildings.
   e. None of the other answers is correct.
4. Each answer lists two types of devices used in a 100BASE-T network. If these devices were connected with UTP Ethernet cables, which pairs of devices would require a straight-through cable? (Choose three answers.)
   a. PC and router
   b. PC and switch
   c. Hub and switch
   d. Router and hub
   e. Wireless access point (Ethernet port) and switch

5. Which of the following are advantages of using multimode fiber for an Ethernet link instead of UTP or single-mode fiber?
   a. To achieve the longest distance possible for that single link.
   b. To extend the link beyond 100 meters while keeping initial costs as low as possible.
   c. To make use of an existing stock of laser-based SFP/SFP+ modules.
   d. To make use of an existing stock of LED-based SFP/SFP+ modules.
6. Which of the following is true about the CSMA/CD algorithm?
   a. The algorithm never allows collisions to occur.
   b. Collisions can happen, but the algorithm defines how the computers should notice a collision and how to recover.
   c. The algorithm works with only two devices on the same Ethernet.
   d. None of the other answers is correct.
7. Which of the following is true about the Ethernet FCS field?
   a. Ethernet uses FCS for error recovery.
   b. It is 2 bytes long.
   c. It resides in the Ethernet trailer, not the Ethernet header.
   d. It is used for encryption.
8. Which of the following are true about the format of Ethernet addresses? (Choose three answers.)
   a. Each manufacturer puts a unique OUI code into the first 2 bytes of the address.
   b. Each manufacturer puts a unique OUI code into the first 3 bytes of the address.
   c. Each manufacturer puts a unique OUI code into the first half of the address.
   d. The part of the address that holds this manufacturer's code is called the MAC.
   e. The part of the address that holds this manufacturer's code is called the OUI.
   f. The part of the address that holds this manufacturer's code has no specific name.
9. Which of the following terms describe Ethernet addresses that can be used to send one frame that is delivered to multiple devices on the LAN? (Choose two answers.)
   a. Burned-in address
   b. Unicast address
   c. Broadcast address
   d. Multicast address

Foundation Topics

An Overview of LANs

The term *Ethernet* refers to a family of LAN standards that together define the physical and data-link layers of the world's most popular wired LAN technology. The standards, defined by the Institute of Electrical and Electronics Engineers (IEEE), define the cabling, the connectors on the ends of the cables, the protocol rules, and everything else required to create an Ethernet LAN.

Typical SOHO LANs

To begin, first think about a small office/home office (SOHO) LAN today, specifically a LAN that uses only Ethernet LAN technology. First, the LAN needs a device called an Ethernet *LAN switch*, which provides many physical ports into which cables can be connected. An Ethernet uses *Ethernet cables*, which is a general reference to any cable that conforms to any of several Ethernet standards. The LAN uses Ethernet cables to connect different Ethernet devices or nodes to one of the switch's Ethernet ports.

Figure 2-1 shows a drawing of a SOHO Ethernet LAN. The figure shows a single LAN switch, five cables, and five other Ethernet nodes: three PCs, a printer, and one network device called a *router*. (The router connects the LAN to the WAN, in this case to the Internet.)

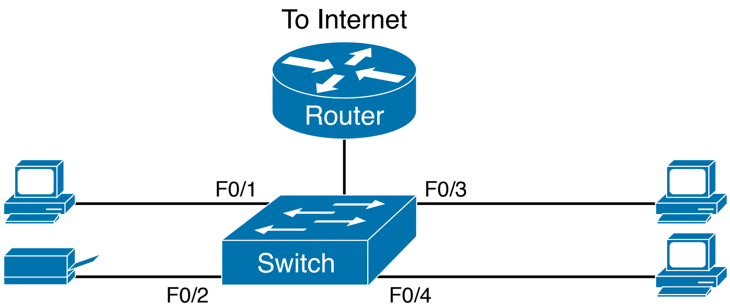

Figure 2-1 *Typical Small Ethernet-Only SOHO LAN*

Although Figure 2-1 shows the switch and router as separate devices, many SOHO Ethernet LANs today combine the router and switch into a single device. Vendors sell consumer-grade integrated networking devices that work as a router and Ethernet switch, as well as doing other functions. These devices typically have "router" on the packaging, but many models also have four-port or eight-port Ethernet LAN switch ports built in to the device.

Typical SOHO LANs today also support wireless LAN connections. You can build a single SOHO LAN that includes both Ethernet LAN technology as well as wireless LAN technology, which is also defined by the IEEE. Wireless LANs, defined by the IEEE using standards that begin with 802.11, use radio waves to send the bits from one node to the next.

Most wireless LANs rely on yet another networking device: a wireless LAN access point (AP). The AP acts somewhat like an Ethernet switch, in that all the wireless LAN nodes communicate with the wireless AP. If the network uses an AP that is a separate physical device, the AP then needs a single Ethernet link to connect the AP to the Ethernet LAN, as shown in Figure 2-2.

Note that Figure 2-2 shows the router, Ethernet switch, and wireless LAN access point as three separate devices so that you can better understand the different roles. However, most SOHO networks today would use a single device, often labeled as a "wireless router," that does all these functions.

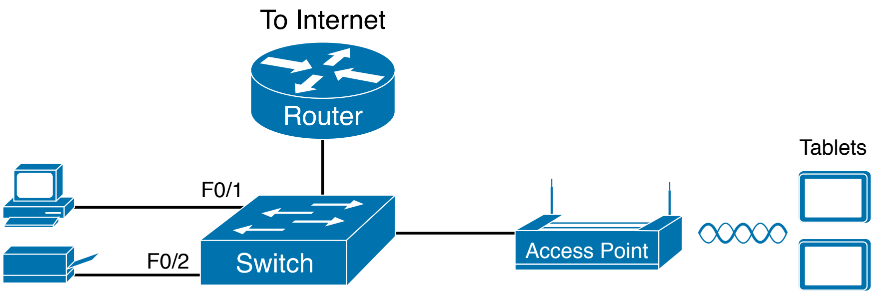

Figure 2-2 *Typical Small Wired and Wireless SOHO LAN*

Typical Enterprise LANs

Enterprise networks have similar needs compared to a SOHO network, but on a much larger scale. For example, enterprise Ethernet LANs begin with LAN switches installed in a wiring closet behind a locked door on each floor of a building. The electricians install the Ethernet cabling from that wiring closet to cubicles and conference rooms where devices might need to connect to the LAN. At the same time, most enterprises also support wireless LANs in the same space, to allow people to roam around and still work and to support a growing number of devices that do not have an Ethernet LAN interface.

Figure 2-3 shows a conceptual view of a typical enterprise LAN in a three-story building. Each floor has an Ethernet LAN switch and a wireless LAN AP. To allow communication between floors, each per-floor switch connects to one centralized distribution switch. For example, PC3 can send data to PC2, but it would first flow through switch SW3 to the first floor to the distribution switch (SWD) and then back up through switch SW2 on the second floor.

Key Topic

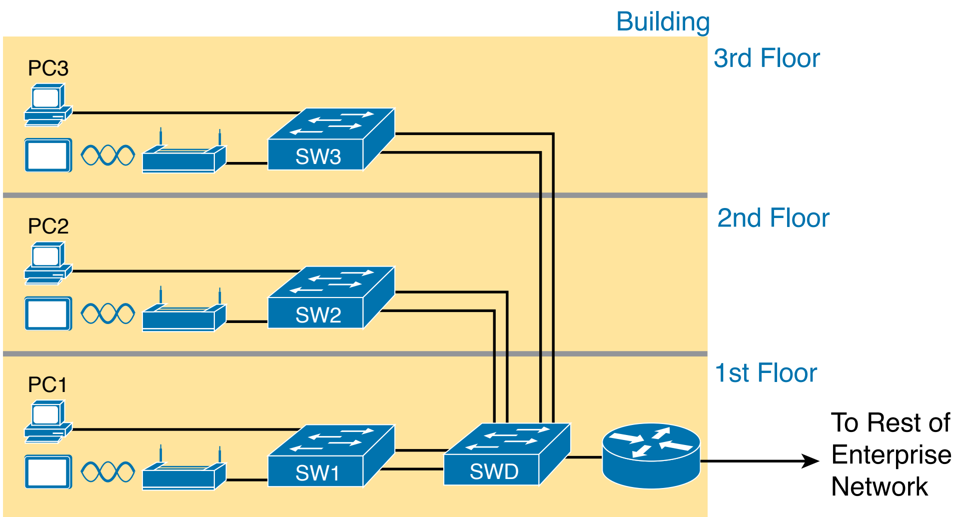

Figure 2-3 *Single-Building Enterprise Wired and Wireless LAN*

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

1 A **2** C **3** B **4** B, D, and E **5** B **6** B **7** C **8** B, C, and E **9** C and D

The figure also shows the typical way to connect a LAN to a WAN using a router. LAN switches and wireless access points work to create the LAN itself. Routers connect to both the LAN and the WAN. To connect to the LAN, the router simply uses an Ethernet LAN interface and an Ethernet cable, as shown on the lower right of Figure 2-3.

The rest of this chapter focuses on Ethernet in particular.

The Variety of Ethernet Physical Layer Standards

The term *Ethernet* refers to an entire family of standards. Some standards define the specifics of how to send data over a particular type of cabling, and at a particular speed. Other standards define protocols, or rules, that the Ethernet nodes must follow to be a part of an Ethernet LAN. All these Ethernet standards come from the IEEE and include the number 802.3 as the beginning part of the standard name.

Ethernet supports a large variety of options for physical Ethernet links given its long history over the last 40 or so years. Today, Ethernet includes many standards for different kinds of optical and copper cabling, and for speeds from 10 megabits per second (Mbps) up to 400 gigabits per second (Gbps). The standards also differ as far as the types and length of the cables.

The most fundamental cabling choice has to do with the materials used inside the cable for the physical transmission of bits: either copper wires or glass fibers. Devices using UTP cabling transmit data over electrical circuits via the copper wires inside the cable. Fiber-optic cabling, the more expensive alternative, allows Ethernet nodes to send light over glass fibers in the center of the cable. Although more expensive, optical cables typically allow longer cabling distances between nodes.

To be ready to choose the products to purchase for a new Ethernet LAN, a network engineer must know the names and features of the different Ethernet standards supported in Ethernet products. The IEEE defines Ethernet physical layer standards using a couple of naming conventions. The formal name begins with 802.3 followed by some suffix letters. The IEEE also uses more meaningful shortcut names that identify the speed, as well as a clue about whether the cabling is UTP (with a suffix that includes *T*) or fiber (with a suffix that includes *X*). Table 2-2 lists a few Ethernet physical layer standards. First, the table lists enough names so that you get a sense of the IEEE naming conventions.

Key Topic

Table 2-2 Examples of Types of Ethernet

Speed	Common Name	Informal IEEE Standard Name	Formal IEEE Standard Name	Cable Type, Maximum Length
10 Mbps	Ethernet	10BASE-T	802.3	Copper, 100 m
100 Mbps	Fast Ethernet	100BASE-T	802.3u	Copper, 100 m
1000 Mbps	Gigabit Ethernet	1000BASE-LX	802.3z	Fiber, 5000 m
1000 Mbps	Gigabit Ethernet	1000BASE-T	802.3ab	Copper, 100 m
10 Gbps	10 Gig Ethernet	10GBASE-T	802.3an	Copper, 100 m

NOTE Fiber-optic cabling contains long thin strands of fiberglass. The attached Ethernet nodes send light over the glass fiber in the cable, encoding the bits as changes in the light.

NOTE You might expect that a standard that began at the IEEE almost 40 years ago would be stable and unchanging, but the opposite is true. The IEEE, along with active industry partners, continues to develop new Ethernet standards with longer distances, different cabling options, and faster speeds. Check out the Ethernet Alliance web page (www.EthernetAlliance.org) and look for the roadmap for some great graphics and tables about the latest happenings with Ethernet.

Consistent Behavior over All Links Using the Ethernet Data-Link Layer

Although Ethernet includes many physical layer standards, Ethernet acts like a single LAN technology because it uses the same data-link layer standard over all types of Ethernet physical links. That standard defines a common Ethernet header and trailer. (As a reminder, the header and trailer are bytes of overhead data that Ethernet uses to do its job of sending data over a LAN.) No matter whether the data flows over a UTP cable or any kind of fiber cable, and no matter the speed, the data-link header and trailer use the same format.

While the physical layer standards focus on sending bits over a cable, the Ethernet data-link protocols focus on sending an *Ethernet frame* from source to destination Ethernet node. From a data-link perspective, nodes build and forward frames. As first defined in Chapter 1, "Introduction to TCP/IP Networking," the term *frame* specifically refers to the header and trailer of a data-link protocol, plus the data encapsulated inside that header and trailer. The various Ethernet nodes simply forward the frame, over all the required links, to deliver the frame to the correct destination.

Figure 2-4 shows an example of the process. In this case, PC1 sends an Ethernet frame to PC3. The frame travels over a UTP link to Ethernet switch SW1, then over fiber links to Ethernet switches SW2 and SW3, and finally over another UTP link to PC3. Note that the bits actually travel at four different speeds in this example: 10 Mbps, 1 Gbps, 10 Gbps, and 100 Mbps, respectively.

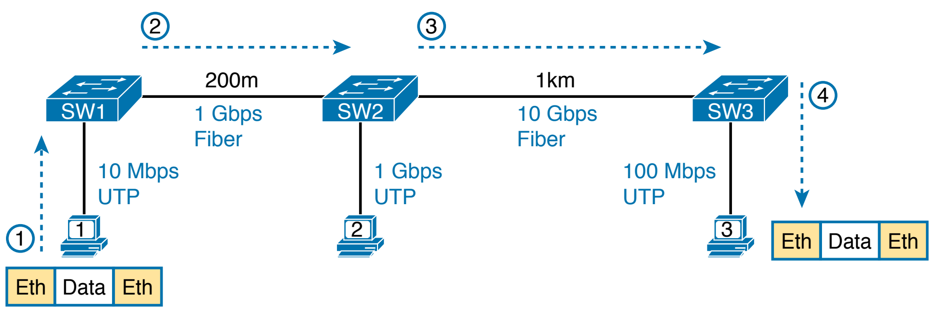

Figure 2-4 *Ethernet LAN Forwards a Data-Link Frame over Many Types of Links*

So, what is an Ethernet LAN? It is a combination of user devices, LAN switches, and different kinds of cabling. Each link can use different types of cables, at different speeds.

However, they all work together to deliver Ethernet frames from the one device on the LAN to some other device.

The rest of this chapter takes these concepts a little deeper. The next section examines how to build a physical Ethernet network using UTP cabling, followed by a similar look at using fiber cabling to build Ethernet LANs. The chapter ends with some discussion of the rules for forwarding frames through an Ethernet LAN.

Building Physical Ethernet LANs with UTP

The next section of this chapter focuses on the individual physical links between any two Ethernet nodes, specifically those that use Unshielded Twisted Pair (UTP) cabling. Before the Ethernet network as a whole can send Ethernet frames between user devices, each node must be ready and able to send data over an individual physical link.

This section focuses on the three most commonly used Ethernet standards: 10BASE-T (Ethernet), 100BASE-T (Fast Ethernet, or FE), and 1000BASE-T (Gigabit Ethernet, or GE). Specifically, this section looks at the details of sending data in both directions over a UTP cable. It then examines the specific wiring of the UTP cables used for 10-Mbps, 100-Mbps, and 1000-Mbps Ethernet.

Transmitting Data Using Twisted Pairs

While it is true that Ethernet sends data over UTP cables, the physical means to send the data uses electricity that flows over the wires inside the UTP cable. To better understand how Ethernet sends data using electricity, break the idea down into two parts: how to create an electrical circuit and then how to make that electrical signal communicate 1s and 0s.

First, to create one electrical circuit, Ethernet defines how to use the two wires inside a single twisted pair of wires, as shown in Figure 2-5. The figure does not show a UTP cable between two nodes, but instead shows two individual wires that are inside the UTP cable. An electrical circuit requires a complete loop, so the two nodes, using circuitry on their Ethernet ports, connect the wires in one pair to complete a loop, allowing electricity to flow.

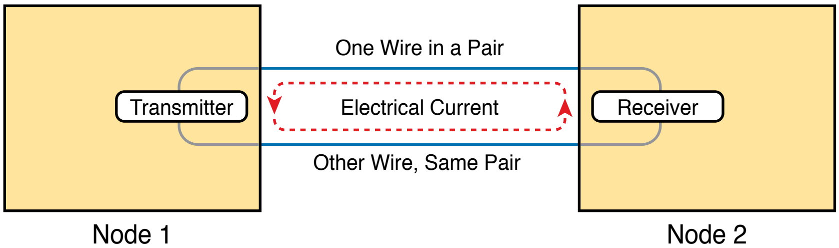

Figure 2-5 *Creating One Electrical Circuit over One Pair to Send in One Direction*

To send data, the two devices follow some rules called an *encoding scheme*. The idea works a lot like when two people talk using the same language: The speaker says some words in a particular language, and the listener, because she speaks the same language, can understand the spoken words. With an encoding scheme, the transmitting node changes the electrical signal over time, while the other node, the receiver, using the same rules, interprets those changes as either 0s or 1s. (For example, 10BASE-T uses an encoding scheme that encodes a binary 0 as a transition from higher voltage to lower voltage during the middle of a 1/10,000,000th-of-a-second interval.)

Note that in an actual UTP cable, the wires will be twisted together, instead of being parallel as shown in Figure 2-5. The twisting helps solve some important physical transmission issues. When electrical current passes over any wire, it creates electromagnetic interference (EMI) that interferes with the electrical signals in nearby wires, including the wires in the same cable. (EMI between wire pairs in the same cable is called *crosstalk*.) Twisting the wire pairs together helps cancel out most of the EMI, so most networking physical links that use copper wires use twisted pairs.

Breaking Down a UTP Ethernet Link

The term *Ethernet link* refers to any physical cable between two Ethernet nodes. To learn about how a UTP Ethernet link works, it helps to break down the physical link into those basic pieces, as shown in Figure 2-6: the cable itself, the connectors on the ends of the cable, and the matching ports on the devices into which the connectors will be inserted.

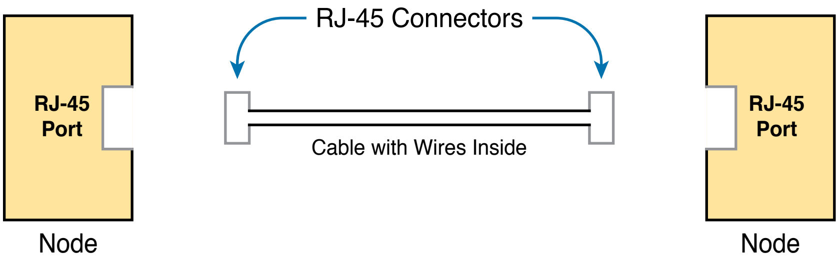

Figure 2-6 *Basic Components of an Ethernet Link*

First, think about the UTP cable itself. The cable holds some copper wires, grouped as twisted pairs. The 10BASE-T and 100BASE-T standards require two pairs of wires, while the 1000BASE-T standard requires four pairs. Each wire has a color-coded plastic coating, with the wires in a pair having a color scheme. For example, for the blue wire pair, one wire's coating is all blue, while the other wire's coating is blue-and-white striped.

Many Ethernet UTP cables use an RJ-45 connector on both ends. The RJ-45 connector has eight physical locations into which the eight wires in the cable can be inserted, called *pin positions*, or simply *pins*. These pins create a place where the ends of the copper wires can touch the electronics inside the nodes at the end of the physical link so that electricity can flow.

NOTE If available, find a nearby Ethernet UTP cable and examine the connectors closely. Look for the pin positions and the colors of the wires in the connector.

To complete the physical link, the nodes each need an RJ-45 *Ethernet port* that matches the RJ-45 connectors on the cable so that the connectors on the ends of the cable can connect to each node. PCs often include this RJ-45 Ethernet port as part of a network interface card (NIC), which can be an expansion card on the PC or can be built in to the system itself.

Switches typically have many RJ-45 ports because switches give user devices a place to connect to the Ethernet LAN. Figure 2-7 shows photos of the cables, connectors, and ports.

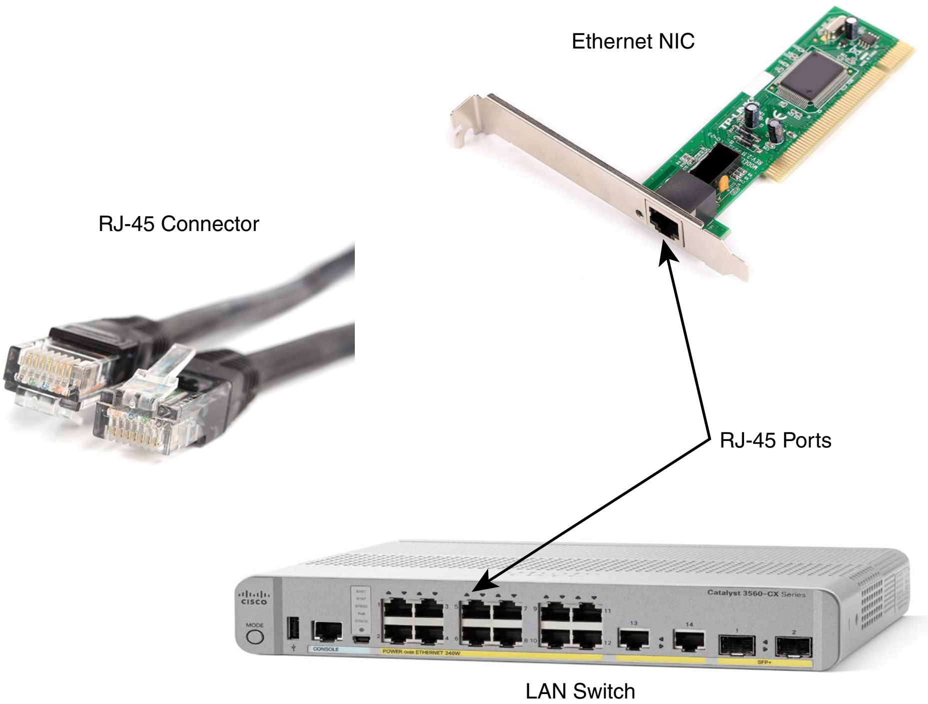

Figure 2-7 *RJ-45 Connectors and Ports (Ethernet NIC © Oleg Begunenko/123RF, RJ-45 Connector © Anton Samsonov/123RF)*

The figure shows a connector on the left and ports on the right. The left shows the eight pin positions in the end of the RJ-45 connector. The upper right shows an Ethernet NIC that is not yet installed in a computer. The lower-right part of the figure shows the side of a Cisco switch, with multiple RJ-45 ports, allowing multiple devices to easily connect to the Ethernet network.

Finally, while RJ-45 connectors with UTP cabling can be common, Cisco LAN switches often support other types of connectors as well. When you buy one of the many models of Cisco switches, you need to think about the mix and numbers of each type of physical ports you want on the switch.

To give its customers flexibility as to the type of Ethernet links, even after the customer has bought the switch, Cisco switches include some physical ports whose port hardware (the transceiver) can be changed later, after you purchase the switch.

For example, Figure 2-8 shows a photo of a Cisco switch with one of the swappable transceivers. In this case, the figure shows an enhanced small form-factor pluggable (SFP+) transceiver, which runs at 10 Gbps, just outside two SFP+ slots on a Cisco 3560CX switch. The SFP+ itself is the silver-colored part below the switch, with a black cable connected to it.

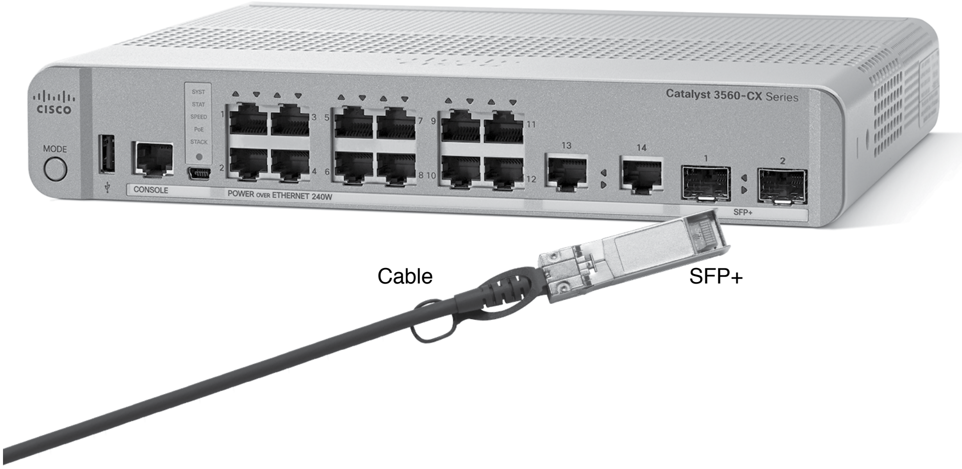

Figure 2-8 *10-Gbps SFP+ with Cable Sitting Just Outside a Catalyst 3560CX Switch*

Gigabit Ethernet Interface Converter (GBIC): The original form factor for a removable transceiver for Gigabit interfaces; larger than SFPs

Small Form Pluggable (SFP): The replacement for GBICs, used on Gigabit interfaces, with a smaller size, taking less space on the side of the networking card or switch.

Small Form Pluggable Plus (SFP+): Same size as the SFP, but used on 10-Gbps interfaces. (The Plus refers to the increase in speed compared to SFPs.)

UTP Cabling Pinouts for 10BASE-T and 100BASE-T

So far in this section, you have learned about the equivalent of how to drive a truck on a 1000-acre ranch: You could drive the truck all over the ranch, any place you wanted to go, and the police would not mind. However, as soon as you get on the public roads, the police want you to behave and follow the rules. Similarly, so far this chapter has discussed the general principles of how to send data, but it has not yet detailed some important rules for Ethernet cabling: the rules of the road so that all the devices send data using the right wires inside the cable.

This next topic discusses some of those rules, specifically for the 10-Mbps 10BASE-T and the 100-Mbps 100BASE-T. Both use UTP cabling in similar ways (including the use of only two wire pairs). A short comparison of the wiring for 1000BASE-T (Gigabit Ethernet), which uses four pairs, follows.

Straight-Through Cable Pinout

10BASE-T and 100BASE-T use two pairs of wires in a UTP cable, one for each direction, as shown in Figure 2-9. The figure shows four wires, all of which sit inside a single UTP cable that connects a PC and a LAN switch. In this example, the PC on the left transmits using the top pair, and the switch on the right transmits using the bottom pair.

Key Topic

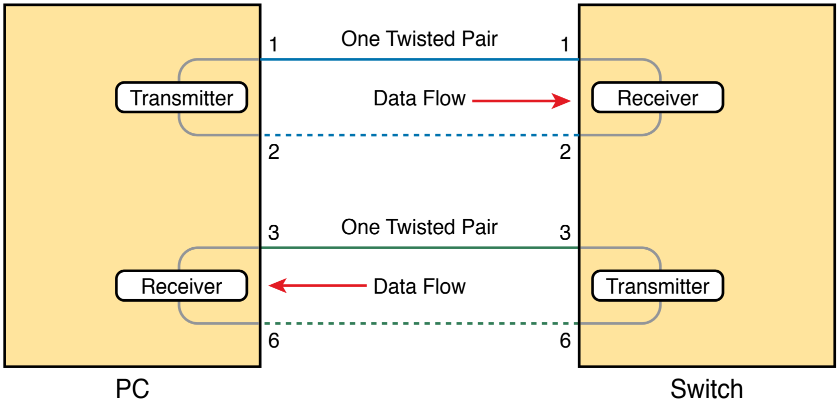

Figure 2-9 *Using One Pair for Each Transmission Direction with 10- and 100-Mbps Ethernet*

For correct transmission over the link, the wires in the UTP cable must be connected to the correct pin positions in the RJ-45 connectors. For example, in Figure 2-9, the transmitter on the PC on the left must know the pin positions of the two wires it should use to transmit. Those two wires must be connected to the correct pins in the RJ-45 connector on the switch so that the switch's receiver logic can use the correct wires.

To understand the wiring of the cable—which wires need to be in which pin positions on both ends of the cable—you need to first understand how the NICs and switches work. As a rule, Ethernet NIC transmitters use the pair connected to pins 1 and 2; the NIC receivers use a pair of wires at pin positions 3 and 6. LAN switches, knowing those facts about what Ethernet NICs do, do the opposite: Their receivers use the wire pair at pins 1 and 2, and their transmitters use the wire pair at pins 3 and 6.

To allow a PC NIC to communicate with a switch, the UTP cable must also use a *straight-through cable pinout*. The term *pinout* refers to the wiring of which color wire is placed in each of the eight numbered pin positions in the RJ-45 connector. An Ethernet straight-through cable connects the wire at pin 1 on one end of the cable to pin 1 at the other end of the cable; the wire at pin 2 needs to connect to pin 2 on the other end of the cable; pin 3 on one end connects to pin 3 on the other, and so on, as seen in Figure 2-10. Also, it uses the wires in one wire pair at pins 1 and 2, and another pair at pins 3 and 6.

Key Topic

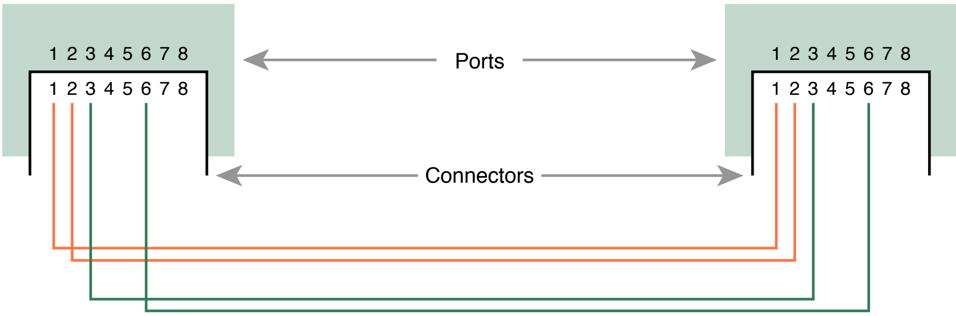

Figure 2-10 *10BASE-T and 100BASE-T Straight-Through Cable Pinout*

Figure 2-11 shows one final perspective on the straight-through cable pinout. In this case, PC Larry connects to a LAN switch. Note that the figure again does not show the UTP cable, but instead shows the wires that sit inside the cable, to emphasize the idea of wire pairs and pins.

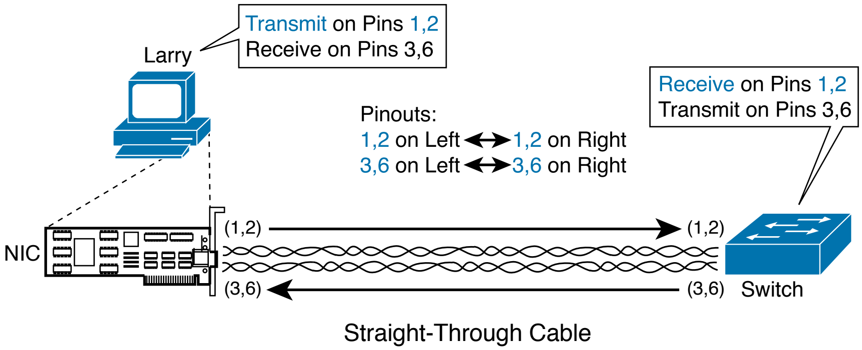

Figure 2-11 *Ethernet Straight-Through Cable Concept*

A straight-through cable works correctly when the nodes use opposite pairs for transmitting data. However, when two like devices connect to an Ethernet link, they both transmit on the same pins. In that case, you then need another type of cabling pinout called a *crossover cable*. The crossover cable pinout crosses the pair at the transmit pins on each device to the receive pins on the opposite device.

While that previous sentence is true, this concept is much clearer with a figure such as Figure 2-12. The figure shows what happens on a link between two switches. The two switches both transmit on the pair at pins 3 and 6, and they both receive on the pair at pins 1 and 2. So, the cable must connect a pair at pins 3 and 6 on each side to pins 1 and 2 on the other side, connecting to the other node's receiver logic. The top of the figure shows the literal pin-outs, and the bottom half shows a conceptual diagram.

Key Topic

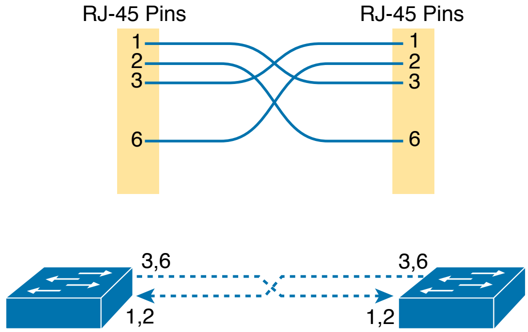

Figure 2-12 *Crossover Ethernet Cable*

Choosing the Right Cable Pinouts

For the exam, you should be well prepared to choose which type of cable (straight-through or crossover) is needed in each part of the network. The key is to know whether a device acts like a PC NIC, transmitting at pins 1 and 2, or like a switch, transmitting at pins 3 and 6. Then, just apply the following logic:

Crossover cable: If the endpoints transmit on the same pin pair

Straight-through cable: If the endpoints transmit on different pin pairs

Table 2-3 lists the devices and the pin pairs they use, assuming that they use 10BASE-T and 100BASE-T.

Key Topic

Table 2-3 10BASE-T and 100BASE-T Pin Pairs Used

Transmits on Pins 1,2	Transmits on Pins 3,6
PC NICs	Hubs
Routers	Switches
Wireless access point (Ethernet interface)	—

For example, Figure 2-13 shows a campus LAN in a single building. In this case, several straight-through cables are used to connect PCs to switches. In addition, the cables connecting the switches require crossover cables.

Key Topic

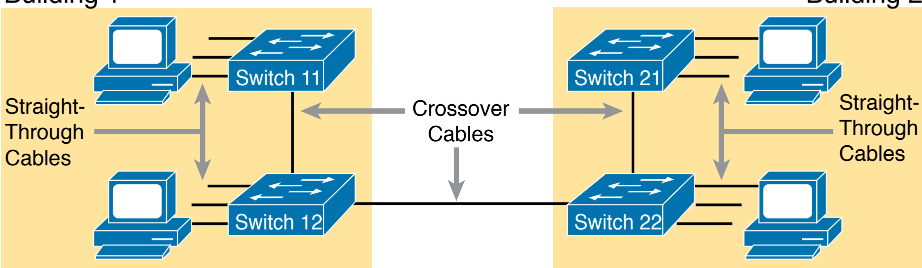

Figure 2-13 *Typical Uses for Straight-Through and Crossover Ethernet Cables*

NOTE If you have some experience with installing LANs, you might be thinking that you have used the wrong cable before (straight-through or crossover), but the cable worked. Cisco switches have a feature called *auto-mdix* that notices when the wrong cable is used and automatically changes its logic to make the link work. However, for the exams, be ready to identify whether the correct cable is shown in the figures.

UTP Cabling Pinouts for 1000BASE-T

1000BASE-T (Gigabit Ethernet) differs from 10BASE-T and 100BASE-T as far as the cabling and pinouts. First, 1000BASE-T requires four wire pairs. Second, it uses more advanced electronics that allow both ends to transmit and receive simultaneously on each wire pair. However, the wiring pinouts for 1000BASE-T work almost identically to the earlier standards, adding details for the additional two pairs.

The straight-through cable for 1000BASE-T uses the four wire pairs to create four circuits, but the pins need to match. It uses the same pinouts for two pairs as do the 10BASE-T and

100BASE-T standards, and it adds a pair at pins 4 and 5 and the final pair at pins 7 and 8, as shown in Figure 2-14.

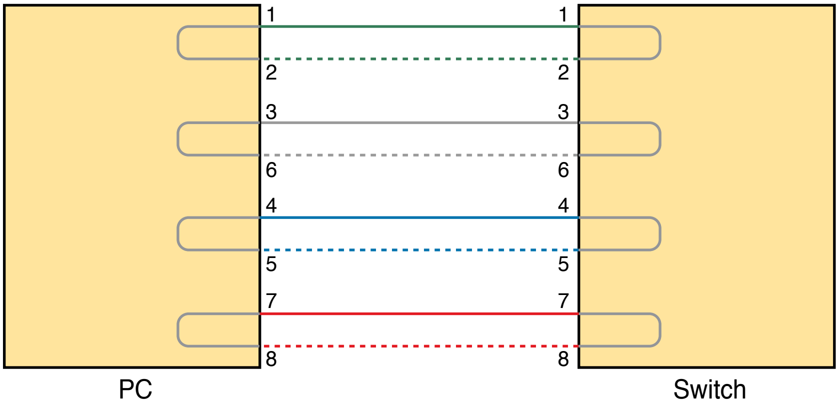

Figure 2-14 *Four-Pair Straight-Through Cable to 1000BASE-T*

The Gigabit Ethernet crossover cable crosses the same two-wire pairs as the crossover cable for the other types of Ethernet (the pairs at pins 1,2 and 3,6). It also crosses the two new pairs as well (the pair at pins 4,5 with the pair at pins 7,8).

Building Physical Ethernet LANs with Fiber

The capability of many UTP-based Ethernet standards to use a cable length up to 100 meters means that the majority of Ethernet cabling in an enterprise uses UTP cables. The distance from an Ethernet switch to every endpoint on the floor of a building will likely be less than 100m. In some cases, however, an engineer might prefer to use fiber cabling for some links in an Ethernet LAN, first to reach greater distances, but for other reasons as well. This next section examines a few of the tradeoffs after discussing the basics of how to transmit data over fiber cabling.

Fiber Cabling Transmission Concepts

Fiber-optic cabling uses glass as the medium through which light passes, varying that light over time to encode 0s and 1s. It might seem strange at first to use glass given that most of us think of glass in windows. Window glass is hard, unbending, and if you hit or bend it enough, the glass will probably shatter—all bad characteristics for a cabling material.

Instead, fiber-optic cables use fiberglass, which allows a manufacturer to spin a long thin string (fiber) of flexible glass. A fiber-optic cable holds the fiber in the middle of the cable, allowing the light to pass through the glass—which is a very important attribute for the purposes of sending data.

Although sending data through a glass fiber works well, the glass fiber by itself needs some help. The glass could break, so the glass fiber needs some protection and strengthening. Figure 2-15 shows a cutout with the components of a fiber cable for perspective.