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Cisco CCENT/ CCNA ICND1 100-101

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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:

- Adobe AIR 3.6.0
- 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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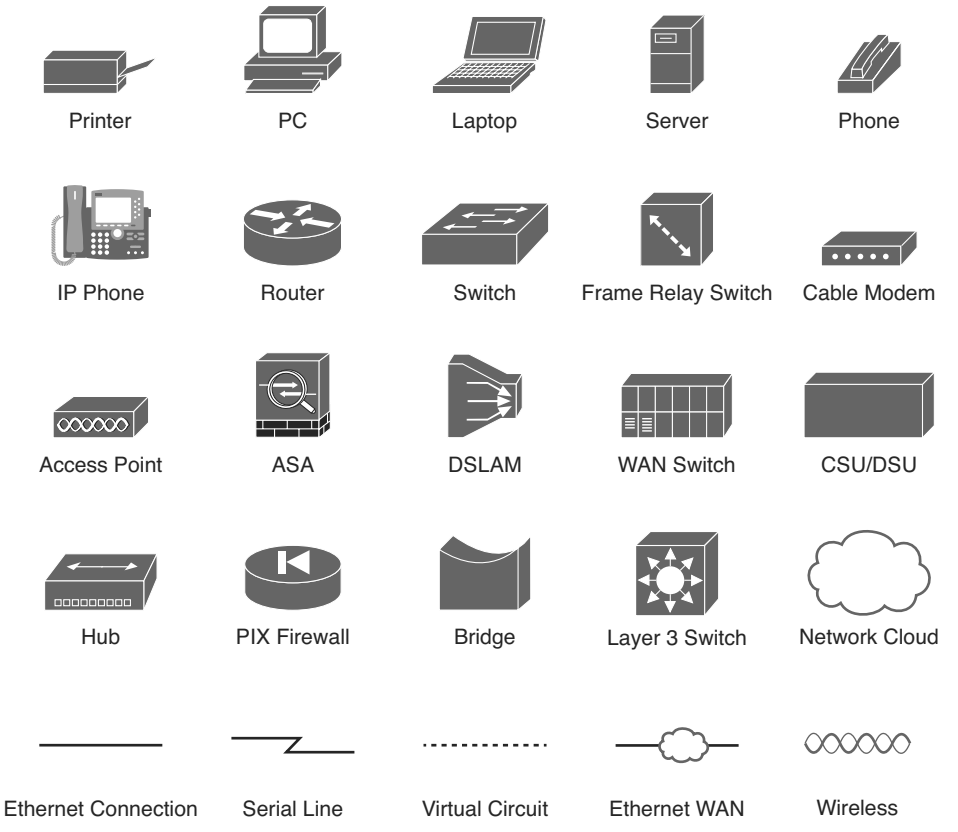

Command Syntax Conventions

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.)

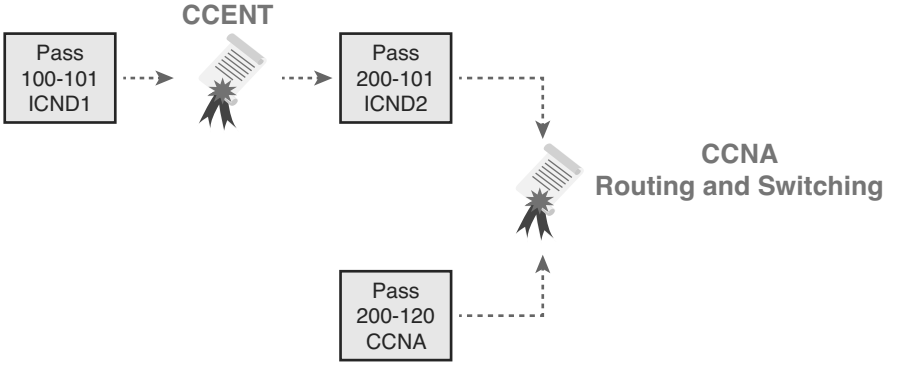

Figure I-1 *Cisco Entry-Level Certifications and Exams*

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.

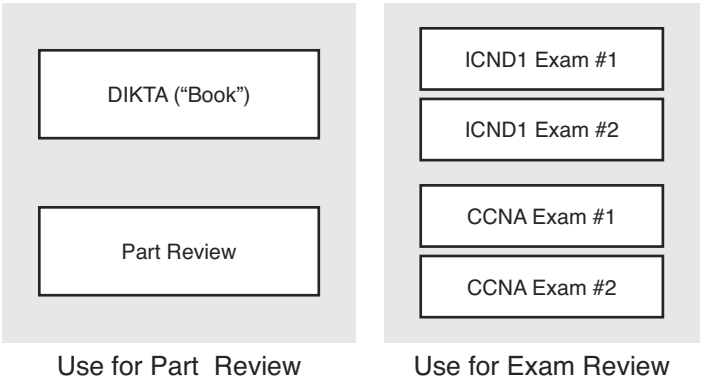

Figure I-2 *PCPT Exams/Exam Databases and When to Use Them*

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.

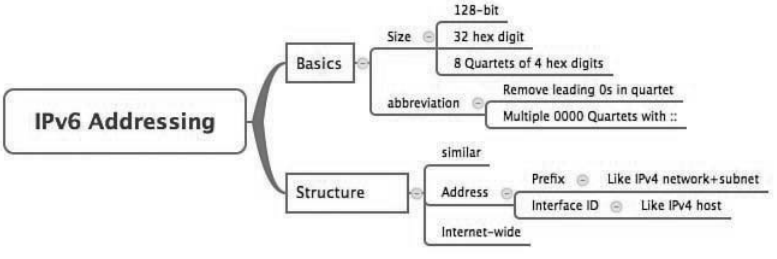

Figure I-3 *Sample Mind Map*

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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This chapter covers the following exam topics:

Operation of IP Data Networks

Predict the data flow between two hosts across a network.

IP addressing (IPv4 / IPv6)

Identify the appropriate IPv6 addressing scheme to satisfy addressing requirements in a LAN/WAN environment.

Describe IPv6 addresses

Global unicast

IP Routing Technologies

Differentiate methods of routing and routing protocols

next hop

ip routing table

Troubleshooting

Troubleshoot and correct common problems associated with IP addressing and host configurations.

CHAPTER 25

Fundamentals of IP Version 6

IPv4 has been a solid and highly useful part of the growth of TCP/IP and the Internet. For most of the long history of the Internet, and for most corporate networks that use TCP/IP, IPv4 is the core protocol that defines addressing and routing. However, even though IPv4 has many great qualities, it does have some shortcomings, creating the need for a replacement protocol: IP version 6 (IPv6).

IPv6 defines the same general functions as IPv4, but with different methods of implementing those functions. For example, both IPv4 and IPv6 define addressing, the concepts of subnetting larger groups of addresses into smaller groups, headers used to create an IPv4 or IPv6 packet, and the rules for routing those packets. At the same time, IPv6 handles the details differently, for example, using a 128-bit IPv6 address rather than the 32-bit IPv4 address.

This chapter focuses on the core network layer functions of addressing and routing. The first section of this chapter looks at the big concepts, while the second section looks at the specifics of how to write and type IPv6 addresses.

"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 25-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundation Topics Section	Questions
Introduction to IPv6	1, 2
IPv6 Addressing Formats and Conventions	3–6

1. Which of the following was a short-term solution to the IPv4 address exhaustion problem?

   a. IP version 6

   b. IP version 5

   c. NAT/PAT

   d. ARP

2. A router receives an Ethernet frame that holds an IPv6 packet. The router then makes a decision to route the packet out a serial link. Which of the following statements is true about how a router forwards an IPv6 packet?

   a. The router discards the Ethernet data link header and trailer of the received frame.

   b. The router makes the forwarding decision based on the packet's source IPv6 address.

   c. The router keeps the Ethernet header, encapsulating the entire frame inside a new IPv6 packet before sending it over the serial link.

   d. The router uses the IPv4 routing table when choosing where to forward the packet.

3. Which of the following is the shortest valid abbreviation for FE80:0000:0000:0100:0000:0000:0000:0123?

   a. FE80::100::123

   b. FE8::1::123

   c. FE80::100:0:0:0:123:4567

   d. FE80:0:0:100::123

4. Which of the following is the shortest valid abbreviation for 2000:0300:0040:0005:6000:0700:0080:0009?

   a. 2:3:4:5:6:7:8:9

   b. 2000:300:40:5:6000:700:80:9

   c. 2000:300:4:5:6000:700:8:9

   d. 2000:3:4:5:6:7:8:9

5. Which of the following is the unabbreviated version of IPv6 address 2001:DB8::200:28?

   a. 2001:0DB8:0000:0000:0000:0000:0200:0028

   b. 2001:0DB8::0200:0028

   c. 2001:0DB8:0:0:0:0:0200:0028

   d. 2001:0DB8:0000:0000:0000:0000:200:0028

6. Which of the following is the prefix for address 2000:0000:0000:0005:6000:0700:0080:0009, assuming a mask of /64?

   a. 2000::5::/64

   b. 2000::5:0:0:0:0/64

   c. 2000:0:0:5::/64

   d. 2000:0:0:5:0:0:0:0/64

Foundation Topics

Introduction to IPv6

IP version 6 (IPv6) serves as the replacement protocol for IP version 4 (IPv4).

Unfortunately, that one bold statement creates more questions than it answers. Why does IPv4 need to be replaced? If IPv4 needs to be replaced, when will that happen—and will it happen quickly? What exactly happens when a company or the Internet replaces IPv4 with IPv6? And the list goes on.

While this introductory chapter cannot get into every detail of why IPv4 needs to eventually be replaced by IPv6, the clearest and most obvious reason for migrating TCP/IP networks to use IPv6 is growth. IPv4 uses a 32-bit address, which totals to a few billion addresses. Interestingly, that seemingly large number of addresses is too small. IPv6 increases the number of addresses to a 128-bit address. For perspective, IPv6 supplies over 10,000,000,000,000,000,000,000,000,000,000 times as many addresses as IPv4.

The fact that IPv6 uses a different size address field, with some different addressing rules, means that many other protocols and functions change as well. For example, IPv4 routing—in other words, the packet-forwarding process—relies on an understanding of IPv4 addresses. To support IPv6 routing, routers must understanding IPv6 addresses and routing. To dynamically learn routes for IPv6 subnets, routing protocols must support these different IPv6 addressing rules, including rules about how IPv6 creates subnets. As a result, the migration from IPv4 to IPv6 is much more than changing one protocol (IP), but it impacts many protocols.

This first section of the chapter discusses some of the reasons for the change from IPv4 to IPv6, along with the protocols that must change as a result.

The Historical Reasons for IPv6

In the last 40 years, the Internet has gone from its infancy to being a huge influence in the world. It first grew through research at universities, from the ARPANET beginnings of the Internet in the late 1960s into the 1970s. The Internet kept growing fast in the 1980s, with the Internet's fast growth still primarily driven by research and the universities that joined in that research. By the early 1990s, the Internet began to transform to allow commerce, allowing people to sell services and products over the Internet, which drove yet another steep spike upward in the growth of the Internet. Figure 25-1 shows some of these major milestones.

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

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

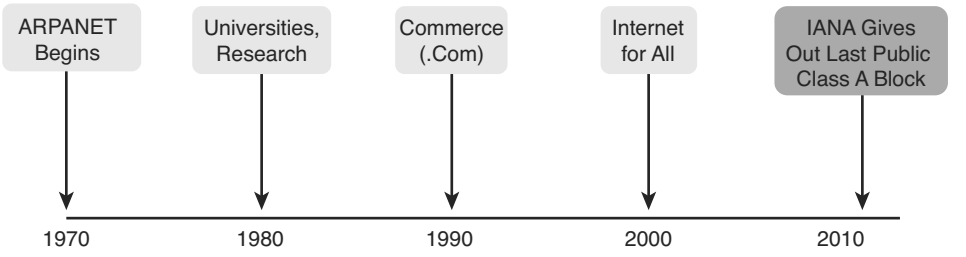

Figure 25-1 *Some Major Events in the Growth of the Internet*

Note that the figure ends the timeline with an event in which IANA/ICANN, the groups that assign public IPv4 addresses, gave out the last public IPv4 address blocks. IANA/ICANN assigned the final Class A networks to each the Regional Internet Registries (RIR) in February 2011. This event was an important event for the Internet, bringing us closer to the day when a company simply cannot get new IPv4 public address blocks.

In other words, one day, a company could want to connect to the Internet, but it cannot, just because IPv4 has no public addresses left.

Even though the press made a big deal about running out of IPv4 addresses in 2011, those who care about the Internet knew about this potential problem since the late 1980s. The problem, generally called the *IPv4 address exhaustion* problem, could literally have caused the huge growth of the Internet in the 1990s to have come to a screeching halt! Something had to be done.

The IETF came up with several short-term solutions to make IPv4 last longer, hoping to put off the day when the world ran out of public IPv4 addresses. The two primary short-term solutions were Network Address Translation / Port Address Translation (NAT/PAT) and classless interdomain routing (CIDR). Both worked wonderfully. At the time, the Internet community hoped to extend the life of IPv4 for a few more years. In practice, these tools help extend IPv4's life another couple of decades, as seen in the timeline of Figure 25-2.

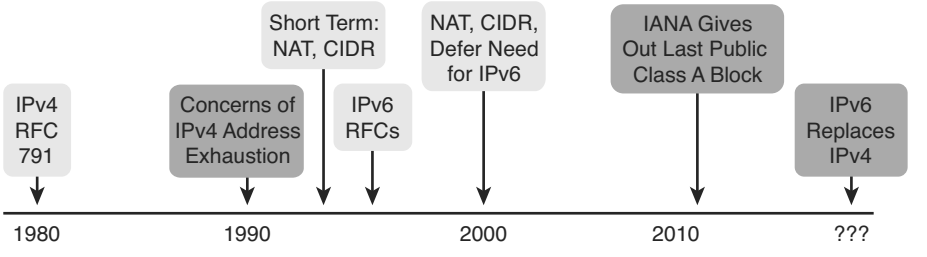

Figure 25-2 *Timeline for IPv4 Address Exhaustion and Short-/Long-Term Solutions*

NOTE The website www.potaroo.net, by Geoff Huston, shows many interesting statistics about the growth of the Internet, including IPv4 address exhaustion.

While the short-term solutions to IPv4 address exhaustion problem gave us all a few more decades to use IPv4, IPv6 gives the world a long-term solution to the problem. IPv6 replaces IPv4 as the core Layer 3 protocol, with a new IPv6 header and new IPv6 addresses. The address size supports a huge number of addresses, solving the address shortage problem for generations (we hope).

The rest of this first section examines IPv6, comparing it to IPv4, focusing on the common features of the two protocols. In particular, this section compares the protocols (including addresses), routing, routing protocols, and miscellaneous other related topics.

NOTE You might wonder why the next version of IP is not called IP version 5. There was an earlier effort to create a new version of IP, and it was numbered version 5. IPv5 did not progress to the standards stage. However, to prevent any issues, because version 5 had been used in some documents, the next effort to update IP was numbered as version 6.

The IPv6 Protocols

The primary purpose of the core IPv6 protocol mirrors the same purpose of the IPv4 protocol. That core IPv6 protocol, as defined in RFC 2460, defines a packet concept, addresses for those packets, and the role of hosts and routers. These rules allow the devices to forward packets sourced by hosts, through multiple routers, so that they arrive at the correct destination host. (IPv4 defines those same concepts for IPv4 back in RFC 791.)

However, because IPv6 impacts so many other functions in a TCP/IP network, many more RFCs must define details of IPv6. Some other RFCs define how to migrate from IPv4 to IPv6. Others define new versions of familiar protocols, or replace old protocols with new ones. For example:

Older OSPF Version 2 Upgraded to OSPF Version 3: The older OSPF version 2 works for IPv4, but not for IPv6, so a newer version, OSPF version 3, was created to support IPv6.

ICMP Upgraded to ICMP Version 6: Internet Control Message Protocol (ICMP) worked well with IPv4, but needed to be changed to support IPv6. The new name is ICMPv6.

ARP Replaced by Neighbor Discovery Protocol: For IPv4, Address Resolution Protocol (ARP) discovers the MAC address used by neighbors. IPv6 replaces ARP with a more general Neighbor Discovery Protocol (NDP).

NOTE But if you go to any website that lists the RFCs, like www.rfc-editor.org, you can find almost 300 RFCs that have IPv6 in the title.

While the term IPv6, when used broadly, includes many protocols, the one specific protocol called IPv6 defines the new 128-bit IPv6 address. Of course, writing these addresses in binary would be a problem—they probably would not even fit on the width of a piece of paper! IPv6 defines a shorter hexadecimal format, requiring at most 32 hexadecimal digits (one hex digit per 4 bits), with methods to abbreviate the hexadecimal addresses as well.

For example, all of the following are IPv6 addresses, each with 32 or less hex digits.

2345:1111:2222:3333:4444:5555:6666:AAAA

2000:1:2:3:4:5:6:A

FE80::1

The upcoming section "IPv6 Addressing Formats and Conventions" discusses the specifics of how to represent IPv6 addresses, including how to legally abbreviate the hex address values.

Like IPv4, IPv6 defines a header, with places to hold both the source and destination address fields. Compared to IPv4, the IPv6 header does make some other changes besides simply making the address fields larger. However, even though the IPv6 header is larger than an IPv4 header, the IPv6 header is actually simpler (on purpose), to reduce the work done each time a router must route an IPv6 packet. Figure 25-3 shows the required 40-byte part of the IPv6 header.

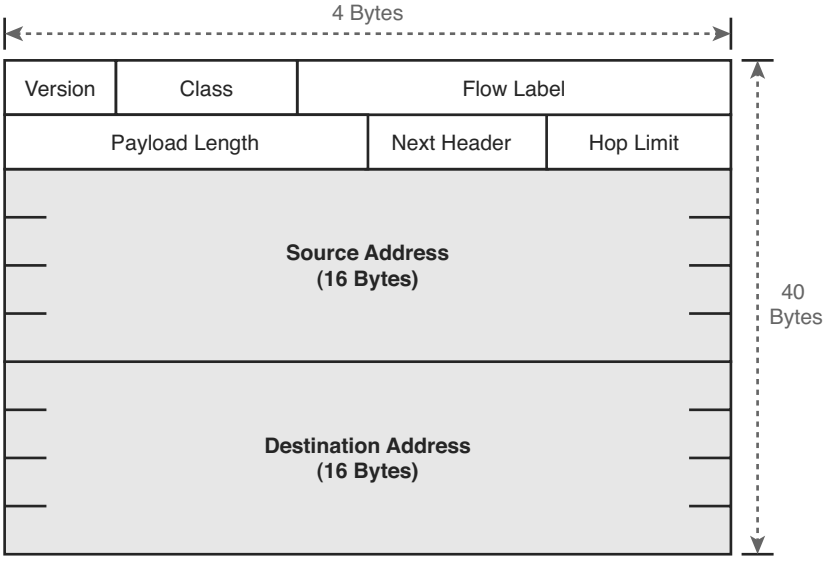

Figure 25-3 *IPv6 Header*

IPv6 Routing

As with many functions of IPv6, IPv6 routing looks just like IPv4 routing from a general perspective, with the differences being clear only once you look at the specifics. Keeping the discussion general for now, IPv6 uses these ideas the same way as IPv4:

Key Topic

- To be able to build and send IPv6 packets out an interface, end-user devices need an IPv6 address on that interface.
- End-user hosts need to know the IPv6 address of a default router, to which the host sends IPv6 packets if the host is in a different subnet.
- IPv6 routers deencapsulate and reencapsulate each IPv6 packet when routing the packet.

- IPv6 routers make routing decisions by comparing the IPv6 packet's destination address to the router's IPv6 routing table; the matched route list directions of where to send the IPv6 packet next.

NOTE You could take the preceding list, and replace every instance of IPv6 with IPv4, and all the statements would be true of IPv4 as well.

While the list shows some concepts that should be familiar from IPv4, the next few figures show the concepts with an example. First, Figure 25-4 shows a few settings on a host. The host (PC1) has an address of 2345::1. PC1 also knows its default gateway of 2345::2. (Both values are valid abbreviations for real IPv6 addresses.) To send an IPv6 packet to host PC2, on another IPv6 subnet, PC1 creates an IPv6 packet and sends it to R1, PC1's default gateway.

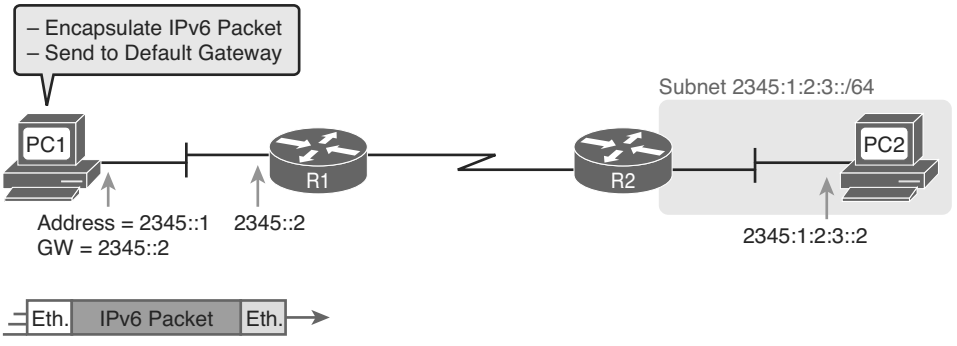

Figure 25-4 *IPv6 Host Building and Sending an IPv6 Packet*

The router (R1) has many small tasks to do when forwarding this IPv6 packet, but for now, focus on the work R1 does related to encapsulation. As seen in Step 1 of Figure 25-5, R1 receives the incoming data link frame, and extracts (deencapsulates) the IPv6 packet from inside the frame, discarding the original data link header and trailer. At Step 2, once R1 knows to forward the IPv6 packet to R2, R1 adds a correct outgoing data link header and trailer to the IPv6 packet, encapsulating the IPv6 packet.

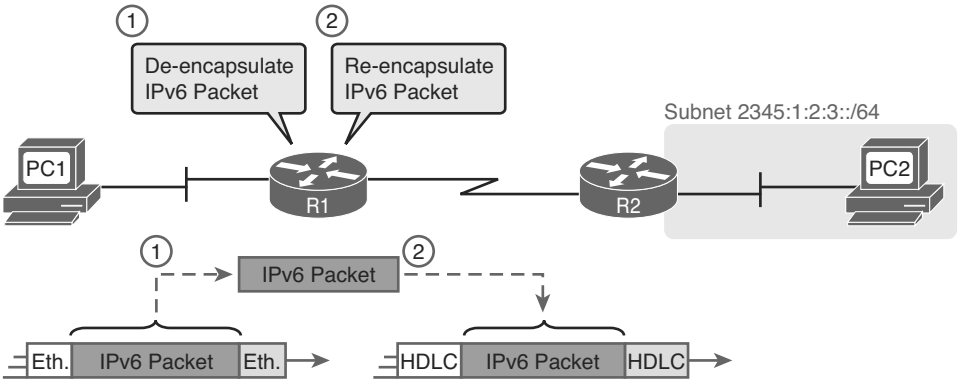

Figure 25-5 *IPv6 Router Performing Routine Encapsulation Tasks When Routing IPv6*

When a router like R1 deencapsulates the packet from the data link frame, it must also decide what type of packet sits inside the frame. To do so, the router must look at a protocol type field in the data link header, which identifies the type of packet inside the data link frame. Today, most data link frames carry either an IPv4 packet or an IPv6 packet.

To route an IPv6 packet, a router must use its IPv6 routing table instead of the IPv4 routing table. The router must look at the packet's destination IPv6 address and compare that address to the router's current IPv6 routing table. The router uses the forwarding instructions in the matched IPv6 route to forward the IPv6 packet. Figure 25-6 shows the overall process.

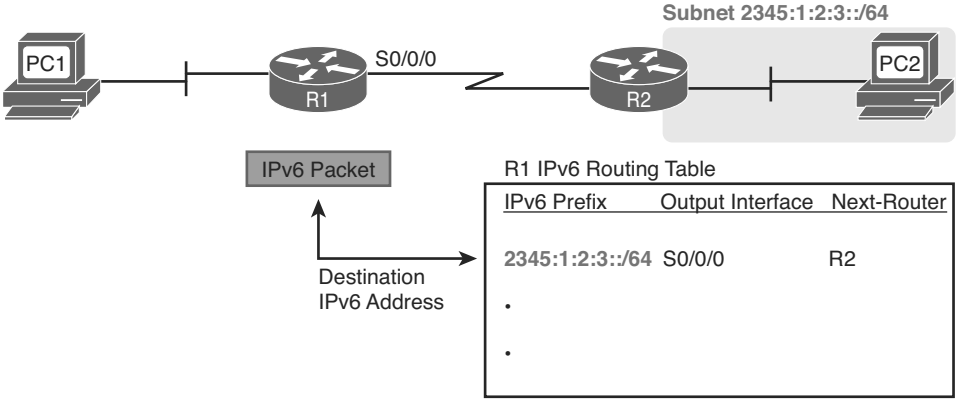

Figure 25-6 *IPv6 Router Performing Routine Encapsulation Tasks When Routing IPv6*

Note that again, the process works like IPv4, except that the IPv6 packet lists IPv6 addresses, and the IPv6 routing table lists routing information for IPv6 subnets (called prefixes).

Finally, in most enterprise networks, the routers will route both IPv4 and IPv6 packets at the same time. That is, your company will not decide to adopt IPv6, and then late one weekend night turn off all IPv4 and enable IPv6 on every device. Instead, IPv6 allows for a slow migration, during which some or all routers forward both IPv4 and IPv6 packets. (The migration strategy of running both IPv4 and IPv6 is called *dual stack*.) All you have to do is configure the router to route IPv6 packets, in addition to the existing configuration for routing IPv4 packets.

IPv6 Routing Protocols

IPv6 routers need to learn routes for all the possible IPv6 prefixes (subnets). Just like with IPv4, IPv6 routers use routing protocols, with familiar names, and generally speaking, with familiar functions.

None of the IPv4 routing protocols could be used to advertise IPv6 routes originally. They all required some kind of update to add messages, protocols, and rules to support IPv6. Over time, Routing Information Protocol (RIP), Open Shortest Path First (OSPF), Enhanced Interior Gateway Routing Protocol (EIGRP), and Border Gateway Protocol (BGP) were all updated to support IPv6. Table 25-2 lists the names of these routing protocols, with a few comments.

Table 25-2 IPv6 Routing Protocols

Routing Protocol	Defined By	Notes
RIPng (RIP Next Generation)	RFC	The "Next Generation" is a reference to a TV series, "Star Trek: the Next Generation."
OSPFv3 (OSPF version 3)	RFC	The OSPF you have worked with for IPv4 is actually OSPF version 2, so the new version for IPv6 is OSPFv3.
EIGRPv6 (EIGRP for IPv6)	Cisco	Cisco owns the rights to the EIGRP protocol, but Cisco also now publishes EIGRP as an informational RFC.
MP BGP-4 (Multiprotocol BGP version 4)	RFC	BGP version 4 was created to be highly extendable; IPv6 support was added to BGP version 4 through one such enhancement, MP BGP-4.

Additionally, these routing protocols also follow the same IGP and EGP conventions as their IPv4 cousins. RIPng, EIGRPv6, and OSPFv3 act as interior gateway protocols, advertising IPv6 routes inside an enterprise.

As you can see from this introduction, IPv6 uses many of the same big ideas as IPv4. Both define headers with a source and destination address. Both define the routing of packets, with the routing process discarding old data link headers and trailers when forwarding the packets. And routers use the same general process to make a routing decision, comparing the packet's destination IP address to the routing table.

The big differences between IPv4 and IPv6 revolve around the bigger IPv6 addresses. The next topic begins the looking at the specifics of these IPv6 addresses.

IPv6 Addressing Formats and Conventions

The CCENT and CCNA R/S exams require some fundamental skills in working with IPv4 addresses. For example, you need to be able to interpret IPv4 addresses, like 172.21.73.14. You need to be able to work with prefix-style masks, like /25, and interpret what that means when used with a particular IPv4 address. And you need to be able to take an address and mask, like 172.21.73.14/25, and find the subnet ID.

This second major section of this chapter discusses these same ideas for IPv6 addresses. In particular, this section looks at

- How to write and interpret unabbreviated 32-digit IPv6 addresses
- How to abbreviate IPv6 addresses, and how to interpret abbreviated addresses
- How to interpret the IPv6 prefix length mask
- How to find the IPv6 prefix (subnet ID), based on an address and prefix length mask

The biggest challenge with these tasks lies in the sheer size of the numbers. Thankfully, the math to find the subnet ID—often a challenge for IPv4—is easier for IPv6, at least to the depth discussed in this book.

Representing Full (Unabbreviated) IPv6 Addresses

IPv6 uses a convenient hexadecimal (hex) format for addresses. To make it more readable, IPv6 uses a format with eight sets of four hex digits, with each set of four digits separated by a colon. For example:

2340:1111:AAAA:0001:1234:5678:9ABC:1234

NOTE For convenience, the author uses the term *quartet* for one set of four hex digits, with eight quartets in each IPv6 address. Note that the IPv6 RFCs do not use the term *quartet*.

IPv6 addresses also have a binary format as well, but thankfully, most of the time you do not need to look at the binary version of the addresses. However, in those cases, converting from hex to binary is relatively easy. Just change each hex digit to the equivalent 4-bit value listed in Table 25-3.

Table 25-3 Hexadecimal/Binary Conversion Chart

Hex	Binary	Hex	Binary
0	0000	8	1000
1	0001	9	1001
2	0010	A	1010
3	0011	B	1011
4	0100	C	1100
5	0101	D	1101
6	0110	E	1110
7	0111	F	1111

Abbreviating and Expanding IPv6 Addresses

IPv6 also defines ways to abbreviate or shorten how you write or type an IPv6 address. Why? Although using a 32-digit hex number works much better than working with a 128-bit binary number, 32 hex digits is still a lot of digits to remember, recognize in command output, and type on a command line. The IPv6 address abbreviation rules let you shorten these numbers.

Computers and routers typically use the shortest abbreviation, even if you type all 32 hex digits of the address. So even if you would prefer to use the longer unabbreviated version of the IPv6 address, you need to be ready to interpret the meaning of an abbreviated IPv6 address as listed by a router or host. This section first looks at abbreviating addresses, and then at expanding addresses.

Abbreviating IPv6 Addresses

Two basic rules let you, or any computer, shorten or abbreviate an IPv6 address:

1. Inside each quartet of four hex digits, remove the leading 0s (0s on the left side of the quartet) in the three positions on the left. (Note: at this step, a quartet of 0000 will leave a single 0.)
2. Find any string of two or more consecutive quartets of all hex 0s, and replace that set of quartets with double colon (::). The :: means "two or more quartets of all 0s." However, you can only use :: once in a single address, because otherwise the exact IPv6 might not be clear.

For example, consider the following IPv6 address. The bold digits represent digits in which the address could be abbreviated.

FE00:0000:0000:0001:0000:0000:0000:0056

Applying the first rule, you would look at all eight quartets independently. In each, remove all the leading 0s. Note that five of the quartets have four 0s, so for these, only remove three 0s, leaving the following value:

FE00:0:0:1:0:0:0:56

While this abbreviation is valid, the address can be abbreviated more, using the second rule. In this case, two instances exist where more than one quartet in a row has only a 0. Pick the longest such sequence, and replace it with ::, giving you the shortest legal abbreviation:

FE00:0:0:1::56

While FE00:0:0:1::56 is indeed the shortest abbreviation, this example happens to make it easier to see the two most common mistakes when abbreviating IPv6 addresses. First, never remove trailing 0s in a quartet (0s on the right side of the quartet). In this case, the first quartet of FE00 cannot be shortened at all, because the two 0s trail. So, the following address, that begins now with only FE in the first quartet, is not a correct abbreviation of the original IPv6 address:

FE:0:0:1::56

The second common mistake is to replace all series of all 0 quartets with a double colon. For example, the following abbreviation would be incorrect for the original IPv6 address listed in this topic:

FE00::1::56

The reason this abbreviation is incorrect is because now you do not know how many quartets of all 0s to substitute into each :: to find the original unabbreviated address.

Expanding Abbreviated IPv6 Addresses

To expand an IPv6 address back into its full unabbreviated 32-digit number, use two similar rules. The rules basically reverse the logic of the previous two rules:

Key Topic

1. In each quartet, add leading 0s as needed until the quartet has four hex digits.
2. If a double colon (::) exists, count the quartets currently shown; the total should be less than 8. Replace the :: with multiple quartets of 0000 so that eight total quartets exist.

The best way to get comfortable with these addresses and abbreviations is to do some yourself. Table 25-4 lists some practice problems, with the full 32-digit IPv6 address on the left, and the best abbreviation on the right. The table gives you either the expanded or abbreviated address, and you need to supply the opposite value. The answers sit at the end of the chapter, in the section "Answers to Earlier Practice Problems."

Table 25-4 IPv6 Address Abbreviation and Expansion Practice

Full	Abbreviation
2340:0000:0010:0100:1000:ABCD:0101:1010	
	30A0:ABCD:EF12:3456:ABC:B0B0:9999:9009
2222:3333:4444:5555:0000:0000:6060:0707	
	3210::
210F:0000:0000:0000:CCCC:0000:0000:000D	
	34BA:B:B::20
FE80:0000:0000:0000:DEAD:BEFF:FEEF:CAFE	
	FE80::FACE:BAFF:FEBE:CAFE
FE80:000F:00E0:0D00:FACE:BAFF:FE00:0000	
	FE80:800:0:40:CAFE:FF:FE00:1

You will become more comfortable with these abbreviations as you get more experience. The "Exam Preparation Tasks" section at the end of this chapter lists several suggestions for getting more practice.

Representing the Prefix Length of an Address

IPv6 uses a mask concept, called the *prefix length*, similar to IPv4 subnet masks. Similar to the IPv4 prefix-style mask, the IPv6 prefix length is written as a /, followed by a decimal number. The prefix length defines how many bits of the IPv6 address defines the IPv6 prefix, which is basically the same concept as the IPv4 subnet ID.

When writing IPv6 addresses, if the prefix length matters, the prefix length follows the IPv6 address. When writing documentation, you can leave a space between the address and the /, but when typing the values into a Cisco router, you might need to configure with or without the space. For example, use either of these for an address with a 64-bit prefix length:

```
2222:1111:0:1:A:B:C:D/64
2222:1111:0:1:A:B:C:D /64
```

Finally, note that the prefix length is a number of bits, so with IPv6, the legal value range is from 0 through 128, inclusive.

Calculating the IPv6 Prefix (Subnet ID)

With IPv4, you can take an IP address and the associated subnet mask, and calculate the subnet ID. With IPv6 subnetting, you can take an IPv6 address and the associated prefix length, and calculate the IPv6 equivalent of the subnet ID: an *IPv6 prefix*.

Like with different IPv4 subnet masks, some IPv6 prefix lengths make for an easy math problem to find the IPv6 prefix, while some prefix lengths make the math more difficult. This section looks at the easier cases, mainly because the size of the IPv6 address space lets us all choose to use IPv6 prefix lengths that make the math much easier.

Finding the IPv6 Prefix

In IPv6, a prefix represents a group of IPv6 addresses. For now, this section focuses on the math, and only the math, for finding the number that represents that prefix. Chapter 26, "IPv6 Addressing and Subnetting," then starts putting more meaning behind the actual numbers.

Each IPv6 prefix, or subnet if you prefer, has a number that represents the group. Per the IPv6 RFCs, the number itself is also called the prefix, but many people just call it a subnet number or subnet ID, using the same terms as IPv4.

Like IPv4, you can start with an IPv6 address and prefix length, and find the prefix, with the same general rules that you use in IPv4. If the prefix length is /P, use these rules:

Key Topic

1. Copy the first P bits.
2. Change the rest of the bits to 0.

When using a prefix length that happens to be a multiple of 4, you do not have to think in terms of bits, but in terms of hex digits. A prefix length that is a multiple of 4 means that

each hex digit is either copied, or changed to 0. Just for completeness, if the prefix length is indeed a multiple of 4, the process becomes

1. Identify the number of hex digits in the prefix by dividing the prefix length (which is in bits) by 4.
2. Copy the hex digits determined to be in the prefix per the first step.
3. Change the rest of the hex digits to 0.

Figure 25-7 shows an example, with a prefix length of 64. In this case, Step 1 looks at the /64 prefix length, and calculates that the prefix has 16 hex digits. Step 2 copies the first 16 digits of the IPv6 address, while Step 3 records hex 0s for the rest of the digits.

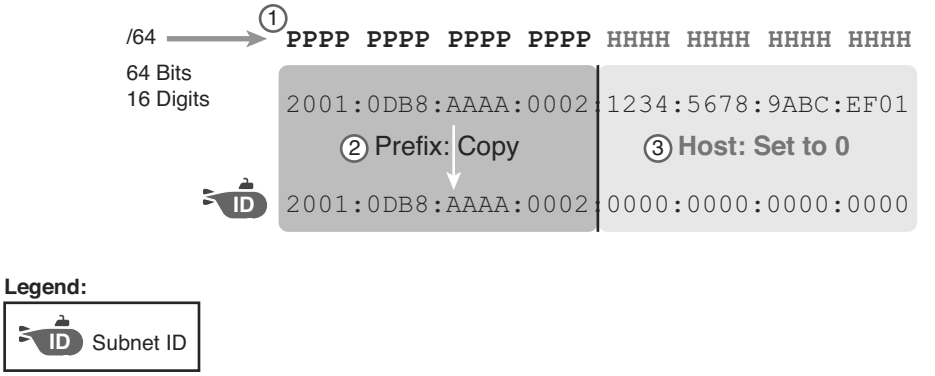

Figure 25-7 *Creating the IPv6 Prefix from an Address/Length*

After you find the IPv6 prefix, you should also be ready to abbreviate the IPv6 prefix using the same rules you use to abbreviate IPv6 addresses. However, you should pay extra attention to the end of the prefix, because it often has several octets of all 0 values. As a result, the abbreviation typically ends with two colons (::).

For example, consider the following IPv6 address that is assigned to a host on a LAN:

2000:1234:5678:9ABC:1234:5678:9ABC:1111/64

This example shows an IPv6 address that itself cannot be abbreviated. After you calculate the prefix for the subnet in which the address resides, by zeroing out the last 64 bits (16 digits) of the address, you find the following prefix value:

2000:1234:5678:9ABC:**0000:0000:0000:0000**/64

This value can be abbreviated, with four quartets of all 0s at the end, as follows:

2000:1234:5678:9ABC::/64

To get better at the math, take some time to work through finding the prefix for several practice problems, as listed in Table 25-5. The answers sit at the end of the chapter, in the section "Answers to Earlier Practice Problems."

Table 25-5 Finding the IPv6 Prefix from an Address/Length Value

Address/Length	Prefix
2340:0:10:100:1000:ABCD:101:1010/64	
30A0:ABCD:EF12:3456:ABC:B0B0:9999:9009/64	
2222:3333:4444:5555::6060:707/64	
3210::ABCD:101:1010/64	
210F::CCCC:B0B0:9999:9009/64	
34BA:B:B:0:5555:0:6060:707/64	
3124::DEAD:CAFE:FF:FE00:1/64	
2BCD::FACE:BEFF:FEBE:CAFE/64	
3FED:F:E0:D00:FACE:BAFF:FE00:0/64	
3BED:800:0:40:FACE:BAFF:FE00:0/64	

The "Exam Preparation Tasks" section at the end of this chapter lists several suggestions for getting more practice. The "Answers to Earlier Practice Problems" section at the end of the chapter also contains Table 25-9, which lists a completed version of this table so that you can check your work.

Working with More Difficult IPv6 Prefix Lengths

Some prefix lengths make the math to find the prefix very easy, some mostly easy, and some require you to work in binary. If the prefix length is a multiple of 16, the process of copying part of the address copies entire quartets. If the prefix length is not a multiple of 16, but is a multiple of 4, at least the boundary sits at the edge of a hex digit, so you can avoid working in binary.

Although the /64 prefix length is by far the most common prefix length, you should be ready to find the prefix when using a prefix length that is any multiple of 4. For example, consider the following IPv6 address and prefix length:

2000:1234:5678:9ABC:1234:5678:9ABC:1111/56

Because this example uses a /56 prefix length, the prefix includes the first 56 bits, or first 14 complete hex digits, of the address. The rest of the hex digits will be 0, resulting in the following prefix:

2000:1234:5678:9A**00:0000:0000:0000:0000**/56

This value can be abbreviated, with four quartets of all 0s at the end, as follows:

2000:1234:5678:9A**00**::/56

This example shows an easy place to make a mistake. Sometimes, people look at the /56 and think of that as the first 14 hex digits, which is correct. However, they then copy the first 14 hex digits, and add a double colon, showing the following:

2000:1234:5678:**9A**::/56

This abbreviation is not correct, because it removed the trailing "00" at the end of the fourth quartet. So, be careful when abbreviating when the boundary is not at the edge of a quartet.

Once again, some extra practice can help. Table 25-6 uses examples that have a prefix length that is a multiple of 4, but is not on a quartet boundary, just to get some extra practice. The answers sit at the end of the chapter, in the section "Answers to Earlier Practice Problems."

Table 25-6 Finding the IPv6 Prefix from an Address/Length Value

Address/Length	Prefix
34BA:B:B:0:5555:0:6060:707/80	
3124::DEAD:CAFE:FF:FE00:1/80	
2BCD::FACE:BEFF:FEBE:CAFE/48	
3FED:F:E0:D00:FACE:BAFF:FE00:0/48	
210F:A:B:C:CCCC:B0B0:9999:9009/40	
34BA:B:B:0:5555:0:6060:707/36	
3124::DEAD:CAFE:FF:FE00:1/60	
2BCD::FACE:1:BEFF:FEBE:CAFE/56	
3FED:F:E0:D000:FACE:BAFF:FE00:0/52	
3BED:800:0:40:FACE:BAFF:FE00:0/44	

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics from this chapter, noted with the Key Topic icon. Table 25-7 lists these key topics and where each is discussed.

Key Topic

Table 25-7 Key Topics for Chapter 25

Key Topic Element	Description	Page Number
List	Similarities between IPv4 and IPv6	693
List	Rules for abbreviating IPv6 addresses	698
List	Rules for expanding an abbreviated IPv6 address	699
List	Process steps to find an IPv6 prefix, based on the IPv6 address and prefix length	700

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 for you 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.

IPv4 address exhaustion, IETF, NAT, CIDR, IP version 6 (IPv6), OSPF version 3 (OSPFv3), EIGRP version 6 (EIGRPv6), prefix, prefix length, quartet

Additional Practice with IPv6 Address Abbreviations

For additional practice abbreviating IPv6 addresses:

- DVD Appendix K, "Practice for Chapter 25: Fundamentals of IP Version 6," has some additional practice problems listed.
- Create your own problems using any real router or simulator. Get into the router CLI, into configuration mode, and configure a 32-digit unabbreviated IPv6 address. Then predict the shortest abbreviation. Finally, use the **show ipv6 interface** command to see if the router used the same abbreviation you used.

Answers to Earlier Practice Problems

This chapter includes practice problems spread around different locations in the chapter. The answers are located in Tables 25-8, 25-9, and 25-10.

Table 25-8 Answers to Questions in the Earlier Table 25-4

Full	Abbreviation
2340:0000:0010:0100:1000:ABCD:0101:1010	2340:0:10:100:1000:ABCD:101:1010
30A0:ABCD:EF12:3456:0ABC:B0B0:9999:9009	30A0:ABCD:EF12:3456:ABC:B0B0:9999:9009
2222:3333:4444:5555:0000:0000:6060:0707	2222:3333:4444:5555::6060:707
3210:0000:0000:0000:0000:0000:0000:0000	3210::
210F:0000:0000:0000:CCCC:0000:0000:000D	210F::CCCC:0:0:D
34BA:000B:000B:0000:0000:0000:0000:0020	34BA:B:B::20
FE80:0000:0000:0000:DEAD:BEFF:FEEF:CAFE	FE80::DEAD:BEFF:FEEF:CAFE
FE80:0000:0000:0000:FACE:BAFF:FEBE:CAFE	FE80::FACE:BAFF:FEBE:CAFE
FE80:000F:00E0:0D00:FACE:BAFF:FE00:0000	FE80:F:E0:D00:FACE:BAFF:FE00:0
FE80:0800:0000:0040:CAFE:00FF:FE00:0001	FE80:800:0:40:CAFE:FF:FE00:1

Table 25-9 Answers to Questions in the Earlier Table 25-5

Address/Length	Prefix
2340:0:10:100:1000:ABCD:101:1010/64	2340:0:10:100::/64
30A0:ABCD:EF12:3456:ABC:B0B0:9999:9009/64	30A0:ABCD:EF12:3456::/64
2222:3333:4444:5555::6060:707/64	2222:3333:4444:5555::/64
3210::ABCD:101:1010/64	3210::/64
210F::CCCC:B0B0:9999:9009/64	210F::/64
34BA:B:B:0:5555:0:6060:707/64	34BA:B:B::/64
3124::DEAD:CAFE:FF:FE00:1/64	3124:0:0:DEAD::/64
2BCD::FACE:BEFF:FEBE:CAFE/64	2BCD::/64
3FED:F:E0:D00:FACE:BAFF:FE00:0/64	3FED:F:E0:D00::/64
3BED:800:0:40:FACE:BAFF:FE00:0/64	3BED:800:0:40::/64

Table 25-10 Answers to Questions in the Earlier Table 25-6

Address/Length	Prefix
34BA:B:B:0:5555:0:6060:707/80	34BA:B:B:0:5555::/80
3124::DEAD:CAFE:FF:FE00:1/80	3124:0:0:DEAD:CAFE::/80
2BCD::FACE:BEFF:FEBE:CAFE/48	2BCD::/48
3FED:F:E0:D00:FACE:BAFF:FE00:0/48	3FED:F:E0::/48
210F:A:B:C:CCCC:B0B0:9999:9009/40	210F:A::/40
34BA:B:B:0:5555:0:6060:707/36	34BA:B::/36
3124::DEAD:CAFE:FF:FE00:1/60	3124:0:0:DEA0::/60
2BCD::FACE:1:BEFF:FEBE:CAFE/56	2BCD:0:0:FA00:/56
3FED:F:E0:D000:FACE:BAFF:FE00:0/52	3FED:F:E0:D000:/52
3BED:800:0:40:FACE:BAFF:FE00:0/44	3BED:800::/44

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Symbols & Numerics

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