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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 CCENT/CCNA ICND1 100-101 Network Simulator Lite software included for free on the DVD that accompanies this book. This software, which simulates the experience of working on actual Cisco routers and switches, contains the following 13 free lab exercises:

1. Configuring IP Addresses I Skill Builder Lab
2. Configuring IP Addresses II Skill Builder Lab
3. Connected Routes Skill Builder Lab
4. Static Routes I Skill Builder Lab
5. Static Routes II Skill Builder Lab
6. Subnet Zero I Skill Builder Lab
7. Loopback Interfaces Skill Builder Lab
8. Subnet ID Calculation I Subnetting Exercise Lab
9. IP Address Rejection I Subnetting Exercise Lab
10. IP Route Selection I Subnetting Exercise Lab
11. Subnetting and Addressing I Configuration Scenario
12. Static Routing I Configuration Scenario
13. Network Discovery II Troubleshooting Scenario

If you are interested in exploring more hands-on labs and practicing configuration and troubleshooting with more router and switch commands, check out our full simulator product offerings at http://www.pearsonitcertification.com/networksimulator.

CCENT ICND1 Network Simulator Lite minimum system requirements:

- Microsoft Windows XP (SP3), Windows Vista (32-bit/64-bit) with SP1, Windows 7 (32-bit/64-bit) or Windows 8 (32-bit/64-bit, x86 processors), Mac OS X 10.6, 10.7, or 10.8
- Intel Pentium III 1GHz or faster processor
- 512 MB RAM (1GB recommended)
- 1 GB hard disk space
- 32-bit color depth at 1024x768 resolution
- Adobe Acrobat Reader version 8 and above

Other applications installed during installation:

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- Captive JRE 6

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Wendell Odom, CCIE No. 1624, has been in the networking industry since 1981. He has worked as a network engineer, consultant, systems engineer, instructor, and course developer; he currently works writing and creating certification tools. He is author of all the previous books in the Cisco Press CCNA Official Certification Guide series, as well as the *CCNP ROUTE 642-902 Official Certification Guide*, the *QoS 642-642 Exam Certification Guide*, coauthor of the *CCIE Routing and Switch Official Certification Guide*, and several other titles. He is also a consultant for the CCNA 640-802 Network Simulator from Pearson and for a forthcoming replacement version of that product. He maintains study tools, links to his blogs, and other resources at www.certskills.com.

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 25 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 through 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, Elan was among the first to attain Cisco System's 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.

Dedication

In memory of William E. York: Mom's dad, Paw Paw, wearing blue-jean overalls, always smiling, tagging along at the water works, fishing on Juliet Lake, the Catawba worm tree, and his big-belly laugh.

Acknowledgments

While this book is published as a first edition for various reasons, this book and the companion *Cisco CCNA Routing and Switching ICND2 200-101 Official Cert Guide* represent the seventh books in a long line of Cisco Press books focused on helping people pass the CCENT and CCNA Routing and Switching certifications. Given the long history, many people have worked on these books from their inception back in 1998. To those many people who have touched these books over these past 15 years—technical edits, development, copyedits, project editing, proofing, indexing, managing the production process, interior design, cover design, marketing, and all the other details that happen to get these books out the door—thanks so much for playing a role in this CCENT/CCNA franchise.

Many of the contributors to the previous editions returned to work on creating these new editions, including Development Editor Drew Cupp. Drew kept all the details straight, with my frequent changes to the outlines and titles, keeping the sequencing on track, while still doing his primary job: keeping the text and features clear and consistent throughout the book. Thanks, Drew, for walking me through the development.

As for the technical editor, Elan Beer did his normal job. That is, he did his usual amazing job of doing every part of the technical edit job well, from finding the tiny little cross-reference errors that sit pages apart, to anticipating how readers might misunderstand certain phrasing, to being all over the details of every technical feature. Fantastic job as usual—thanks, Elan.

Brett Bartow again served as Executive Editor on the book, as he has almost since the beginning of these titles. When my family has asked me over the years about Brett's role with these books, the best single word definition is "teammate." Brett might be employed at Pearson Education, but he is always working with me and for me, watching out for the business end of the books and finding ways to make the publisher/author relationship work seamlessly. Thanks for another great ride through these books, Brett!

Word docs go in and out come these beautiful finished products. Thanks to Sandra Schroeder, Tonya Simpson, and all the production team for working through the magic that takes those Word docs and makes the beautiful finished product. From fixing all my grammar, crummy word choices, and passive-voice sentences, and then pulling the design and layout together, they do it all—thanks for putting it all together and making it look easy. And Tonya, managing the details through several process steps for roughly 100 elements between the pair of CCNA books in a short time frame—thanks for the amazing juggling act! And thanks especially for the attention to detail.

The figures for these books go through a little different process than they do for other books. Together we invested a large amount of labor in updating the figures for these books, both for the design, the volume of figures, and for the color versions of the figures for the electronic versions of the books. A special thanks goes out to Laura Robbins for working with me on the color and design standards early in the process. Also, thanks to Mike Tanamachi for drawing all the figures so well—and then redrawing them every time I changed my mind about something.

Thanks to Chris Burns of Certskills for all the work on the mind maps, both those used in the final product and those used to build the book, as well as for being a bit of a test case for some of the chapters.

A special thanks you to you readers who write in with suggestions, possible errors, and especially those of you who post online at the Cisco Learning Network. Without question, the comments I receive directly and overhear by participating at CLN made this edition a better book.

Thanks to my wife, Kris. Book schedules have a bigger impact that I would like, but you always make it work. Thanks to my daughter, Hannah, for all the great study/work breaks on some of these busy school days. And thanks to Jesus Christ, for this opportunity to write.

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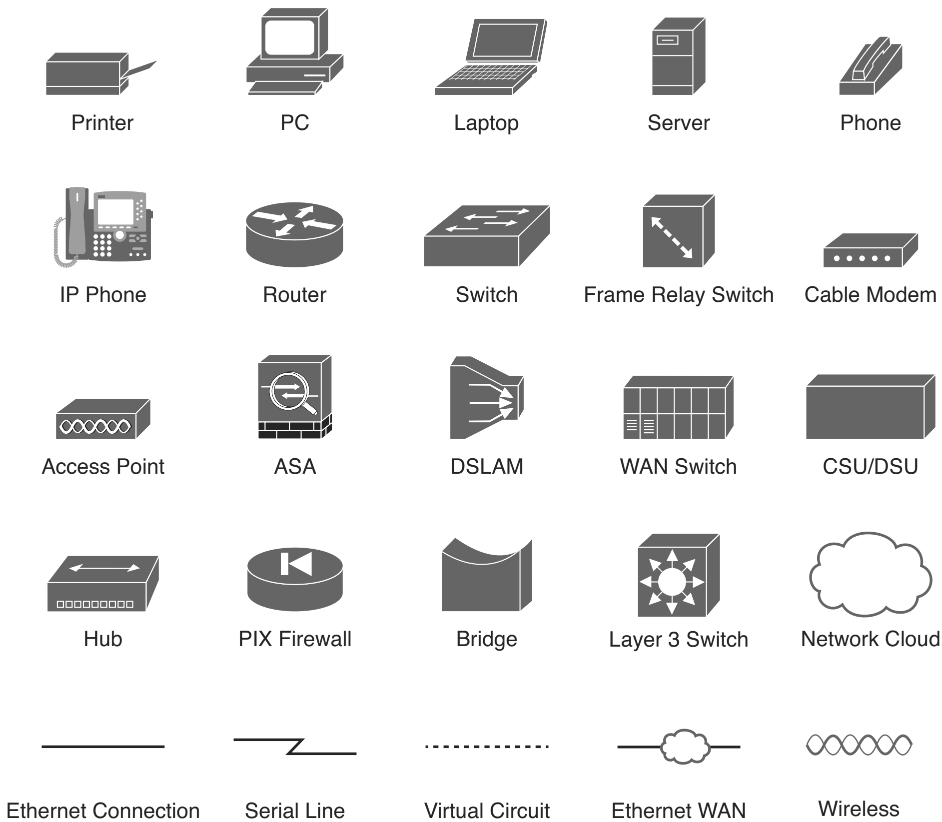

Command Syntax Conventions

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

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

Introduction

About the Exams

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

The Exams That Help You Achieve CCENT and CCNA

Cisco announced changes to the CCENT and CCNA Routing and Switching certifications, and the related 100-101 ICND1, 200-101 ICND2, and 200-120 CCNA exams, early in 2013. For those of you who understand the how the old Cisco ICND1, ICND2, and CCNA exams worked, the structure remains the same. For those of you new to Cisco certifications, this Introduction begins by discussing the basics.

Almost everyone new to Cisco certifications begins with either CCENT or CCNA Routing and Switching. CCENT certification requires knowledge and skills on about half as much material as does CCNA Routing and Switching, so CCENT is the easier first step.

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

The CCNA Routing and Switching certification gives you two options, as show in Figure I-1: Pass both the ICND1 and ICND2 exams, or just pass the CCNA exam. (Note that there is no separate certification for passing the ICND2 exam.)

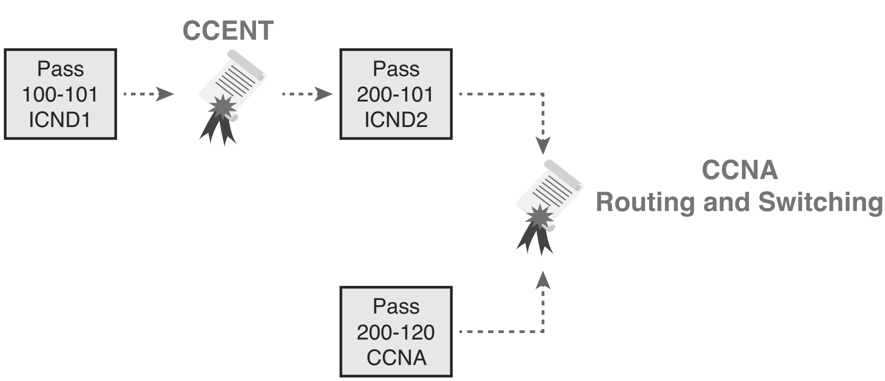

Figure I-1 *Cisco Entry-Level Certifications and Exams*

As you can see, although you can obtain the CCENT certification by taking the ICND1 exam, you do not have to be CCENT certified before you get your CCNA Routing and Switching certification. You can choose to take the CCNA exam and bypass the CCENT certification.

As for the topics themselves, the ICND1 and ICND2 exams cover different topics, but with some overlap required. For example, ICND1 covers the basics of the Open Shortest Path First (OSPF) routing protocol. ICND2 covers more detail about OSPF, but to discuss those additional details, ICND2 must rely on the parts of OSPF included in ICND1. Many topics in ICND2 build upon topics in ICND1, causing some overlap.

The CCNA exam covers all the topics in both ICND1 and ICND2—no more, no less.

Types of Questions on the Exams

The ICND1, ICND2, and CCNA exams all follow the same general format. At the testing center, you will sit in a quiet room with a PC. Before the exam timer begins, you will have a chance to do a few other tasks on the PC—for example, you can take a sample quiz just to get accustomed to the PC and the testing engine. Anyone who has user-level skills in getting around a PC should have no problems with the testing environment.

After the exam starts, the screen shows you question after question. The questions typically fall into one of the following categories:

- Multiple-choice (MC) single answer
- Multiple-choice (MC) multiple answer
- Testlet
- Drag-and-drop (DND)
- Simulated lab (Sim)
- Simlet

The first three items in the list are all actually multiple-choice questions. The multiple-choice format simply requires that you point and click a circle beside the correct answer(s). Cisco traditionally tells you how many answers you need to choose, and the testing software prevents you from choosing too many answers. The Testlet style gives you one larger scenario statement, with multiple different multichoice questions about that one scenario.

Drag-and-drop questions require you to move some items around on the GUI. You left-click and hold, move a button or icon to another area, and release the mouse button to place the object somewhere else—typically into a list. So, for some questions, to get the question correct, you might need to put a list of five things in the proper order.

The last two types both use a network simulator to ask questions. Interestingly, the two types actually allow Cisco to assess two very different skills. First, Sim questions generally describe a problem, and your task is to configure one or more routers and switches to fix the problem. The exam then grades the question based on the configuration you changed or added.

The Simlet questions might well be the most difficult style of question on the exams. Simlet questions also use a network simulator, but instead of answering the question by changing the configuration, the question includes one or more MC questions. The questions require that you use the simulator to examine the current behavior of a network, interpreting the output of any show commands that you can remember to answer the question. While Sim questions require you to troubleshoot problems related to a configuration, Simlets require you to both analyze both working and broken networks, correlating show command output with your knowledge of networking theory and configuration commands.

You can watch and even experiment with these command types using the Cisco Exam Tutorial. To find the Cisco Certification Exam Tutorial, go to www.cisco.com and search for "exam tutorial."

What's on the CCNA Exam(s)?

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

Cisco tells the world the topics on each of its exams. Cisco wants the public to know both the variety of topics, and an idea about the kinds of knowledge and skills required for each topic, for every Cisco certification exam. To that end, Cisco publishes a set of exam topics for each exam.

Many Cisco exam topics list both a networking topic and an important verb. The verb tells us to what degree the topic must be understood, and what skills are required. The topic also implies the kinds of skills required for that topic. For example, one topic might start with "Describe…," another with "Configure…," another with "Verify…," and another might begin with "Troubleshoot…." That last topic has the highest required skill level, because to troubleshoot, you must understand the topic, be able to configure it (to see what's wrong with the configuration), and verify it (to find the root cause of the problem). By listing the topics and skill level, Cisco helps us all prepare for its exams.

Although the exam topics are helpful, keep in mind that Cisco adds a disclaimer that the posted exam topics for all of its certification exams are guidelines. Cisco makes the effort to keep the exam questions within the confines of the stated exam topics, and I know from talking to those involved that every question is analyzed for whether it fits within the stated exam topics.

ICND1 Exam Topics

Tables I-1 through I-7 lists the exam topics for the ICND1 exam. Following those tables, Tables I-8 through I-12 list the exam topics for ICND2. These tables note the book chapters in which each exam topic is covered.

The tables follow the Cisco organization of topics, by both grouping similar topics and listing subtopics. The subtopics simply give more specific terms and concepts to provide more detail about some exam topics. The tables show the main topics with bold, and the subtopics as indented text inside the tables.

Table I-1 ICND1 Exam Topics: Operation of IP Data Networks

Chapter	Operation of IP Data Networks
1–4, 6, 15	**Recognize the purpose and functions of various network devices such as Routers, Switches, Bridges and Hubs.**
1–4, 6, 15	**Select the components required to meet a given network specification.**
5	**Identify common applications and their impact on the network**
1	**Describe the purpose and basic operation of the protocols in the OSI and TCP/IP models.**
2–5, 6, 9, 16, 24, 25	**Predict the data flow between two hosts across a network.**
2, 6, 15	**Identify the appropriate media, cables, ports, and connectors to connect Cisco network devices to other network devices and hosts in a LAN**

Table I-2 ICND1 Exam Topics: LAN Switching Technologies

Chapter	LAN Switching Technologies
2, 6	**Determine the technology and media access control method for Ethernet networks**
6, 8, 9	**Identify basic switching concepts and the operation of Cisco switches**
6, 8	Collision Domains
6, 9	Broadcast Domains
6	Types of switching
6, 8, 9	CAM Table
7	**Configure and verify initial switch configuration including remote access management.**
7	Cisco IOS commands to perform basic switch setup
7, 18, 28	**Verify network status and switch operation using basic utilities such as ping, telnet and ssh.**
9	**Describe how VLANs create logically separate networks and the need for routing between them.**
9	**Explain network segmentation and basic traffic management concepts**
9	**Configure and verify VLANs**
9, 10	**Configure and verify trunking on Cisco switches**
9, 10	DTP
10	Auto negotiation

Table I-3 ICND1 Exam Topics: IP Addressing (IPv4 / IPv6)

Chapter	IP Addressing (IPv4/IPv6)
11	**Describe the operation and necessity of using private and public IP addresses for IPv4 addressing**
25, 26	**Identify the appropriate IPv6 addressing scheme to satisfy addressing requirements in a LAN/WAN environment.**
11, 19, 20, 21	**Identify the appropriate IPv4 addressing scheme using VLSM and summarization to satisfy addressing requirements in a LAN/WAN environment.**
27, 28, 29	**Describe the technological requirements for running IPv6 in conjunction with IPv4 such as dual stack**
25–28	**Describe IPv6 addresses**
25, 26	Global unicast
27	Multicast
27	Link local
26	Unique local
27	eui 64
28	autoconfiguration

Table I-4 ICND1 Exam Topics: IP Routing Technologies

Chapter	IP Routing Technologies
16	**Describe basic routing concepts**
16	CEF
16	Packet forwarding
16	Router lookup process
15–18, 27	**Configure and verify utilizing the CLI to set basic Router configuration**
16–18, 27	Cisco IOS commands to perform basic router setup
16, 27	**Configure and verify operation status of an ethernet interface**
16–18, 27–29	**Verify router configuration and network connectivity**
16–18, 27, 29	Cisco IOS commands to review basic router information and network connectivity
16, 29	**Configure and verify routing configuration for a static or default route given specific routing requirements**
4, 16, 17, 25, 29	**Differentiate methods of routing and routing protocols**
4, 17, 29	Static vs. Dynamic
17	Link state v. Distance Vector
16, 25	next hop
16, 25	ip routing table
17, 29	Passive interfaces
17, 29	**Configure and verify OSPF (single area)**
17, 29	Benefit of single area
17	Configure OSPF v2

Chapter	IP Routing Technologies
29	Configure OSPF v3
17, 29	Router ID
17, 29	Passive interface
16	**Configure and verify interVLAN routing (Router on a stick)**
16	sub interfaces
16	upstream routing
16	encapsulation
8, 16	**Configure SVI interfaces**

Table I-5 ICND1 Exam Topics: IP Services

Chapter	IP Services
18, 28	**Configure and verify DHCP (IOS Router)**
18, 28	configuring router interfaces to use DHCP
18	DHCP options
18	excluded addresses
18	lease time
22, 23	**Describe the types, features, and applications of ACLs**
22	Standard
23	Sequence numbers
23	Editing
23	Extended
23	Named
22, 23	Numbered
22	Log option
22, 23	**Configure and verify ACLs in a network environment**
23	Named
22, 23	Numbered
22	Log option
24	**Identify the basic operation of NAT**
24	Purpose
24	Pool
24	Static
24	1 to 1
24	Overloading
24	Source addressing
24	One way NAT
24	**Configure and verify NAT for given network requirements**
23	**Configure and verify NTP as a client**

Table I-6 ICND1 Exam Topics: Network Device Security

Chapter	Network Device Security
8, 15	**Configure and verify network device security features such as**
8, 15	Device password security
8, 15	Enable secret vs enable
23	Transport
23	Disable telnet
8	SSH
8	VTYs
23	Physical security
8	Service password
8	Describe external authentication methods
8, 10	**Configure and verify Switch Port Security features such as**
8	Sticky MAC
8	MAC address limitation
8, 10	Static/dynamic
8, 10	Violation modes
8, 10	Err disable
8, 10	Shutdown
8, 10	Protect restrict
8	Shutdown unused ports
8	Err disable recovery
8	Assign unused ports to an unused VLAN
23	Setting native VLAN to other than VLAN 1
22, 23	**Configure and verify ACLs to filter network traffic**
23	**Configure and verify an ACLs to limit telnet and SSH access to the router**

Table I-7 ICND1 Exam Topics: Troubleshooting

Chapter	Troubleshooting
12–15, 18–21, 25–28	**Troubleshoot and correct common problems associated with IP addressing and host configurations.**
9, 10	**Troubleshoot and Resolve VLAN problems**
9, 10	identify that VLANs are configured
9, 10	port membership correct
9, 10	IP address configured
9, 10	**Troubleshoot and Resolve trunking problems on Cisco switches**
9, 10	correct trunk states
9, 10	correct encapsulation configured
9, 10	correct vlans allowed
22, 23	**Troubleshoot and Resolve ACL issues**
22, 23	Statistics

Chapter	Troubleshooting
22, 23	Permitted networks
22, 23	Direction
22, 23	Interface
10	**Troubleshoot and Resolve Layer 1 problems**
10	Framing
10	CRC
10	Runts
10	Giants
10	Dropped packets
10	Late collision
10	Input / Output errors

ICND2 Exam Topics

Tables I-8 through I-12 list the exam topics for ICND2. These tables note the book chapters in which each exam topic is covered in the ICND2 book. Note that each table covers a main exam topic. Cisco released further information on each topic to several sublevels of hierarchy. In this table, those sublevels are indented to indicate the topic above them that they are related to.

Table I-8 ICND2 Exam Topics: LAN Switching Technologies

Chapters	LAN Switching Technologies
1	**Identify enhanced switching technologies**
1	RSTP
1	PVSTP
1	Etherchannels
1, 2	**Configure and verify PVSTP operation**
1, 2	describe root bridge election
2	spanning tree mode

Table I-9 ICND2 Exam Topics, IP Routing Technologies

Chapters	IP Routing Technologies
20	**Describe the boot process of Cisco IOS routers**
20	POST
20	Router bootup process
12	**Configure and verify operation status of a Serial interface.**
20, 21	**Manage Cisco IOS Files**
20	Boot preferences
20	Cisco IOS image(s)
21	Licensing
21	Show license
21	Change license

Chapters	IP Routing Technologies
8–11, 16–18	**Differentiate methods of routing and routing protocols**
8	Administrative distance
9	split horizon
8, 9, 17, 18	metric
8, 9, 17, 18	next hop
8, 17	**Configure and verify OSPF (single area)**
8, 11, 17	neighbor adjacencies
8, 11, 17	OSPF states
8, 17	Discuss Multi area
8	Configure OSPF v2
17	Configure OSPF v3
8, 17	Router ID
8, 17	LSA types
9, 10, 18	**Configure and verify EIGRP (single AS)**
9, 10, 18	Feasible Distance / Feasible Successors /Administrative distance
9, 18	Feasibility condition
9, 18	Metric composition
9, 10, 18	Router ID
9, 10	Auto summary
9, 10, 18	Path selection
9, 10, 18	Load balancing
9, 10, 18	Equal
9, 10, 18	Unequal
9, 10, 18	Passive interface

Table I-10 ICND2 Exam Topics, IP Services

Chapters	IP Services
6	**Recognize High availability (FHRP)**
6	VRRP
6	HSRP
6	GLBP
19	**Configure and verify Syslog**
19	Utilize Syslog Output
19	**Describe SNMP v2 & v3**

Table I-11 ICND2 Exam Topics, Troubleshooting

Chapters	Troubleshooting
3, 4, 5, 16	**Identify and correct common network problems**
19	**Utilize netflow data**
2	**Troubleshoot and Resolve Spanning Tree operation issues**
2	root switch
2	priority
2	mode is correct
2	port states
4, 5, 16	**Troubleshoot and Resolve routing issues**
4, 5, 16	routing is enabled
4, 5, 16	routing table is correct
4, 5, 16	correct path selection
11, 17	**Troubleshoot and Resolve OSPF problems**
11, 17	neighbor adjacencies
11, 17	Hello and Dead timers
11, 17	OSPF area
11, 17	Interface MTU
11, 17	Network types
11, 17	Neighbor states
11, 17	OSPF topology database
11, 18	**Troubleshoot and Resolve EIGRP problems**
11, 18	neighbor adjacencies
11, 18	AS number
11, 18	Load balancing
11, 18	Split horizon
3, 5	**Troubleshoot and Resolve interVLAN routing problems**
5	Connectivity
5	Encapsulation
5	Subnet
3, 5	Native VLAN
3, 5	Port mode trunk status
12, 14	**Troubleshoot and Resolve WAN implementation issues**
12	Serial interfaces
12	PPP
14	Frame relay
19	**Monitor NetFlow statistics**
2	**Troubleshoot etherchannel problems**

Table I-12 ICND2 Exam Topics: WAN Technologies

Chapters	WAN Technologies
15, 13, 7	**Identify different WAN Technologies**
15	Metro Ethernet
15	VSAT
15	Cellular 3G / 4G
15	MPLS
12, 15	T1 / E1
15	ISDN
15	DSL
13	Frame relay
15	Cable
7	VPN
12	**Configure and verify a basic WAN serial connection**
12	**Configure and verify a PPP connection between Cisco routers**
14	**Configure and verify Frame Relay on Cisco routers**
15	**Implement and troubleshoot PPPoE**

200-120 CCNA Exam Topics

The 200-120 CCNA exam actually covers everything from both the ICND1 and ICND2 exams, at least based on the published exam topics. As of this writing, the CCNA exam topics include all topics in Tables I-1 through I-12. In short, CCNA = ICND1 + ICND2.

NOTE Because it is possible that the exam topics can change over time, it might be worth the time to double-check the exam topics as listed on the Cisco website (www.cisco.com/go/ccent and www.cisco.com/go/ccna). If Cisco does happen to add exam topics at a later date, note that Appendix B, "ICND1 Exam Updates," describes how to go to www.ciscopress.com and download additional information about those newly added topics.

About This Book

This book discusses the content and skills needed to pass the 100-101 ICND1 exam. That content also serves as basically the first half of the CCNA content, with this book's companion title, CCNA ICND2 200-101 Official Cert Guide, discussing the second half of the content.

Each of these books uses the same kinds of book features, so if you are reading both this book and the ICND2 book, there is no need to read the Introduction to the other book. Also, for those of you using both books to prepare for the 200-120 CCNA exam (rather than taking the two-exam option), the end of this Introduction lists a suggested reading plan.

Book Features

The most important and somewhat obvious objective of this book is to help you pass the ICND1 exam or the CCNA exam. In fact, if the primary objective of this book were different, the book's title would be misleading! However, the methods used in this book to help you pass the exams are also designed to make you much more knowledgeable about how to do your job.

This book uses several tools to help you discover your weak topic areas, to help you improve your knowledge and skills with those topics, and to prove that you have retained your knowledge of those topics. So, this book does not try to help you pass the exams only by memorization, but by truly learning and understanding the topics. The CCNA Routing and Switching certification is the foundation for many of the Cisco professional certifications, and it would be a disservice to you if this book did not help you truly learn the material. Therefore, this book helps you pass the CCNA exam by using the following methods:

- Helping you discover which exam topics you have not mastered
- Providing explanations and information to fill in your knowledge gaps
- Supplying exercises that enhance your ability to recall and deduce the answers to test questions
- Providing practice exercises on the topics and the testing process through test questions on the DVD

Chapter Features

To help you customize your study time using these books, the core chapters have several features that help you make the best use of your time:

- **"Do I Know This Already?" Quizzes:** Each chapter begins with a quiz that helps you determine the amount of time you need to spend studying that chapter.
- **Foundation Topics:** These are the core sections of each chapter. They explain the protocols, concepts, and configurations for the topics in that chapter.
- **Exam Preparation Tasks:** At the end of the "Foundation Topics" section of each chapter, the "Exam Preparation Tasks" section lists a series of study activities that should be done at the end of the chapter. Each chapter includes the activities that make the most sense for studying the topics in that chapter. The activities include the following:
  - **Review Key Topics:** The Key Topic icon is shown next to the most important items in the "Foundation Topics" section of the chapter. The Key Topics Review activity lists the key topics from the chapter and their corresponding page numbers. Although the contents of the entire chapter could be on the exam, you should definitely know the information listed in each key topic.
  - **Complete Tables and Lists from Memory:** To help you exercise your memory and memorize some lists of facts, many of the more important lists and tables from the chapter are included in a document on the DVD. This document lists only partial information, allowing you to complete the table or list.

- **Define Key Terms:** Although the exams are unlikely to ask a question like, "Define this term," the CCNA exams require that you learn and know a lot of networking terminology. This section lists the most important terms from the chapter, asking you to write a short definition and compare your answer to the Glossary at the end of this book.
- **Command Reference Tables:** Some book chapters cover a large amount of configuration and EXEC commands. These tables list the commands introduced in the chapter, along with an explanation. For exam preparation, use it for reference, but also read the table once when performing the Exam Preparation Tasks to make sure that you remember what all the commands do.

Part Review

The Part Review tasks help you prepare to apply all the concepts in this part of the book. (Each book part contains a number of related chapters.) The part review includes sample test questions, which require you to apply the concepts from multiple chapters in that part, uncovering what you truly understood and what you did not quite yet understand. The part review also uses mind map exercises that help you mentally connect concepts, configuration, and verification, so that no matter what perspective a single exam question takes, you can analyze and answer the question.

The part reviews list tasks, along with checklists so that you can track your progress. The following list explains the most common tasks you will see in the Part Review sections; note that not all Part Review sections use every type of task:

- **Review DIKTA Questions:** Although you have already seen the DIKTA questions from the chapters in a part, reanswering those questions can be a useful way to review facts. The Part Review section suggests that you repeat the DIKTA questions, but using the PCPT exam software that comes with the book, for extra practice in answering multi-choice questions on a computer.
- **Answer Part Review Questions:** The PCPT exam software includes several exam databases. One exam database holds Part Review questions, written specifically for Part Review. These questions purposefully include multiple concepts in each question, sometimes from multiple chapters, to help build the skills needed for the more challenging analysis questions on the exams.
- **Review Key Topics:** Yes, again! They are indeed the most important topics in each chapter.
- **Create Configuration Mind Maps:** Mind maps are graphical organizing tools that many people find useful when learning and processing how concepts fit together. The process of creating mind maps helps you build mental connections between concepts and configuration commands, as well as develop your recall of the individual commands. For this task, you can create the mind map on paper or using any mind-mapping or graphic organizer software. (For more information on mind maps, refer to this book's Introduction, in the section "About Mind Maps.")

- **Create Verification Mind Maps:** These mind-mapping exercises focus on helping you connect router and switch show commands to either networking concepts or to configuration commands. Simply create the mind maps on paper or use any mind-mapping or graphic organizer software.
- **Repeat Chapter Review Tasks:** (Optional) Browse through the Chapter Review tasks, and repeat any Chapter Review tasks that you think might help you with review at this point.

Final Prep Tasks

Chapter 30, "Final Review," near the end of this book, lists a series of preparation tasks that you can best use for your final preparation before taking the exam.

Other Features

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

- **DVD-based practice exam:** The companion DVD contains the powerful Pearson IT Certification Practice Test exam engine. You can take simulated ICND1 exams, as well as simulated CCNA exams, with the DVD and activation code included in this book. (You can take simulated ICND2 and CCNA exams with the DVD in the *Cisco CCNA Routing and Switching ICND2 200-101 Official Cert Guide*.)
- **CENT/CCNA ICND1 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). There's no need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the DVD in the back of this book.
- **eBook:** If you are interested in obtaining an eBook version of this title, we have included a special offer on a coupon card inserted in the DVD sleeve in the back of the book. This offer allows you to purchase the *Cisco CCENT/CCNA ICND1 100-101 Official Cert Guide* Premium Edition eBook and Practice Test at a 70 percent discount off the list price. In addition to three versions of the eBook—PDF (for reading on your computer), EPUB (for reading on your tablet, mobile device, or Nook or other eReader), and Mobi (the native Kindle version)—you will also receive additional practice test questions and enhanced practice test features.
- **Subnetting videos:** The companion DVD contains a series of videos that show you how to calculate various facts about IP addressing and subnetting (in particular, using the shortcuts described in this book).
- **Subnetting practice:** The companion DVD contains five appendices (D through H), and each appendix contains a set of IPv4 subnetting practice problems, with the answers, and with explanations of how the answers were found. This is a great resource to get ready to do subnetting well and fast.
- **Other practice:** The companion DVD contains four other appendices (I through L) that each contain other practice problems related to a particular chapter from the book. Use these for more practice on the particulars with some of the math- and process-oriented activities in the chapters.

- **Mentoring videos:** The DVD included with this book includes four other instructional videos, about the following topics: Switch Basics, CLI Navigation, Router Configuration, and VLANs.
- **Companion website:** The website www.ciscopress.com/title/9781587143854 posts up-to-the-minute materials that further clarify complex exam topics. Check this site regularly for new and updated postings written by the author that provide further insight into the more troublesome topics on the exam.
- **PearsonITCertification.com:** The www.pearsonitcertification.com website is a great resource for all things IT-certification related. Check out the great CCNA Routing and Switching articles, videos, blogs, and other certification preparation tools from the industry's best authors and trainers.
- **CCNA Simulator:** If you are looking for more hands-on practice, you might want to consider purchasing the CCNA Network Simulator. You can purchase a copy of this software from Pearson at http://pearsonitcertification.com/networksimulator or from other retail outlets. To help you with your studies, I have created a mapping guide that maps each of the labs in the simulator to the specific sections in these CCNA Cert Guides. You can get this mapping guide for free on the "Extras" tab of the companion website.
- **Author's website and blogs:** The author maintains a website that hosts tools and links useful when studying for CCENT and CCNA Routing and Switching. The site lists information to help you build your own lab, study pages that correspond to each chapter of this book and the ICND2 book, and links to the author's CCENT Skills blog and CCNA Skills blog. Start at www.certskills.com; check the tabs for study and blogs in particular.

Book Organization, Chapters, and Appendices

This book contains 29 core chapters, Chapters 1 through 29, with Chapter 30 including some suggestions for how to approach the actual exams. Each core chapter covers a subset of the topics on the ICND1 exam. The core chapters are organized into sections. The core chapters cover the following topics:

Part I: Networking Fundamentals

- **Chapter 1, "The TCP/IP and OSI Networking Models,"** introduces the terminology surrounding two different networking architectures, namely Transmission Control Protocol/Internet Protocol (TCP/IP) and Open Systems Interconnection (OSI).
- **Chapter 2, "Fundamental of Ethernet LANs,"** covers the concepts and terms used for the most popular option for the data link layer for local-area networks (LAN), namely Ethernet.
- **Chapter 3, "Fundamentals of WANs,"** covers the concepts and terms used for the most popular options for the data link layer for wide-area networks (WAN), including High-Level Data Link Control (HDLC).
- **Chapter 4, "Fundamentals of IPv4 Addressing and Routing":** The Internet Protocol (IP) is the main network layer protocol for TCP/IP. This chapter introduces the basics of IP version 4 (IPv4), including IPv4 addressing and routing.

- **Chapter 5, "Fundamentals of TCP/IP Transport and Applications":** The Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are the main transport layer protocols for TCP/IP. This chapter introduces the basics of TCP and UDP.

Part II: Ethernet LANs and Switches

- **Chapter 6, "Building Ethernet LANs with Switches,"** deepens and expands the introduction to LANs from Chapter 2, discussing the roles and functions of LAN switches.
- **Chapter 7, "Installing and Operating Cisco LAN Switches,"** explains how to access, examine, and configure Cisco Catalyst LAN switches.
- **Chapter 8, "Configuring Ethernet Switching,"** shows how to configure a variety of switch features, including duplex and speed, port security, securing the CLI, and the switch IP address.
- **Chapter 9, "Implementing Ethernet Virtual LANs":** This chapter explains the concepts and configuration surrounding virtual LANs, including VLAN trunking and the VLAN Trunking Protocol.
- **Chapter 10, "Troubleshooting Ethernet LANs,"** focuses on how to tell whether the switch is doing what it is supposed to be doing, mainly through the use of show commands.

Part III: IP Version 4 Addressing and Subnetting

- **Chapter 11, "Perspectives on IPv4 Subnetting,"** walks you through the entire concept of subnetting, from starting with a Class A, B, or C network; analyzing requirements; making choices; calculating the resulting subnets; and assigning those on paper, all in preparation to deploy and use those subnets by configuring the devices.
- **Chapter 12, "Analyzing Classful IPv4 Networks":** IPv4 addresses originally fell into several classes, with unicast IP addresses being in Class A, B, and C. This chapter explores all things related to address classes and the IP network concept created by those classes.
- **Chapter 13, "Analyzing Subnet Masks":** In most jobs, someone else came before you and chose the subnet mask used in a network. What does that mean? What does that mask do for you? This chapter focuses on how to look at the mask (and IP network) to discover key facts, like the size of a subnet (number of hosts) and the number of subnets in the network.
- **Chapter 14, "Analyzing Existing Subnets":** Most troubleshooting of IP connectivity problems starts with an IP address and mask. This chapter takes that paired information and shows you how to find and analyze the subnet in which that IP address resides, including finding the subnet ID, range of addresses in the subnet, and subnet broadcast address.

Part IV: Implementing IP Version 4

- **Chapter 15, "Operating Cisco Routers,"** is like Chapter 8, but it focuses on routers instead of switches.
- **Chapter 16, "Configuring IPv4 Addresses and Routes,"** discusses how to add IPv4 address configuration to router interfaces, the routes that the router creates as a result, and how to configure static IPv4 routes.

- **Chapter 17, "Learning IPv4 Routes with OSPFv2,"** explains how routers work together to find all the best routes to each subnet using a routing protocol. This chapter also shows how to configure the OSPF routing protocol for use with IPv4.
- **Chapter 18, "Configuring and Verifying Host Connectivity,"** discusses several tools useful when working with IPv4 configuration on hosts. In particular, this chapter discusses DHCP, ping, and traceroute and how to configure IPv4 settings on a host.

Part V: Advanced IPv4 Addressing Concepts

- **Chapter 19, "Subnet Design,"** reverses the approach to IPv4 subnetting as compared to Part III of this book. Instead, this chapter consider questions about why a particular mask might be chosen, and if chosen, what subnet IDs exist.
- **Chapter 20, "Variable-Length Subnet Masks,"** takes IPv4 subnetting to another challenge level, in which different subnets in the same network can use a different subnet mask so that the subnets in the same network have different sizes.
- **Chapter 21, "Route Summarization,"** looks at a process that can be configured for routing protocols so that the protocol advertises one route, for a larger set of addresses, rather than many routes, each for a smaller set of addresses.

Part VI: IPv4 Services

- **Chapter 22, "Basic IPv4 Access Control Lists":** This chapter examines how standard IP ACLs can filter packets based on the source IP address so that a router will not forward the packet.
- **Chapter 23, "Advanced IPv4 ACLs and Device Security":** This chapter examines both named and numbered ACLs, with emphasis on how extended IP ACLs can match packets based on both source and destination IP address, and by matching source and destination TCP and UDP port numbers.
- **Chapter 24, "Network Address Translation":** This chapter closely examines the concepts behind the depletion of the IPv4 address space, and how NAT, in particular the Port Address Translation (PAT) option, helps solve the problem. The chapter also shows how to configure NAT on routers using the IOS CLI.

Part VII: IP Version 6

- **Chapter 25, "Fundamentals of IP Version 6,"** discusses the most basic concepts of IP version 6, focusing on the rules for writing and interpreting IPv6 addresses.
- **Chapter 26, "IPv6 Addressing and Subnetting,"** works through the two branches of unicast IPv6 addresses—global unicast addresses and unique local addresses—that act somewhat like IPv4 public and private addresses, respectively. This chapter also shows how IPv6 implements subnetting.
- **Chapter 27, "Implementing IPv6 Addressing on Routers,"** shows how to configure IPv6 routing and addresses on routers. It also shows the link-local unicast address, plus other special addresses used by routers.
- **Chapter 28, "Implementing IPv6 Addressing on Hosts,"** shows how to add IPv6 configuration on hosts, with emphasis on the two methods by which hosts can learn IPv6 settings: stateful DHCPv6 and Stateless Address Autoconfiguration (SLAAC).

- **Chapter 29, "Implementing IPv6 Routing,"** shows how to adds routes to an IPv6 router's routing table, both through static configuration and with OSPF version 3 (OSPFv3).

Part VIII: Final Preparation

- **Chapter 30, "Final Review,"** suggests a plan for final preparation after you have finished the core parts of the book, in particular explaining the many study options available in the book.

Part IX: Appendices (In Print)

- **Appendix A, "Numeric Reference Tables,"** lists several tables of numeric information, including a binary-to-decimal conversion table and a list of powers of 2.
- **Appendix B, "ICND1 Exam Updates**," covers a variety of short topics that either clarify or expand upon topics covered earlier in the book. This appendix is updated from time to time, and posted at www.ciscopress.com/title/1587143852, with the most recent version available at the time of printing included here as Appendix B. (The first page of the appendix includes instructions on how to check to see whether a later version of Appendix B is available online.)
- The **Glossary** contains definitions for all the terms listed in the "Definitions of Key Terms" sections at the conclusion of Chapters 1 through 29.

Appendixes (on the DVD)

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

- **Appendix C, "Answers to the 'Do I Know This Already?' Quizzes,"** includes the explanations to all the questions from Chapters 1 through 29.
- **Appendix D, "Practice for Chapter 12: Analyzing Classful IPv4 Networks,"** lists practice problems associated with Chapter 12. In particular, the practice questions ask you to find the classful network number in which an address resides, and all other facts about that network.
- **Appendix E, "Practice for Chapter 13: Analyzing Subnet Masks,"** lists practice problems associated with Chapter 13. In particular, the practice questions ask you to convert masks between the three formats, and to examine an existing mask, determine the structure of the IP addresses, and calculate the number of hosts/subnet and number of subnets.
- **Appendix F, "Practice for Chapter 14: Analyzing Existing Subnets,"** lists practice problems associated with Chapter 14. In particular, the practice questions ask you to take an IP address and mask, and find the subnet ID, subnet broadcast address, and range of IP addresses in the subnet.
- **Appendix G, "Practice for Chapter 19: Subnet Design,"** lists practice problems associated with Chapter 19. In particular, the practice questions ask you to examine a set of requirements, determine which mask (if any) meets those requirements, and choose the best mask based on the requirements. It also asks you to find all the subnet IDs in a classful network when given a single mask used throughout the network.

- **Appendix H, "Practice for Chapter 20: Variable-Length Subnet Masks,"** lists practice problems associated with Chapter 20, including problems in which you look for a place to add a new VLSM subnet so that no VLSM overlap is created.
- **Appendix I, "Practice for Chapter 21: Route Summarization,"** lists practice problems associated with Chapter 21. In particular, the practice questions ask you to find the best summary route that includes all the subnets in a list.
- **Appendix J, "Practice for Chapter 22: Basic IPv4 Access Control Lists,"** lists practice problems associated with Chapter 22. In particular, the practice questions give you a chance to practice working with ACL wildcard masks.
- **Appendix K, "Practice for Chapter 25: Fundamentals of IP Version 6,"** lists practice problems associated with Chapter 25. In particular, it provides practice for abbreviating full IPv6 addresses and expanded abbreviated IPv6 addresses.
- **Appendix L, "Practice for Chapter 27: Implementing IPv6 on Routers,"** lists practice problems associated with Chapter 27. In particular, it provides practice in using the EUI-64 process to build an IPv6 address, and in how to find the solicited node multicast used based on a unicast address.
- **Appendix M, "Memory Tables,"** holds the key tables and lists from each chapter, with some of the content removed. You can print this appendix and, as a memory exercise, complete the tables and lists. The goal is to help you memorize facts that can be useful on the exams.
- **Appendix N, "Memory Tables Answer Key,"** contains the answer key for the exercises in Appendix M.
- **Appendix O, "Mind Map Solutions,"** shows an image of sample answers for all the part-ending mind map exercises.
- **Appendix P, "Study Planner,"** is a spreadsheet with major study milestones, where you can track your progress through your study.

Reference Information

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

Install the Pearson IT Certification Practice Test Engine and Questions

The DVD in the book includes the Pearson IT Certification Practice Test (PCPT) engine—software that displays and grades a set of exam-realistic multiple-choice, drag and drop, fill-in-the-blank, and Testlet questions. Using the Pearson IT Certification Practice Test engine, you can either study by going through the questions in Study Mode, or take a simulated ICND1 or CCNA exam that mimics real exam conditions.

The installation process requires two major steps. The DVD in the back of this book has a recent copy of the Pearson IT Certification Practice Test engine. The practice exam—the database of ICND1 and CCNA exam questions—is not on the DVD. After you install the software, the PCPT software will download the latest versions of both the software and the question databases for this book using your Internet connection.

NOTE The cardboard DVD case in the back of this book includes both the DVD and a piece of thick paper. The paper lists the activation code for the practice exam associated with this book. *Do not lose the activation code.*

Also on this same piece of paper, on the opposite side from the exam activation code, you will find a one-time-use coupon code that will give you 70 percent off the purchase of the *Cisco CCENT/CCNA ICND1 100-101 Official Cert Guide, Premium Edition eBook and Practice Test*.

Install the Software from the DVD

The software installation process is pretty routine as compared with other software installation processes. If you have already installed the Pearson IT Certification Practice Test software from another Pearson product, there is no need for you to reinstall the software. Simply launch the software on your desktop and proceed to activate the practice exam from this book by using the activation code included in the DVD sleeve. The following steps outline the installation process:

Step 1. Insert the DVD into your PC.

Step 2. The software that automatically runs is the Cisco Press software to access and use all DVD-based features, including the exam engine and the DVD-only appendices. From the main menu, click the Install the Exam Engine option.

Step 3. Respond to windows prompts as with any typical software installation process.

The installation process will give you the option to activate your exam with the activation code supplied on the paper in the DVD sleeve. This process requires that you establish a Pearson website login. You will need this login to activate the exam, so please do register when prompted. If you already have a Pearson website login, there is no need to register again. Just use your existing login.

Activate and Download the Practice Exam

When the exam engine is installed, you should then activate the exam associated with this book (if you did not do so during the installation process) as follows:

Step 1. Start the PCPT software from the Windows **Start** menu or from your desktop shortcut icon.

Step 2. To activate and download the exam associated with this book, from the **My Products** or **Tools** tab, click the **Activate** button.

Step 3. At the next screen, enter the activation key from the paper inside the cardboard DVD holder in the back of the book. When it is entered, click the **Activate** button.

Step 4. The activation process will download the practice exam. Click **Next**, and then click **Finish**.

After the activation process is completed, the **My Products** tab should list your new exam. If you do not see the exam, make sure that you have selected the **My Products** tab on the menu. At this point, the software and practice exam are ready to use. Simply select the exam and click the **Open Exam** button.

To update a particular product's exams that you have already activated and downloaded, simply select the Tools tab and click the **Update Products** button. Updating your exams will ensure that you have the latest changes and updates to the exam data.

If you want to check for updates to the PCPT software, simply select the Tools tab and click the **Update Application** button. This will ensure that you are running the latest version of the software engine.

Activating Other Products

The exam software installation process and the registration process only have to happen once. Then for each new product, only a few steps are required. For example, if you buy another new Cisco Press Official Cert Guide or Pearson IT Certification Cert Guide, extract the activation code from the DVD sleeve in the back of that book—you don't even need the DVD at this point. From there, all you have to do is start PCPT (if not still up and running) and perform Steps 2 through 4 from the previous list.

PCPT Exam Databases with This Book

This book includes an activation code that allows you to load a set of practice questions. The questions come in different exams or exam databases. When you install the PCPT software, and type in the activation code, the PCPT software downloads the latest version of all these exam databases. And with the ICND1 book alone, you get six different "exams," or six different sets of questions, as listed in Figure I-2.

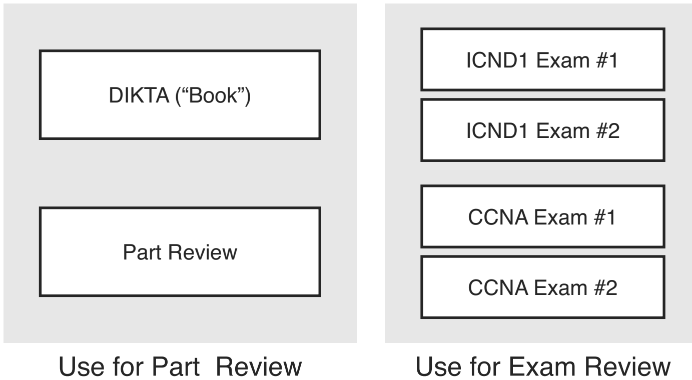

Figure I-2 *PCPT Exams/Exam Databases and When to Use Them*

You can choose to use any of these exam databases at any time, both in study mode and practice exam mode. However, many people find it best to save some of the exams until exam review time, after you have finished reading the entire book. Figure I-2 begins to suggest a plan, spelled out here:

- During part review, use PCPT to review the DIKTA questions for that part, using study mode.
- During part review, use the questions built specifically for part review (the Part Review questions) for that part of the book, using study mode.
- Save the remaining exams to use with the Final Review chapter, using practice exam mode, as discussed in Chapter 30.

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

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

How to View Only DIKTA Questions by Part

Each Part Review section asks you to repeat the Do I Know This Already? (DIKTA) quiz questions from the chapters in that part. While you can simply scan the book pages to review these questions, it is slightly better to review these questions from inside the PCPT software, just to get a little more practice in how to read questions from the testing software. But, you can just read them in the book as well.

To view these DIKTA (book) questions inside the PCPT software, you need to select "Book Questions" and the chapters in this part, using the PCPT menus. To do so, follow these steps:

Step 1. Start the PCPT software.

Step 2. From the main (home) menu, select the item for this product, with a name like **Cisco CCENT/CCNA ICND1 100-101 Official Cert Guide**, and click **Open Exam**.

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

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

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

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

How to View Only Part Review Questions by Part

The exam databases you get with this book include a database of questions created solely for study during the Part Review process. DIKTA questions focus more on facts, with basic application. The Part Review questions instead focus more on application, and look more like real exam questions.

To view these questions, follow the same process as you did with DIKTA/Book questions, but select the "Part Review" database instead of the "Book" database. Specifically:

Step 1. Start the PCPT software.

Step 2. From the main (home) menu, select the item for this product, with a name like **CCENT/CCNA ICND1 100-101 Official Cert Guide**, and click **Open Exam**.

Step 3. The top of the next window should list some exams; select the check box beside **Part Review Questions** and deselect the other check boxes. This selects the questions intended for part-ending review.

Step 4. In this same window, click at the bottom of the screen to deselect all objectives, and then select (check) the box beside the book part you want to review. This tells the PCPT software to give you Part Review questions from the selected part.

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

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

About Mind Maps

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

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

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

Mind Map Mechanics

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

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

For example, Figure I-3 shows a sample mind map that begins to output some of the IPv6 content from Part VII of the book. The central concept of the mind map is IPv6 addressing, and the Part Review activity asks you to think of all facts you learned about IPv6 addressing and organize them with a mind map. The mind map allows a more visual representation of the concepts as compared with just written notes.

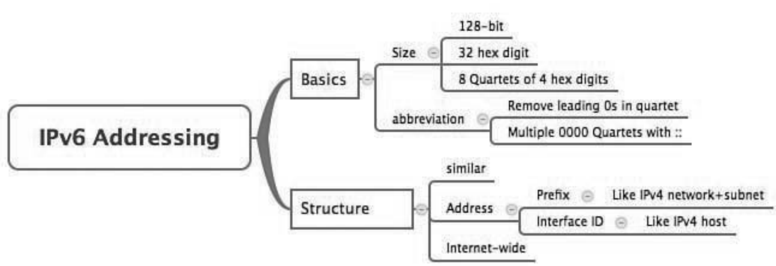

Figure I-3 *Sample Mind Map*

About Mind Maps Used During Part Review

This book suggests mind-mapping exercises during Part Review. This short topic lists some details about the Part Review mind-mapping exercises, listed in one place for reference.

The Part Review sections use two main types of mind mapping exercises:

Configuration exercises ask you to recall the related configuration commands and group them. For example, in a configuration exercise, related commands that happen to be interface subcommands should be grouped, but as shown as being inside interface configuration mode.

Verification exercises ask you to think about the output of show commands and link the output to either the configuration commands that cause that output or the concepts that explain the meaning of some of that output.

Create these configuration mind maps on paper, using any mind-mapping software, or even any drawing application. Many mind-mapping apps exist as well. Regardless of how you draw them, follow these rules:

- If you have only a little time for this exercise, spend your time making your own mind map, instead of looking at suggested answers. The learning happens when thinking through the problem of making your own mind map.
- Set aside the book and all your notes, and do not look at them when first creating these maps, and do as much as you can without looking at the book or your notes (or Google, or anything else).
- Try all the mind maps listed in a Part Review section before looking at your notes.
- Finally, look at your notes to complete all the mind maps.
- Make a note of where you put your final results so that you can find them later during final exam review.

Finally, when learning to use these tools, take two other important suggestions as well. First, use as few words as possible for each node in your mind map. The point is for you to remember the idea and its connections, rather than explain the concept to someone else. Just write enough to remind yourself of the concept. Second, if the mind map process just is not working for you, discard the tool. Instead, take freeform notes on a blank piece of paper. Try to do the important part of the exercise—the thinking about what concepts go together—without letting the tool get in the way.

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 in which 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.

The best way to master these commands is to use them. Sometime during your initial reading of the first part of this book, you need to decide how you personally plan to build your CLI skills. This next topic discusses your options for getting the tools you need to build CLI skills.

Overview of Lab Options

To effectively build your hands-on CLI skills, you either need real routers and switches, or at least something that acts like routers and switches. People who are new to Cisco technology often choose from a few options to get those skills.

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. You can even rent virtual Cisco router and switch lab pods from Cisco, in an offering called Cisco Learning Labs.

Simulators provide another option. Router and switch Simulators are software products that mimic the behavior of the Cisco CLI, generally for the purpose of allowing people to learn. These products have an added advantage when learning: They usually have lab exercises as well.

Simulators come in many shapes and sizes, but the publisher sells Simulators that are designed to help you with CCENT and CCNA study—plus they match this book! The Pearson CCENT Network Simulator and the Pearson CCNA Network Simulator both provide an excellent environment to practice the commands, as well as hundreds of focused labs to help you learn what you need to know for the exams. Both products have the same software code base. The CCNA product simply has labs for both ICND1 and ICND2, while the CCENT product has only the ICND1 labs.

This book does not tell you what option you have 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.

I (Wendell) have collected some information and opinions about this decision on my website, at certskills.com/labgear. Those pages link to sites for Dynamips and for the Pearson Simulator. Also, because the information never seemed to exist in any one place, this website includes many details about how to build a CCNA lab using used real Cisco routers and switches.

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: Install the Pearson NetSim Lite that comes with this book.

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). There's no need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the DVD in the back of this book.

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

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

For More Information

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

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

The *Cisco CCENT/CCNA ICND1 100-101 Official Cert Guide* helps you attain both CCENT and CCNA Routing and Switching certifications. This is the CCENT/CCNA ICND1 certification book from the only Cisco-authorized publisher. We at Cisco Press believe that this book certainly can help you achieve CCNA Routing and Switching certification, but the real work is up to you! I trust that your time will be well spent.

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Getting Started

You just got this book. You have probably already read (or quickly skimmed) the Introduction. And you are wondering, is this where I really start reading, or can I skip ahead to Chapter 1?

Stop to read this "Getting Started" section to think about how you will study for this 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 will take you many hours, over many weeks. That's what this "Getting Started" section will help you do.

A Brief Perspective on Cisco Certification Exams

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

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

The more challenging questions on these exams work a lot like a jigsaw puzzle—but with four out of every five puzzle pieces not even in the room. To solve the puzzle, you have to mentally re-create the missing pieces. To do that, you must know each networking concept and remember how the concepts work together. You also have to match the concepts with what happens on the devices with the configuration commands that tell the devices what to do. You also have to connect the concepts, and the configuration, with the meaning of the output of various troubleshooting commands, to analyze how the network is working and why it is not working right now.

For example, you need to know IP subnetting well, and that topic includes some math. A simple question—one that might be too simple to be a real exam question—would tell you enough of the numbers so that all you have to do is the equivalent of a little addition or multiplication to find a number called a subnet ID.

A more exam-realistic question makes you connect concepts together to set up the math problem. For example, a question might give you a network diagram and ask you to list the subnet ID used in one part of the diagram. But the diagram has no numbers at all. Instead, you have the output of a command from a router, for example, the **show ip ospf database** command, which does list some numbers. But before you can use those numbers, you might need to predict how the devices are configured and what other troubleshooting commands would tell you. So you end up with a question like a puzzle, as shown in Figure 1. The question puts some pieces in the right place; you have to find other pieces using different commands and by applying your knowledge. And some pieces will just remain unknown for a given question.

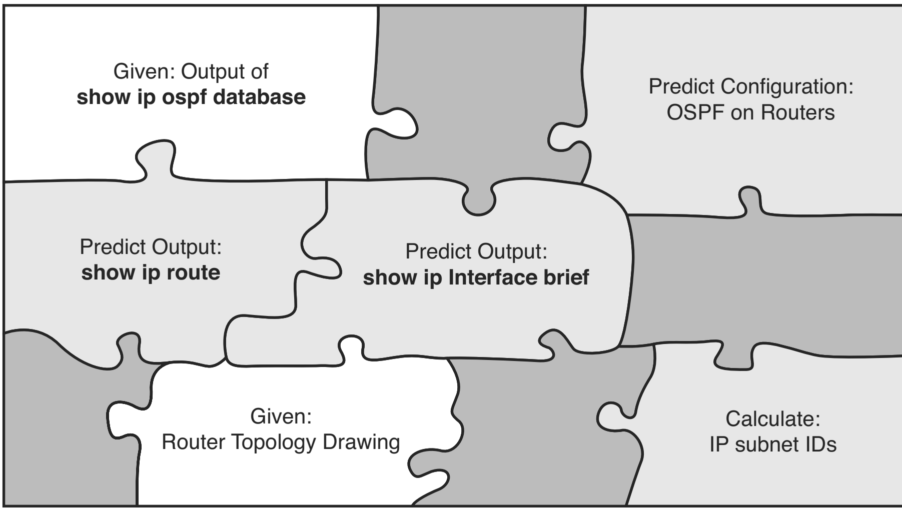

Figure 1 *Filling in Puzzle Pieces with Your Analysis Skills*

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

Suggestions for How to Approach Your Study with This Book

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

Not One Book: 29 Short Read-and-Review Sessions

First, look at your study as a series of read-and-review tasks, each on a relatively small set of related topics.

Each of the core chapters of this book (1 through 29) have around 22 pages of content on average. If you glance around any of those chapters, you will find a heading called "Foundation Topics" on about the fifth page of each chapter. From there to the "Exam Preparation Tasks" section at the end of the chapter, the chapters average about 22 pages.

So, do not approach this book as one big book. Treat the task of your first read of a chapter as a separate task. Anyone can read 22 pages. Having a tough day? Each chapter has two or three major sections, so read just one of them. Or, do some related labs or review something you have already read. This book organizes the content into topics of a more manageable size to give you something more digestible to manage your study time throughout the book.

For Each Chapter, Do Not Neglect Practice

Next, plan to use the practice tasks at the end of each chapter.

Each chapter ends with practice and study tasks under a heading "Exam Preparation Tasks." Doing these tasks, and doing them at the end of the chapter, really does help you get ready. Do not put off using these tasks until later! The chapter-ending "Exam Preparation Tasks" section helps 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 the majority of the activities you will find in "Exam Preparation Tasks" sections:

- Review key topics
- Complete memory tables
- Define key terms
- Review command summary tables
- Review feature configuration checklists
- Do subnetting exercises

Approach each chapter with the same plan. You can choose to read the entire core (Foundation Topics) section of each chapter, or you can choose to skim some chapters, based on your score on the "Do I Know This Already?" (DIKTA) quiz, a pre-chapter self-assessment quiz at the beginning of most chapters. However, regardless of whether you skim or read thoroughly, do the study tasks in the "Exam Preparation Tasks" section at the end of the chapter. Figure 2 shows the overall flow.

Figure 2 *Suggested Approach to Each Chapter*

Use Book Parts for Major Milestones

Third, view the book as having seven major milestones, one for each major topic.

Beyond the more obvious organization into chapters, this book also organizes the chapters into seven major topic areas called book parts. Completing each part means that you have completed a major area of study. At the end of each part, take a little extra time. Do the Part Review tasks at the end of each part. Ask yourself where you are weak and where you are strong. And give yourself some reward for making it to a major milestone. Figure 3 lists the seven parts in this book.

Seven Major Milestones: Book Parts

Networking Fundamentals	Part Prep Tasks
Ethernet LANs and Switches	Part Prep Tasks
IP Version 4 Addressing and Subnetting	Part Prep Tasks
Implementing IP Version 4	Part Prep Tasks
Advanced IPv4 Addressing Concepts	Part Prep Tasks
IPv4 Services	Part Prep Tasks
IP Version 6	Part Prep Tasks

Figure 3 *Parts as Major Milestones*

The tasks in the Part Review sections focus on helping you apply concepts (from that book part) to new scenarios for the exam. Some tasks use sample test questions so that you can think through and analyze a problem. This process helps you refine what you know and to realize what you did not quite yet understand. Some tasks use mind map exercises that help you mentally connect the theoretical concepts with the configuration and verification commands. These Part Review activities help build these skills.

Note that the part review directs you to use the Pearson Certification Practice Test (PCPT) software to access the practice questions. Each part review tells you to repeat the DIKTA questions, but using the PCPT software. Each part review also directs you how to access a specific set of questions reserved for reviewing concepts at part review. Note that the PCPT software and exam databases with this book give you the rights to additional questions as well; Chapter 30, "Final Review," gives some recommendations on how to best use those questions for your final exam preparation.

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.

Use the Final Review Chapter to Refine Skills

Fourth, do the tasks outlined in the final preparation chapter (Chapter 30) at the end of this book.

The Final Review chapter has two major goals. First, it helps you further develop the analysis skills you need to answer the more complicated questions on the exam. Many questions require that you connect ideas about concepts, configuration, verification, and troubleshooting. More reading on your part does not develop all these skills; this chapter's tasks give you activities to further develop these skills.

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

Set Goals and Track Your Progress

Finally, 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 might or might 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.

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 "Exam Preparation Tasks" section, every task in the Part Review tasks section, and every task in the Final Preparation Tasks 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 "Exam Preparation Tasks" section 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 Exam Prep Tasks			
Chapter 2	Read Foundation Topics			
Chapter 2	Do Exam Prep Tasks			
Chapter 3	Read Foundation Topics			
Chapter 3	Do Exam Prep Tasks			
Chapter 4	Read Foundation Topics			
Chapter 4	Do Exam Prep Tasks			
Chapter 5	Read Foundation Topics			
Chapter 5	Do Exam Prep Tasks			
Part I Review	Do Part Review Activities			

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

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

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

Two Options When Studying for the 200-120 CCNA Exam

To get a CCNA certification, you choose either a one-exam or two-exam path.

When using the two-exam path, use each book separately, and take the matching Cisco exam. In other words, use the *Cisco CCENT/CCNA ICND1 100-101 Official Cert Guide*, then pass the 100-101 ICND1 exam, and then do the same with the *Cisco CCNA Routing and Switching ICND2 200-101 Official Cert Guide* and the 200-101 ICND2 exam.

The one-exam path gives you a couple of study options. The 200-120 CCNA exam covers the topics in the combined ICND1 and ICND2 books. The only question is when to read each part of the two books. Two reasonable options exist when going with the one-exam option:

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

While the first option is pretty obvious, the second one is less obvious. So, Figure 4 shows a study plan when using the one-exam option, and you want to move back and forth between the two books. Why move back and forth? To read about similar topics all at once, as shown in Figure 4.

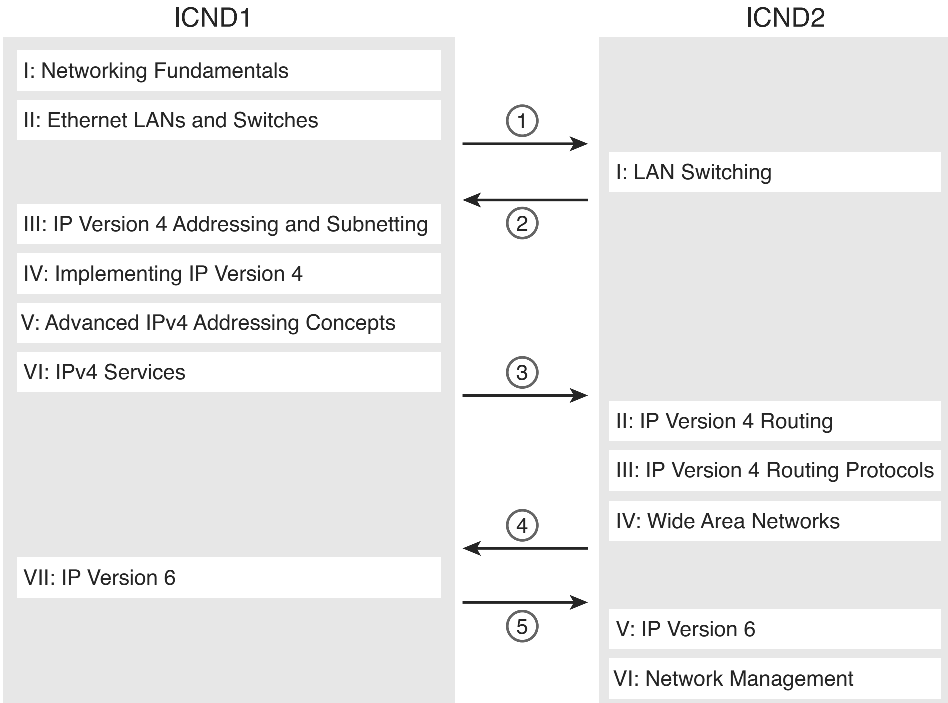

Figure 4 *Alternate Reading Plan for CCNA—Moving Between Books by Part*

Note that you should wait to use the Final Review chapter of either book until you complete both books. However, do the Part Review activities at the end of each part.

Other Small Tasks Before Getting Started

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

Register (for free) at the Cisco Learning Network (CLN, http://learningnetwork.cisco.com) and join the CCENT and CCNA study groups. These mailing lists allow you to lurk and participate in discussions about topics related to CCENT (ICND1) and CCNA (ICND1 + ICND2). Register, 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.

Find and print a copy of Appendix M, "Memory Tables." Many of the Chapter Review sections use this tool, in which you take the incomplete tables from the appendix and complete the table to help you remember some key facts.

If you bought an eBook version of this book, find and download the media files (videos and Sim Lite software) per the instructions supplied on the last page of the eBook file under the heading "Where Are the Companion Files?"

Install the PCPT exam software and activate the exams. For more details on how to load the software, refer to the Introduction, under the heading "Install the Pearson Certification Practice Test Engine and Questions."

Finally, install the Sim Lite software (unless you bought the full simulator product already). The Sim Lite that comes with this book contains a subset of the lab exercises in the full Pearson Network Simulator product.

Getting Started—Now

Now dive in to your first of many short, manageable tasks: reading Chapter 1, "The TCP/IP and OSI Networking Models." Enjoy!

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This chapter covers the following exam topics:

Operation of IP Data Networks

Recognize the purpose and functions of various network devices such as Routers, Switches, Bridges and Hubs.

Select the components required to meet a given network specification.

Predict the data flow between two hosts across a network.

CHAPTER 3

Fundamentals of WANs

Most Layer 1 and 2 networking technology falls into one of two primary categories: wide-area networks (WAN) and LANs. Because both WANs and LANs match OSI Layers 1 and 2, they have many similarities: Both define cabling details, transmission speeds, encoding, and how to send data over physical links, as well as data link frames and forwarding logic.

Of course, WANs and LANs have many differences as well, most notably the distances between nodes and the business model for paying for the network. First, in terms of the distance, the terms *local* and *wide* give us a small hint: LANs typically include nearby devices, while WANs connect devices that can be far apart, potentially hundreds or thousands of miles apart.

The other big difference between the two is this: You pay for and own LANs, but you lease WANs. With LANs, you buy the cables and LAN switches and install them in spaces you control. WANs physically pass through other people's property, and you do not have the right to put your cables and devices there. So, a few companies, like a telephone company or cable company, install and own their own devices and cables, creating their own networks, and lease the right to send data over their networks.

This chapter introduces WANs in three major sections. The first introduces leased line WANs, a type of WAN link that has been part of enterprise networks since the 1960s. The second part shows how Ethernet can be used to create WAN services by taking advantage of the longer cable length possibilities of modern fiber-optic Ethernet standards. The last part of the chapter takes a survey of common WAN technology used to access the Internet.

"Do I Know This Already?" Quiz

Use the "Do I Know This Already?" quiz to help decide whether you might want to skim this chapter, or a major section, moving more quickly to the "Exam Preparation Tasks" section near the end of the chapter. You can find the answers at the bottom of the page following the quiz. For thorough explanations, see DVD Appendix C, "Answers to the 'Do I Know This Already?' Quizzes."

Table 3-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
Leased Line WANs	1–4
Ethernet as a WAN Technology	5
Accessing the Internet	6, 7

1. Which of the following best describes the main function of OSI Layer 1 as used in WANs?
   a. Framing
   b. Delivery of bits from one device to another
   c. Addressing
   d. Error detection
2. In the cabling for a leased line, which of the following typically connects to a four-wire line provided by a telco?
   a. Router serial interface without internal CSU/DSU
   b. CSU/DSU
   c. Router serial interface with internal transceiver
   d. Switch serial interface
3. Which of the following is an accurate speed at which a leased line can operate in the United States?
   a. 100 Mbps
   b. 100 Kbps
   c. 256 Kbps
   d. 6.4 Mbps
4. Which of the following fields in the HDLC header used by Cisco routers does Cisco add, beyond the ISO standard HDLC?
   a. Flag
   b. Type
   c. Address
   d. FCS

5. Two routers, R1 and R2, connect using an Ethernet over MPLS service. The service provides point-to-point service between these two routers only, as a Layer 2 Ethernet service. Which of the following are the most likely to be true about this WAN? (Choose two answers.)

   a. R1 will connect to a physical Ethernet link, with the other end of the cable connected to R2.

   b. R1 will connect to a physical Ethernet link, with the other end of the cable connected to a device at the WAN service provider point of presence.

   c. R1 will forward data link frames to R2 using an HDLC header/trailer.

   d. R1 will forward data link frames to R2 using an Ethernet header/trailer.

6. Which of the following Internet access technologies, used to connect a site to an ISP, offers asymmetric speeds? (Choose two answers.)

   a. Leased lines

   b. DSL

   c. Cable Internet

   d. BGP

7. Fred has just added DSL service at his home, with a separate DSL modem and consumer-grade router with four Ethernet ports. Fred wants to use the same old phone he was using before the installation of DSL. Which is most likely true about the phone cabling and phone used with his new DSL installation?

   a. He uses the old phone, cabled to one of the router/switch device's Ethernet ports.

   b. He uses the old phone, cabled to the DSL modem's ports.

   c. He uses the old phone, cabled to an existing telephone port, and not to any new device.

   d. The old phone must be replaced with a digital phone.

Foundation Topics

Leased Line WANs

Imagine that you are the primary network engineer for an enterprise TCP/IP internetwork. Your company is building a new building at a site 100 miles away from your corporate headquarters. You will of course install a LAN throughout the new building, but you also need to connect that new remote LAN to the rest of the existing enterprise TCP/IP network.

To connect the new building's LAN to the rest of the existing corporate network, you need some kind of a WAN. At a minimum, that WAN needs to be able to send data from the remote LAN back to the rest of the existing network and vice versa. Leased line WANs do exactly that, forwarding data between two routers.

From a basic point of view, a leased line WAN works a lot like an Ethernet crossover cable connecting two routers, but with few distance limitations. Each router can send at any time (full-duplex) over the leased line, for tens, hundreds, or even thousands of miles.

This section begins by giving some perspective about where leased lines fit with LANs and routers, because one main goal for a WAN is to move data between LANs. The rest of this first section explains the physical details about leased lines, followed with information about data link protocols.

Positioning Leased Lines with LANs and Routers

The vast majority of end-user devices in an enterprise or SOHO network connect directly into a LAN. Many PCs use an Ethernet NIC that connects to a switch. More and more, devices use 802.11 wireless LANs, with some devices like phones and tablets supporting only wireless LAN connections.

Now think about a typical company that has many different locations. From a human resources perspective, it might have lots of employees that work at many locations. From a facilities perspective, the company might have a few large sites, with hundreds or even thousands of individual branch offices, stores, or other small locations. However, from a networking perspective, think of each site as being one or more LANs that need to communicate with each other, and to communicate, those LANs need to be connected to each other using a WAN.

To connect LANs together using a WAN, the internetwork uses a router connected to each LAN, with a WAN link between the routers. First, the enterprise's network engineer would order some kind of WAN link. A router at each site connects to both the WAN link and the LAN, as shown in Figure 3-1. Note that crooked line between the routers is the common way to represent a leased line when the drawing does not need to show any of the physical details of the line.

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

1 B **2** B **3** C **4** B **5** B and D **6** B and C **7** C

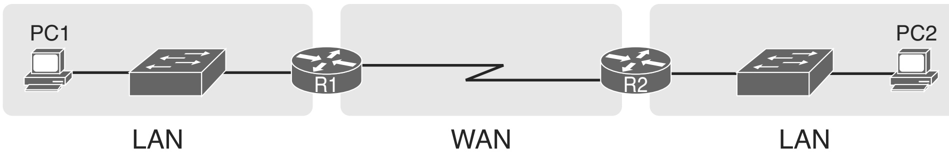

Figure 3-1 *Small Enterprise Network with One Leased Line*

The world of WAN technologies includes many different options in addition to the leased line shown in the figure. WAN technology includes a large number of options for physical links, as well as the data link protocols that control those links. By comparison, the wired LAN world basically has one major option today—Ethernet—because Ethernet won the wired LAN battle in the marketplace back in the 1980s and 1990s.

3

Physical Details of Leased Lines

The leased line service delivers bits in both directions, at a predetermined speed, using full-duplex logic. In fact, conceptually it acts as if you had a full-duplex crossover Ethernet link between two routers, as shown in Figure 3-2. The leased line uses two pair of wires, one pair for each direction of sending data, which allows full-duplex operation.

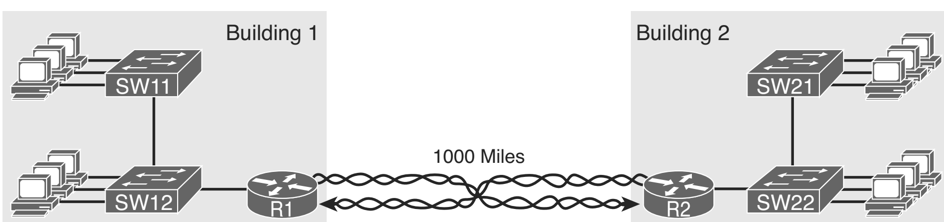

Figure 3-2 *Conceptual View of the Leased Line Service*

Of course, leased lines have many differences compared to an Ethernet crossover cable. To create such possibly long links, or circuits, a leased line does not actually exist as a single long cable between the two sites. Instead, the telco installs a large network of cables and specialized switching devices to create its own computer network. The telco network creates a service that acts like a crossover cable between two points, but the physical reality is hidden from the customer.

Leased lines come with their own set of terminology as well. First, the term *leased line* refers to the fact that the company using the leased line does not own the line, but instead pays a monthly lease fee to use it. However, many people today use the generic term *service provider* to refer to a company that provides any form of WAN connectivity, including Internet services.

Given its long history, leased lines have had many names. Table 3-2 lists some of those names, mainly so that in a networking job, you have a chance to translate from the terms each person uses with a basic description as to the meaning of the name.

Table 3-2 Different Names for a Leased Line

Name	Meaning or Reference
Leased circuit, Circuit	The words *line* and *circuit* are often used as synonyms in telco terminology; *circuit* makes reference to the electrical circuit between the two endpoints.
Serial link, Serial line	The words *link* and *line* are also often used as synonyms. *Serial* in this case refers to the fact that the bits flow serially, and that routers use serial interfaces.
Point-to-point link, Point-to-point line	Refers to the fact that the topology stretches between two points, and two points only. (Some older leased lines allowed more than two devices.)
T1	A specific type of leased line that transmits data at 1.544 megabits per second (1.544 Mbps).
WAN link, Link	Both these terms are very general, with no reference to any specific technology.
Private line	Refers to the fact that the data sent over the line cannot be copied by other telco customers, so the data is private.

Leased Line Cabling

To create a leased line, some physical path must exist between the two routers on the ends of the link. The physical cabling must leave the buildings where each router sits. However, the telco does not simply install one cable between the two buildings. Instead, it uses what is typically a large and complex network that creates the appearance of a cable between the two routers.

Figure 3-3 gives a little insight into the cabling that could exist inside the telco for a short leased line. Telcos put their equipment in buildings called central offices (CO). The telco installs cables from the CO to most every other building in the city, expecting to sell services to the people in those buildings one day. The telco would then configure its switches to use some of the capacity on each cable to send data in both directions, creating the equivalent of a crossover cable between the two routers.

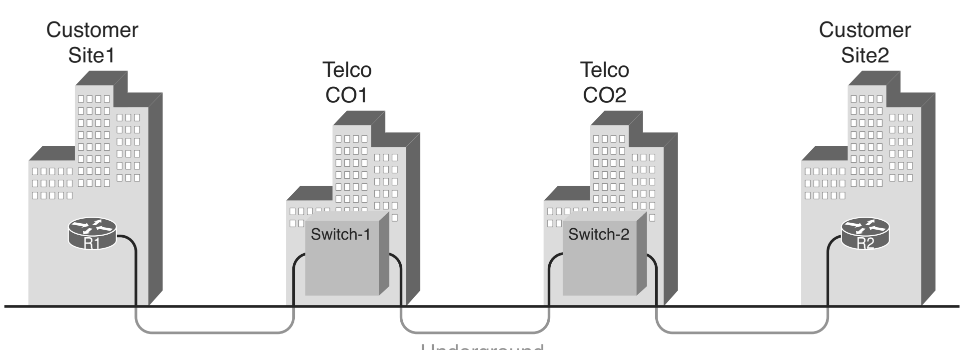

Figure 3-3 *Possible Cabling Inside a Telco for a Short Leased Line*

Although what happens inside the telco is completely hidden from the telco customer, enterprise engineers do need to know about the parts of the link that exist inside the customer's building at the router.

First, each site has *customer premises equipment (CPE)*, which includes the router, serial interface card, and CSU/DSU. Each router uses a serial interface card that acts somewhat like an Ethernet NIC, sending and receiving data over the physical link. The physical link requires a function called a channel service unit/data service unit (CSU/DSU). The CSU/DSU can either be integrated into the serial interface card in the router or sit outside the router as an external device. Figure 3-4 shows the CPE devices, along with the cabling.

Key Topic

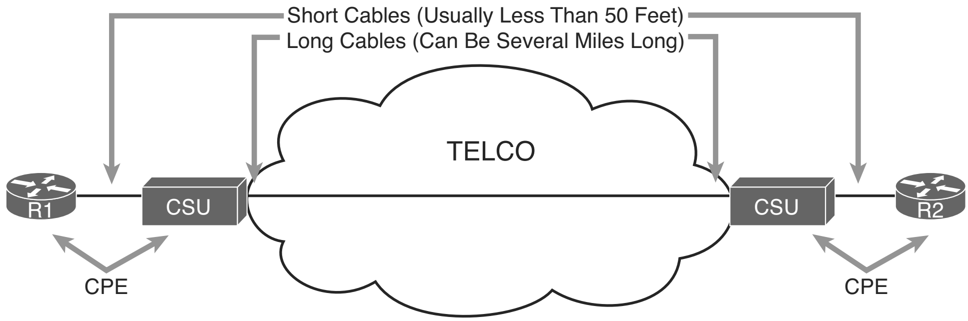

Figure 3-4 *Point-to-Point Leased Line: Components and Terminology*

The cabling includes a short serial cable (only if an external CSU/DSU is used) plus the cable installed by the telco for the leased line itself. The serial cable connects the router serial interface to the external CSU/DSU. (Many cable options exist; the cable just needs to match the connector of the serial interface on one end and the CSU/DSU on the other end.) The four-wire cable from the telco plugs into the CSU/DSU, typically using an RJ-48 connector that has the same size and shape as an RJ-45 connector (as seen in Chapter 2's Figure 2-7).

Telcos offer a wide variety of speeds for leased lines. However, you cannot pick the exact speed you want; instead, you must pick from a long list of predefined speeds. Slower-speed links run at multiples of 64 kbps (kilobits per second), while faster links run at multiples of about 1.5 Mbps (megabits per second).

Building a WAN Link in a Lab

On a practical note, to prepare for the CCENT and CCNA exams, you can choose to buy some used router and switch hardware for hands-on practice. If you do, you can create the equivalent of a leased line without a real leased line from a telco, and without CSU/DSUs, just using a cabling trick. This short topic tells you enough information to create a WAN link in your home lab.

First, the serial cables normally used between a router and an external CSU/DSU are called *data terminal equipment (DTE) cables*. To create a physical WAN link in a lab, you need two serial cables: one serial DTE cable, plus a similar but slightly different matching *data communications equipment (DCE) cable*. The DCE cable has a female connector, while the DTE cable has a male connector, which allows the two cables to be attached directly. The DCE cable also does the equivalent task of an Ethernet crossover cable by swapping the transmit and receive wire pairs, as shown in Figure 3-5.

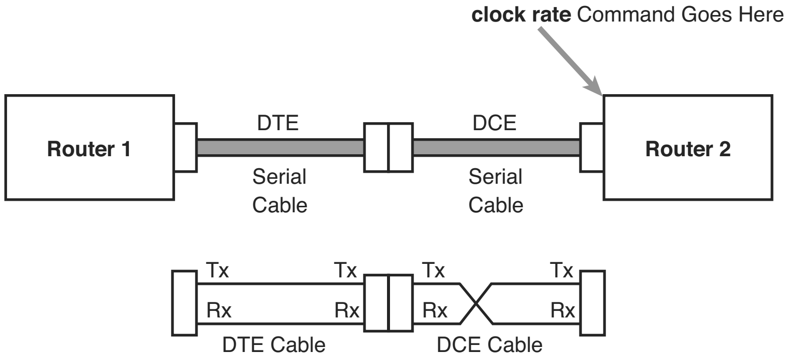

Figure 3-5 *Serial Cabling Uses a DTE Cable and a DCE Cable*

The figure shows the cable details at the top, with the wiring details inside the cable at the bottom. In particular, at the bottom of the figure, note that the DTE serial cable acts as a straight-through cable, and does not swap the transmit and receive pair, while the DCE cable does swap the pairs.

Finally, to make the link work, the router with the DCE cable installed must do one function normally done by the CSU/DSU. The CSU/DSU normally provides a function called *clocking*, in which it tells the router exactly when to send each bit through signaling over the serial cable. A router serial interface can provide clocking, but the router does not do so unless configured with the **clock rate** command. Chapter 15's section "Bandwidth and Clock Rate on Serial Interfaces" shows a sample configuration.

Data Link Details of Leased Lines

A leased line provides a Layer 1 service. In other words, it promises to deliver bits between the devices connected to the leased line. However, the leased line itself does not define a data link layer protocol to be used on the leased line.

Because leased lines define only the Layer 1 transmission service, many companies and standards organizations have created data link protocols to control and use leased lines. Today, the two most popular data link layer protocols used for leased lines between two routers are High-Level Data Link Control (HDLC) and Point-to-Point Protocol (PPP). This next topic takes a brief look at HDLC, just to show one example, plus a few comments about how routers use WAN data link protocols.

HDLC Basics

All data link protocols perform a similar role: to control the correct delivery of data over a physical link of a particular type. For example, the Ethernet data link protocol uses a destination address field to identify the correct device that should receive the data, and an FCS field that allows the receiving device to determine whether the data arrived correctly. HDLC provides similar functions.

HDLC has less work to do because of the simple point-to-point topology of a point-to-point leased line. When one router sends an HDLC frame, it can only go one place: to the other end of the link. So, while HDLC has an address field, the destination is implied. The idea is sort of like when I have lunch with my friend Gary, and only Gary. I do not need to start every sentence with "Hey Gary"—he knows I am talking to him.

NOTE In case you wonder why HDLC has an address field at all, in years past, the telcos offered multidrop circuits. These circuits included more than two devices, so there was more than one possible destination, requiring an address field to identify the correct destination.

HDLC has other fields and functions similar to Ethernet as well. Table 3-3 lists the HDLC fields, with the similar Ethernet header/trailer field, just for the sake of learning HDLC based on something you have already learned about (Ethernet).

Table 3-3 Comparing HDLC Header Fields to Ethernet

HDLC Header or Trailer Field	Ethernet Equivalent	Description
Flag	Preamble	Lists a recognizable bit pattern so that the receiving nodes realize that a new frame is arriving
Address	Destination Address	Identifies the destination device
Type	Type	Identifies the type of Layer 3 packet encapsulated inside the frame
FCS	FCS	A field used by the error detection process; it is the only trailer field in this table

HDLC exists today as a standard of the International Organization for Standardization (ISO), the same organization that brought us the OSI model. However, ISO standard HDLC does not have a Type field, and routers need to know the type of packet inside the frame. So, Cisco routers use a Cisco-proprietary variation of HDLC that adds a Type field, as shown in Figure 3-6.

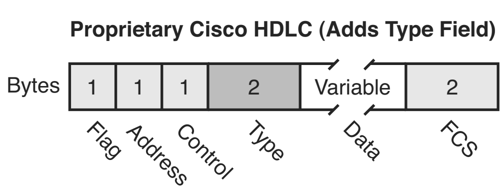

Figure 3-6 *HDLC Framing*

How Routers Use a WAN Data Link

Today, most leased lines connect to routers, and routers focus on delivering packets to a destination host. However, routers physically connect to both LANs and WANs, with those LANs and WANs requiring that data be sent inside data link frames. So, now that you know a little about HDLC, it helps to think about how routers use the HDLC protocol when sending data.

First, the TCP/IP network layer focuses on forwarding IP packets from the sending host to the destination host. The underlying LANs and WANs just act as a way to move the packets to the next router or end-user device. Figure 3-7 shows that network layer perspective.

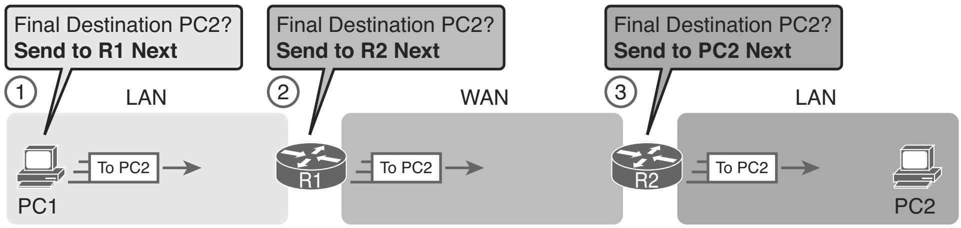

Figure 3-7 *IP Routing Logic over LANs and WANs*

Following the steps in the figure, for a packet sent by PC1 to PC2's IP address:

1. PC1's network layer (IP) logic tells it to send the packet to a nearby router (R1).
2. Router R1's network layer logic tells it to forward (route) the packet out the leased line to router R2 next.
3. Router R2's network layer logic tells it to forward (route) the packet out the LAN link to PC2 next.

While Figure 3-7 shows the network layer logic, the PCs and routers must rely on the LANs and WANs in the figure to actually move the bits in the packet. Figure 3-8 shows the same figure, with the same packet, but this time showing some of the data link layer logic used by the hosts and routers. Basically, three separate data link layer steps encapsulate the packet, inside a data link frame, over three hops through the internetwork: from PC1 to R1, from R1 to R2, and from R2 to PC2.

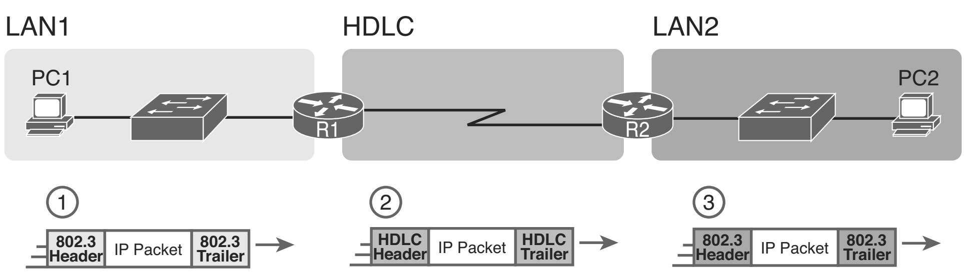

Figure 3-8 *General Concept of Routers Deencapsulating and Reencapsulating IP Packets*

Following the steps in the figure, again for a packet sent by PC1 to PC2's IP address:

1. To send the IP packet to router R1 next, PC1 encapsulates the IP packet in an Ethernet frame that has the destination MAC address of R1.
2. Router R1 deencapsulates (removes) the IP packet from the Ethernet frame, encapsulates the packet into an HDLC frame using an HDLC header and trailer, and forwards the HDLC frame to router R2 next.
3. Router R2 deencapsulates (removes) the IP packet from the HDLC frame, encapsulates the packet into an Ethernet frame that has the destination MAC address of PC2, and forwards the Ethernet frame to PC2.

In summary, a leased line with HDLC creates a WAN link between two routers so that they can forward packets for the devices on the attached LANs. The leased line itself provides the physical means to transmit the bits, in both directions. The HDLC frames provide the means to encapsulate the network layer packet correctly so that it crosses the link between routers.

Leased lines have many benefits that have led to their relatively long life in the WAN marketplace. These lines are simple for the customer, are widely available, are of high quality, and are private. However, they do have some negatives as well compared to newer WAN technologies, including a higher cost and typically longer lead times to get the service installed. The next section looks at an alternative WAN technology used in some examples in this book: Ethernet.

Ethernet as a WAN Technology

For the first several decades of the existence of Ethernet, Ethernet was only appropriate for LANs. The restrictions on cable lengths and devices might allow a LAN that stretched a kilometer or two, to support a campus LAN, but that was the limit.

As time passed, the IEEE improved Ethernet standards in ways that made Ethernet a reasonable WAN technology. For example, the 1000BASE-LX standard uses single-mode fiber cabling, with support for a 5-km cable length; the 1000BASE-ZX standard supports an even longer 70-km cable length. As time went by, and as the IEEE improved cabling distances for fiber Ethernet links, Ethernet became a reasonable WAN technology.

Today, in this second decade of the twenty-first century, many WAN service providers (SP) offer WAN services that take advantage of Ethernet. SPs offer a wide variety of these Ethernet WAN services, with many different names. But all of them use a similar model, with Ethernet used between the customer site and the SP's network, as shown in Figure 3-9.

Key Topic

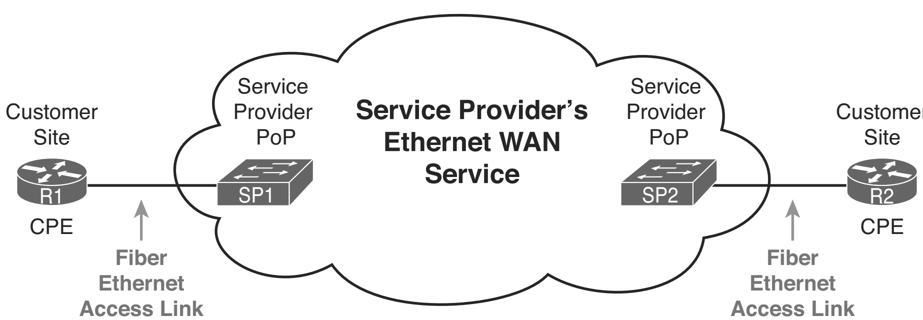

Figure 3-9 *Fiber Ethernet Link to Connect a CPE Router to a Service Provider's WAN*

The model shown in Figure 3-9 has many of the same ideas of how a telco creates a leased line, as seen earlier in Figure 3-3, but now with Ethernet links and devices. The customer connects to an Ethernet link using a router interface. The (fiber) Ethernet link leaves the customer building and connects to some nearby SP location called a point of presence (POP). Instead of a telco switch as seen in Figure 3-3, the SP uses an Ethernet switch. Inside the SP's network, the SP uses any technology that it wants to create the specific Ethernet WAN services.

Ethernet WANs that Create a Layer 2 Service

The WAN services implied by Figure 3-9 include a broad number of services, with a lot of complex networking concepts needed to understand those services. Yet, we sit here at the third chapter of what is probably your first Cisco certification book, so clearly, getting into depth on these WAN services makes little sense. So, for the purposes of the CCENT certification, this book focuses on one specific Ethernet WAN service that can be easily understood if you understand how Ethernet LANs work.

> **NOTE** For perspective about the broad world of the service provider network shown in Figure 3-9, consider the Cisco certification paths for a moment. Cisco has CCNA, CCNP, and CCIE certifications in many areas: routing and switching, voice, security, and so on. Two paths—Service Provider and Service Provider Operations—focus on technologies and tasks in the service provider arena. See www.cisco.com/go/certifications for more details.

The one Ethernet WAN service used for CCENT and CCNA Routing and Switching examples goes by two names: Ethernet emulation and Ethernet over MPLS (EoMPLS). Ethernet emulation is a general term, meaning that the service acts like one Ethernet link. EoMPLS refers to Multiprotocol Label Switching (MPLS), which is one technology that can be used inside the SP's cloud. This book will refer to this specific service either as Ethernet emulation or EoMPLS.

The type of EoMPLS service discussed in this book gives the customer an Ethernet link between two sites. In other words, the EoMPLS service provides

- A point-to-point connection between two customer devices
- Behavior as if a fiber Ethernet link existed between the two devices

So, if you can imagine two routers, with a single Ethernet link between the two routers, you understand what this particular EoMPLS service does.

Figure 3-10 shows the idea. In this case, the two routers, R1 and R2, connect with an EoMPLS service instead of a serial link. The routers use Ethernet interfaces, and they can send data in both directions at the same time. Physically, each router actually connects to some SP PoP, as shown earlier in Figure 3-9, but logically, the two routers can send Ethernet frames to each other over the link.

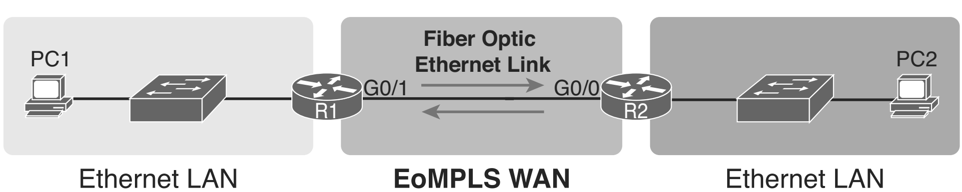

Figure 3-10 *EoMPLS Acting Like a Simple Ethernet Link Between Two Routers*

How Routers Route IP Packets Using Ethernet Emulation

WANs, by their very nature, give IP routers a way to forward IP packets from a LAN at one site, over the WAN, and to another LAN at another site. Routing over an EoMPLS WAN link still uses the WAN like a WAN, as a way to forward IP packets from one site to another. However, the WAN link happens to use the same Ethernet protocols as the Ethernet LAN links at each site.

The EoMPLS link uses Ethernet for both Layer 1 and Layer 2 functions. That means the link uses the same familiar Ethernet header and trailer, as seen in the middle of Figure 3-11.

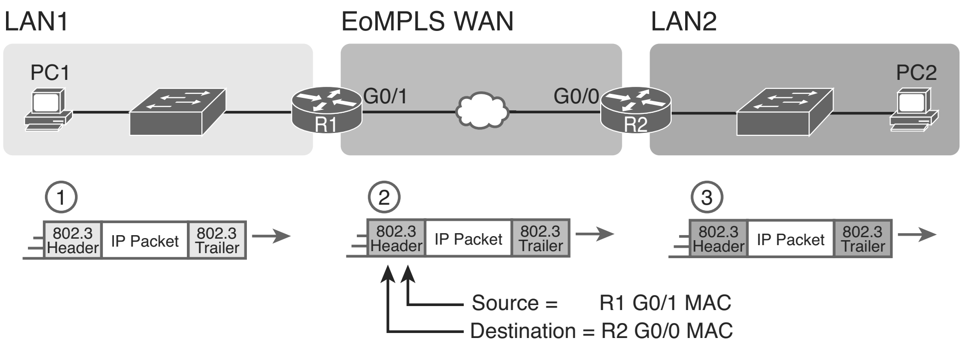

Figure 3-11 *Routing over an EoMPLS Link*

NOTE This book shows EoMPLS connections as a familiar single black line, like other Ethernet links, but with a small cloud overlaid to note that this particular Ethernet link is through an Ethernet WAN service.

The figure shows the same three routing steps as shown with the serial link in the earlier Figure 3-8. In this case, all three routing steps use the same Ethernet (802.3) protocol. However, note that each frame's data link header and trailer are different. Each router discards the old data link header/trailer and adds a new set, as described in these steps. Focus mainly on Step 2, because compared to the similar example shown in Figure 3-8, Steps 1 and 3 are unchanged:

1. To send the IP packet to router R1 next, PC1 encapsulates the IP packet in an Ethernet frame that has the destination MAC address of R1.
2. Router R1 deencapsulates (removes) the IP packet from the Ethernet frame and encapsulates the packet into a new Ethernet frame, with a new Ethernet header and trailer. The destination MAC address is R2's G0/0 MAC address, and the source MAC address is R1's G0/1 MAC address. R1 forwards this frame over the EoMPLS service to R2 next.
3. Router R2 deencapsulates (removes) the IP packet from the HDLC frame, encapsulates the packet into an Ethernet frame that has the destination MAC address of PC2, and forwards the Ethernet frame to PC2.

Accessing the Internet

Many people begin their CCENT and CCNA study never having heard of leased lines, but many people have heard of two other WAN technologies used to gain access to the Internet: digital subscriber line (DSL) and cable. These two WAN technologies do not replace leased lines in all cases, but they do play an important role in the specific case of creating a WAN connection between a home or office and the Internet.

This last major section of the chapter begins by introducing the basic networking concepts behind the Internet, followed with some specifics of how DSL and cable provide a way to send data to/from the Internet.

The Internet as a Large WAN

The Internet is an amazing cultural phenomenon. Most of us use it every day. We post messages on social media sites, we search for information using a search engine like Google, and we send emails. We use apps on our phones to pull down information, like weather reports, maps, and movie reviews. We use the Internet to purchase physical products and to buy and download digital products like music and videos. The Internet has created completely new things to do and changed the old ways of living life compared to a generation ago.

However, if you instead focus on the networking technology that creates the Internet, the Internet is simply one huge TCP/IP network. In fact, the name "Internet" comes from the core network layer protocol: Internet Protocol. The Internet includes many LANs, and because the Internet spans the globe, it of course needs WAN links to connect different sites.

As a network of networks, the Internet is actually owned by countless companies and people. The Internet includes most every enterprise TCP/IP network and a huge number of home-based networks, as well as a huge number of individuals from their phones and other wireless devices, as shown in Figure 3-12.

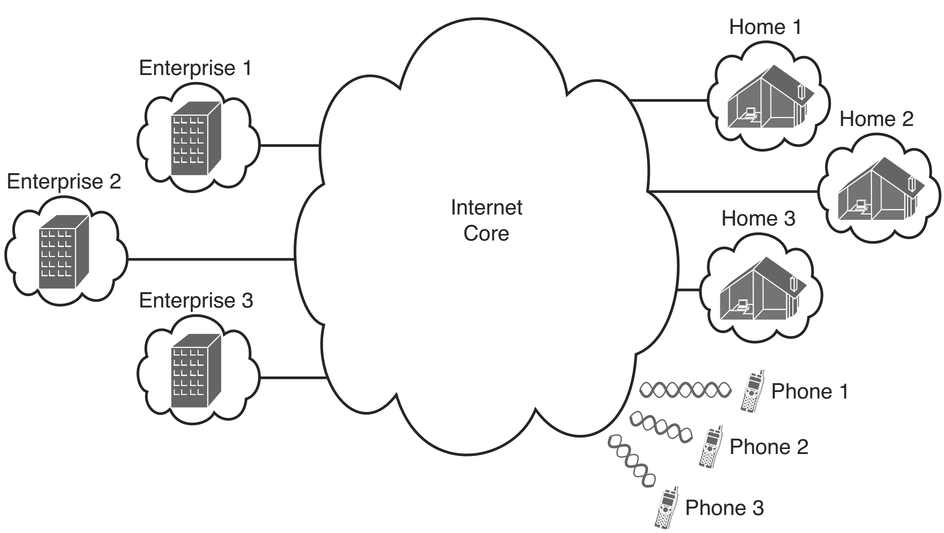

Figure 3-12 *Internet with Enterprise, Home, and Phone Subscribers*

The middle of the Internet, called the *Internet core*, exists as LANs and WANs owned and operated by Internet service providers (ISP). (Figure 3-12 shows the Internet core as a cloud, because network diagrams show a cloud when hiding the details of a part of the network.) ISPs cooperate to create a mesh of links between each other in the Internet core, so that no matter through which ISP a particular company or person connects, some path exists to every device.

Figure 3-13 shows a slightly different version of Figure 3-12, in this case showing the concept of the Internet core: ISP networks that connect to both their customers, as well as each other, so that IP packets can flow from every customer of every ISP to every other customer of every other ISP.

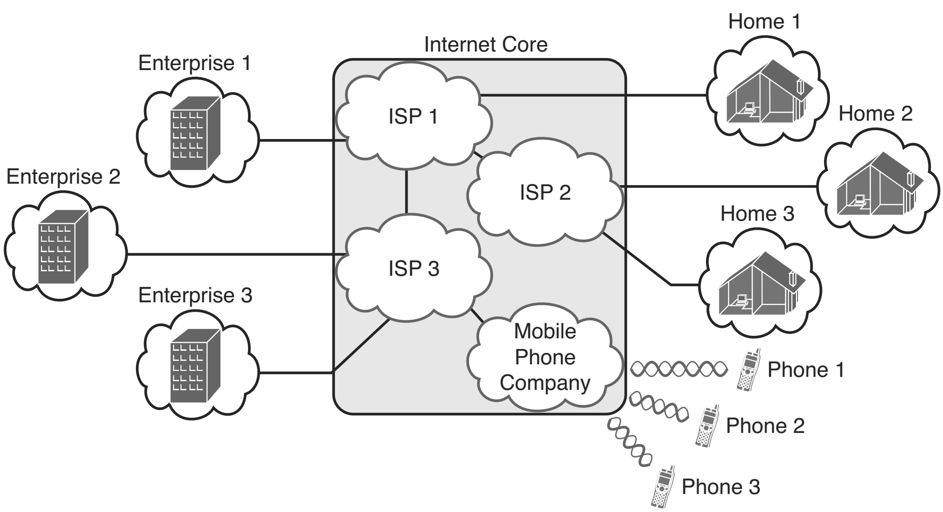

Figure 3-13 *Internet Core with Multiple ISPs and Telcos*

Internet Access (WAN) Links

The Internet also happens to use a huge number of WAN links. All of those lines connecting an enterprise or home to one of the ISPs in Figure 3-13 represent some kind of WAN link that uses a cable, while the phones create their WAN link using wireless technology. These links usually go by the name *Internet access link*.

Historically, businesses tend to use one set of WAN technologies as Internet access links, while home-based consumers use others. Businesses often use leased lines, connecting a router at the business to a router at the ISP. The top of Figure 3-14 shows just such an example.

Key Topic

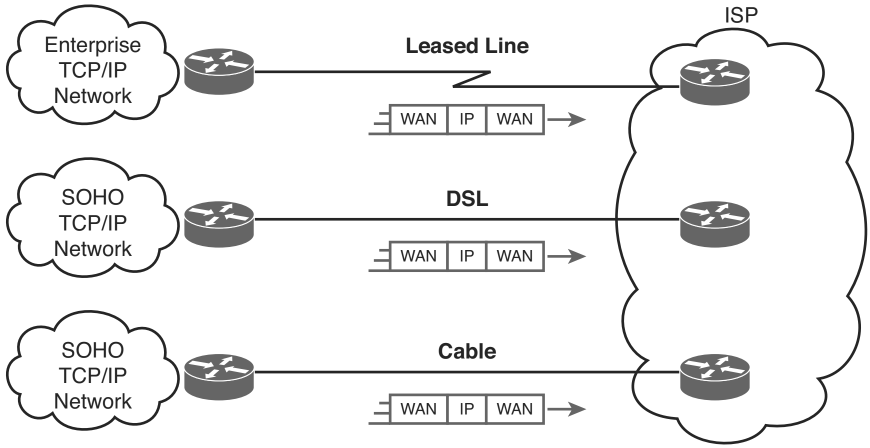

Figure 3-14 *Three Examples of Internet Access Links*

Consumers often use technologies like DSL and cable for Internet access links. These technologies use cabling that is already installed in most homes, making these services somewhat inexpensive for home users. DSL uses the analog phone lines that are already installed in homes, while cable Internet uses the cable TV (CATV) cable.

> **NOTE** While mostly home-based consumers use DSL and cable, there is no restriction against businesses using them as well.

All three of the Internet access technologies in Figure 3-14 happen to use a pair of routers: one at the customer side of the WAN link and one at the ISP side. The routers will continue to think about network layer logic, of sending IP packets to their destination by forwarding the packets to the next router. However, the physical and data link layer details on the WAN link differ as compared to leased lines. The next few pages examine both DSL and cable Internet to show some of those differences.

Digital Subscriber Line

Digital subscriber line (DSL) creates a relatively short (miles long, not tens of miles) high-speed link WAN between a telco customer and an ISP. To do so, it uses the same single-pair telephone line used for a typical home phone line. DSL, as a technology, does not try to replace leased lines, which run between any two sites, for potentially very long distances. DSL instead just provides a short physical link from a home to the telco's network, allowing access to the Internet. .

First, to get an idea about the cabling, think about typical home telephone service in the United States, before adding DSL service. Each home has one phone line that runs from a nearby telco CO to the home. As shown on the left side of Figure 3-15, the telephone wiring splits out and terminates at several wall plates, often with RJ-11 ports that are a slightly skinnier cousin of the RJ-45 connector.

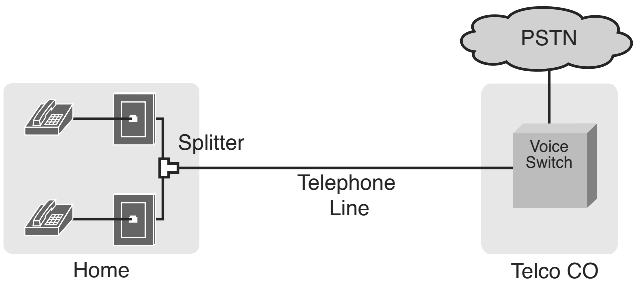

Figure 3-15 *Typical Voice Cabling Concepts in the United States*

Next, think about the telephone line and the equipment at the CO. Sometime in the past, the telco installed all the telephone lines from its local CO to each neighborhood, apartment, and so on. At the CO, each line connects to a port on a telco switch. This switch supports the ability to set up voice calls, take them down, and forward the voice through the worldwide voice network, called the public switched telephone network, or PSTN.

To add DSL service at the home in Figure 3-15, two changes need to be made. First, you need to add DSL-capable devices at the home. Second, the telco has to add DSL equipment at the CO. Together, the DSL equipment at each side of the local telephone line can send data while still supporting the same voice traffic.

The left side of Figure 3-16 shows the changes. A new *DSL modem* now connects to a spare phone outlet. The DSL modem follows the DSL physical and data link layer standards to send data to/from the telco. The home now has a small LAN, implemented with a consumer-grade router, which often includes an Ethernet switch and possibly a wireless LAN access point.

Key Topic

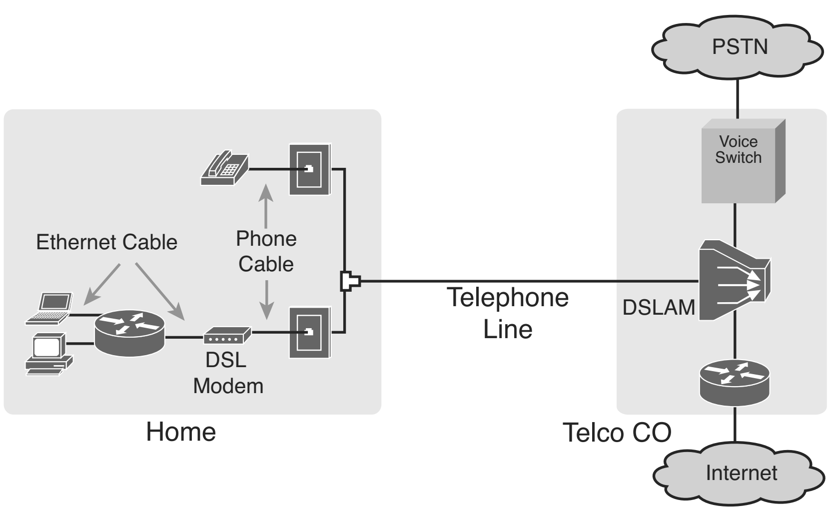

Figure 3-16 *Wiring and Devices for a Home DSL Link*

The home-based router on the left needs to be able to send data to/from the Internet. To make that happen, the telco CO uses a product called a DSL Access Multiplexer (DSLAM). The DSLAM splits out the data over to the router on the lower right, which completes the connection to the Internet. The DSLAM also splits out the voice signals over to the voice switch on the upper right.

DSL gives telcos a useful high-speed Internet service to offer their customers. Telcos have had other offerings that happen to use the same telephone line for data, but these options ran much slower than DSL. DSL supports asymmetric speeds, meaning that the transmission speed from the ISP toward the home (downstream) is much faster than the transmissions toward the ISP (upstream). Asymmetric speeds work better for consumer Internet access from the home, because clicking a web page sends only a few hundred bytes upstream into the Internet, but can trigger many megabytes of data to be delivered downstream to the home.

Cable Internet

Cable Internet creates an Internet access service which, when viewed generally rather than specifically, has many similarities to DSL. Like DSL, cable Internet takes full advantage of existing cabling, using the existing cable TV (CATV) cable to send data. Like DSL, cable Internet uses asymmetric speeds, sending data faster downstream than upstream, which works better than symmetric speeds for most consumer locations. And like DSL, cable Internet does not attempt to replace long leased lines between any two sites, instead focusing on the short WAN links from a customer to an ISP.

Cable Internet also uses the same basic in-home cabling concepts as does DSL. Figure 3-17 shows a figure based on the earlier DSL Figure 3-16, but with the DSL details replaced with cable Internet details. The telephone line has been replaced with coaxial cable from the CATV company, and the DSL modem has been replaced by a cable modem. Otherwise, the details in the home follow the same overall plan.

Key Topic

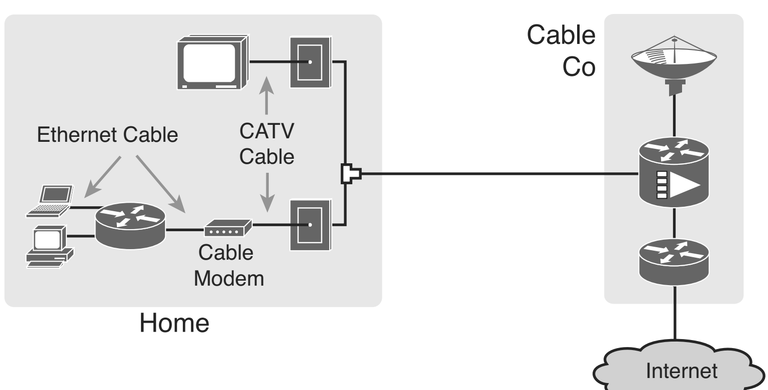

Figure 3-17 *Wiring and Devices for a Home Cable Internet Link*

On the CATV company side of the cable Internet service, the CATV company has to split out the data and video, as shown on the right side of the figure. Data flows to the lower right, through a router, while video comes in from video dishes for distribution out to the TVs in people's homes.

Cable Internet service and DSL directly compete for consumer and small-business Internet access. Generally speaking, while both offer high speeds, cable Internet typically runs at faster speeds than DSL, with DSL providers keeping their prices a little lower to compete. Both support asymmetric speeds, and both provide an "always on" service, in that you can communicate with the Internet without the need to first take some action to start the Internet connection.

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics from this chapter, noted with the Key Topic icon. Table 3-4 lists these key topics and where each is discussed.

Key Topic

Table 3-4 Key Topics for Chapter 3

Key Topic Element	Description	Page Number
Figure 3-4	Typical cabling diagram of CPE for a leased line	73
Figure 3-9	Ethernet over MPLS—physical connections	77
Figure 3-14	Common Internet access links	82
Figure 3-16	Typical DSL cabling at home	83
Figure 3-17	Typical cable Internet cabling at home	84

Complete the Tables and Lists from Memory

Print a copy of DVD Appendix M, "Memory Tables," or at least the section for this chapter, and complete the tables and lists from memory. DVD Appendix N, "Memory Tables Answer Key," includes completed tables and lists to check your work.

Definitions of Key Terms

After your first reading of the chapter, try to define these key terms, but do not be concerned about getting them all correct at that time. Chapter 30 directs you in how to use these terms for late-stage preparation for the exam.

leased line, wide-area network (WAN), telco, serial interface, HDLC, DSL, cable Internet, DSL modem, Ethernet over MPLS

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This chapter covers the following exam topics:

Operation of IP Data Networks

Recognize the purpose and functions of various network devices such as Routers, Switches, Bridges and Hubs.

Select the components required to meet a given network specification.

Predict the data flow between two hosts across a network.

IP Routing Technologies

Differentiate methods of routing and routing protocols

Static vs. Dynamic

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