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CCNA ICND2 640-816

Third Edition

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CCNA ICND2
640-816 Official Cert Guide
Third Edition

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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 editions of the Cisco Press *CCNA Official Certification Guide* series, as well as the *CCNP ROUTE 642-902 Official Certification Guide*, the *CCIE Routing and Switching Official Certification Guide*, *Computer Networking First Step*, the *CCNA Video Mentor*, *IP Networking* (a college textbook), and he is the primary networking consultant for the *CCNA 640-802 Network Simulator* from Pearson. He maintains study tools, links to his blogs, and other resources at www.certskills.com.

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In 1993, Elan was amongst the first to obtain Cisco's Certified System Instructor (CCSI) certification and in 1996, Elan was amongst the first to attain Cisco System's highest technical certification the Cisco Certified Internetworking Expert (CCIE). Since then Elan has been involved in numerous large-scale telecommunications networking projects worldwide. Elan is known internationally as a leader in network architecture and training and has worked on many high profile projects assisting companies with their goal of implementing leading edge technologies in their corporate infrastructure.

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Dedication

For Hannah Odom, from your earthly Dad. I love you, my girl!

Acknowledgments

You know, after writing books for 13 years now, I would think that there would be something normal, something repetitive, and that each book would pretty much follow the same process as others. It now seems that normal is actually abnormal, and that requires everyone to think outside the box.

More so than probably any other editions of these books, these books really are the result of a team effort. The biggest news relates to all the extras Cisco Press added to the package. Thanks to Dave, Brett, Kourtnaye, Sandra, and all the folks at Cisco Press for going several extra miles to make this "extra" edition happen, and with so many extra valuable pieces. I think the readers will appreciate the added value. Now, on to the specifics.

First, my hat's off to Drew Cupp. Wow. Between this book, the matching *ICND2 Official Cert Guide*, and another title, Drew and I went from having no books to working on three together all at once. And they all fell into the same 5-month stretch from start to finish. It makes my head hurt thinking about it. Besides taking on extra work to get it done, Drew's clarity of thought about how to get from here to there through the process, with so many different print, DVD, and online elements, wow, no way this book gets done without Drew. Thanks, Drew: You da man!

Brian, Teri, and Steve all did a great job technical editing the book. Besides helping find mistakes and keeping the book accurate, each tech editor brought a different perspective to the process. I hope we can work together on future editions. And a special thanks to Elan Beer, the best tech editor in the business, for working on the new materials for this edition.

You know, it's great when the person you rely on most at work is consistently helpful and always comes through, whether working on an opportunity or an issue. But, when that person actually works for a partner company, it's all the more impressive. I am fortunate enough to have such an ally in Brett Bartow—thank you so much for walking this journey with me.

Mandie Frank gets the "hot potato" award for working as the project editor with this book and with *ICND1*. The nature of this project plus the ICND1 book at practically the same time can create some challenges. Mandie handled them all with grace and aplomb, and she seamlessly managed the entire process with the rest of the production team. Thanks, Mandie, and the whole group! And thanks especially for the extra attention to the pages review.

Thanks to Richard Bennett, who slaved on a short schedule on some figure improvements that I really wanted to include in this book and for his work on the question database. Dude, Robin Williams would be proud!

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

Finally, thanks to my wife Kris for all her support with my writing efforts, her prayers, and understanding when the deadline didn't quite match with our vacation plans this summer. (Yes, that's twice in a row that when this book reved, we cancelled vacation—you're a doll!) And thanks to Jesus Christ—all this effort is just striving after the wind without Him.

Contents at a Glance

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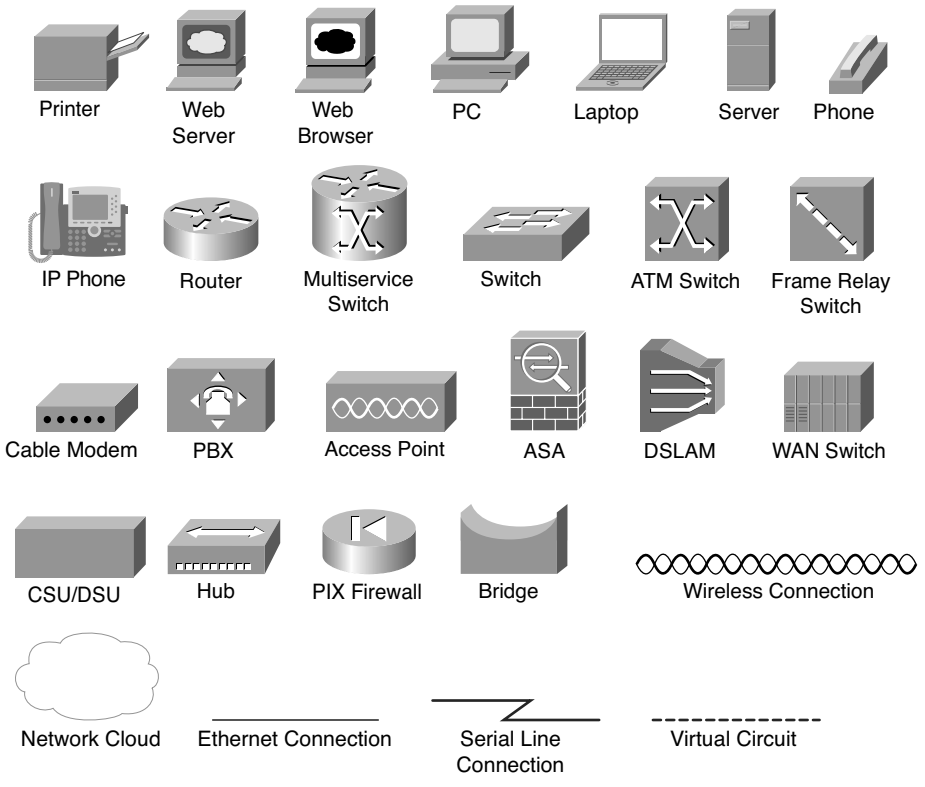


Command Syntax Conventions

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

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

Introduction

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

Historically speaking, the first entry-level Cisco certification has been the Cisco Certified Network Associate (CCNA) certification, first offered in 1998. The first three versions of the CCNA certification required that you pass a single exam to become certified. However, over time, the exam kept growing, both in the amount of material covered, and the difficulty level of the questions. So, for the fourth major revision of the exams, announced in 2003, Cisco continued with a single certification (CCNA), but offered two options for the exams to get certified: a single exam option and a two-exam option. The two-exam option allowed people to study roughly half of the material, take and pass one exam, before they moved to the next one.

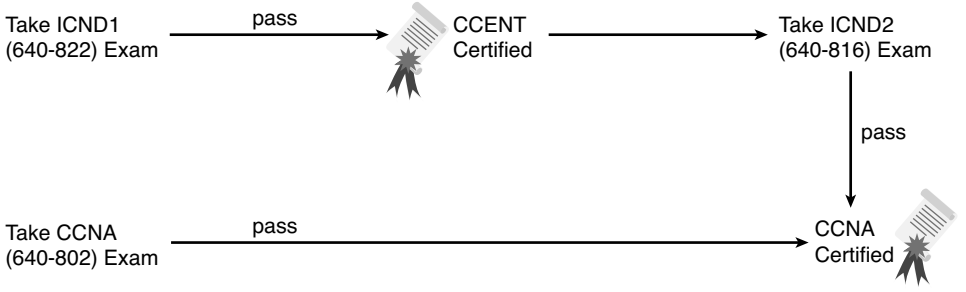
Structure of the Exams

For the current certifications, announced in June 2007, Cisco created the ICND1 (640-822) and ICND2 (640-816) exams, along with the CCNA (640-802) exam. (The exams just prior, from 2003 to 2007, followed the same structure, but were called INTRO, ICND, and CCNA.) To become CCNA certified, you can pass both the ICND1 and ICND2 exams, or just pass the CCNA exam. The CCNA exam simply covers all the topics on the ICND1 and ICND2 exams, which gives you two options for gaining your CCNA certification. The two-exam path gives those people with less experience a chance to study for a smaller set of topics at a time, whereas the one-exam option provides an option for those who want to prepare for all the topics at once.

Although the two-exam option will be useful for some certification candidates, Cisco designed the ICND1 exam with a much more important goal in mind. The CCNA certification had grown to the point that it tested knowledge and skills beyond what an entry-level network technician would need to have. Cisco needed a certification that was more reflective of the skills required for entry-level networking jobs. So, Cisco designed its Interconnecting Cisco Networking Devices 1 (ICND1) course, and the corresponding ICND1 exam, to include the knowledge and skills most needed by an entry-level technician in a small enterprise network. To show that you have the skills required for those entry-level jobs, Cisco created a new certification: CCENT.

Figure I-1 shows the basic organization of the certifications and the exams used for getting your CCENT and CCNA certifications. (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 certification. You can choose to take the CCNA exam and bypass the CCENT certification.

The ICND1 and ICND2 exams cover different sets of topics, with a minor amount of overlap. For example, ICND1 covers IP addressing and subnetting, while ICND2 covers a more complicated use of subnetting called variable-length subnet masking (VLSM), so ICND2 must then cover subnetting to some degree. The CCNA exam covers all the topics covered on both the ICND1 and ICND2 exams.

Although CCENT has slowly gained popularity over time, the Cisco CCNA certification remains the most popular entry-level networking certification program in the IT world. A CCNA certification proves that you have a firm foundation in the most important components of the Cisco product line—namely, routers and switches. It also proves that you have a broad knowledge of protocols and networking technologies.

New 2011 Editions, But Cisco Did Not Change the Exams

Unlike any previous editions of this book, this edition (Edition 3, 2011) was published even though Cisco did not revise the exams in 2011 and has not changed the exam topics nor the exam numbers. The previous editions (Editions 2, 2007) work well and still include all the content related to the current 640-822, 640-816, and 640-802 exams. So why come out with a 2011 edition when the content of the exam remains unchanged, and the coverage of the topics in the 2007 editions still does a great job?

Two reasons. First, the publisher wanted to add value other than just what's printed on the pages of the book. To that end, the publisher has added:

- A free copy of CCNA Simulator Lite. This product runs the same software as the full CCNA Network Simulator, but with some commands disabled compared to the full-price product. This is a wonderful addition, especially for those totally new to Cisco, because you can get some exposure to the user interface of Cisco gear before choosing from the many options of how to practice.
- A special offer to purchase the *CCENT/CCNA ICND2 640-816 Official Cert Guide Premium Edition* eBook and Practice Test at a 70 percent discount off the list price. This digital product provides you with two additional complete ICND2 exams and two additional full CCNA exams worth of practice questions in the powerful Pearson IT Certification Practice Test engine. It also includes two versions of the eBook version of this title: a PDF version to read on your computer and an EPUB version to read on your mobile device, tablet, or eReader. In addition to the eBook and extra practice questions, the Premium Edition eBook and Practice Test also has enhanced features in the Pearson IT Certification Practice Test, which provides you with direct links from every question to the specific section in the eBook, giving you in-depth insight into the concepts behind the questions. To take advantage of this special offer, simply refer to the instructions printed on the coupon card inserted into the DVD sleeve. This card contains a unique coupon code you can use when purchasing the Premium Edition eBook and Practice Test from one of Pearson IT Certification's sites.

Those changes alone make the new book, and the new library (that holds this book and the *ICND1 Official Cert Guide*), a much better deal than the earlier books. However, the books do change as well—not for new content, but for how the content is presented. I (Wendell) had already rewritten and improved many topics, particularly subnetting, with an eye toward a consistent approach to exercises that help you overcome the big mental hurdles. And while we were updating the books, I also updated several small topics to improve figures, clarify a point, and make adjustments when a technology might have changed in the last four years.

So, if you compare the new and the old books side by side, you will see a completely re-organized subnetting section (seven shorter chapters rather than one long one), updated figures in some chapters, and a few other changes here and there (often because of your feedback!). What you won't see are a bunch of new topics, because the exams did not change at the same time, and the existing books already covered all the exam topics.

So, how do you know that Cisco hasn't changed the exams since the time this book came out? Well, first ignore online speculation that's not from Cisco, because sometimes people like to guess. Second, look at Cisco's website. In particular, use www.cisco.com/go/ccna,

Cisco's main page for the CCNA certification. If you see exam numbers other than the ones listed in the earlier figure, the exams have changed. (And if they have changed, go to www.ciscopress.com to learn about how to find the yet again new edition of this book!)

Format of the CCNA Exams

The ICND1, ICND2, and CCNA exams all follow the same general format. When you get to the testing center and check in, the proctor gives you some general instructions and then take you into a quiet room with a PC. When you're at the PC, you have a few things to do before the timer starts on your exam—for instance, 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. Additionally, Chapter 20, "Final Preparation," points to a Cisco website at which you can see a demo of Cisco's actual test engine.

When you start the exam, you will be asked a series of questions. You answer the question and then move on to the next question. *The exam engine does not let you go back and change your answer.* Yes, that's true—when you move on to the next question, that's it for the earlier question.

The exam questions can be in one of the following formats:

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

The first three types of questions are relatively common in many testing environments. 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. Testlets are questions with one general scenario, with multiple MC questions about the overall scenario. Drag-and-drop questions require you to left-click and hold, move a button or icon to another area, and release the clicker 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. Interestingly, Sim questions are the only questions that Cisco (to date) has openly confirmed that partial credit is given.

The Simlet questions may 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 1 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 in order 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.

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 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 objectives for each exam. The objectives list the specific topics, like IP addressing, RIP, and VLANs. The objectives also implies the kinds of skills required that that topic. For example, one objective might start with "Describe…" and another might begin with "Describe, configure, and troubleshoot…." The second objective clearly states that you need a thorough and deep understanding of that topic. By listing the topics and skill level, Cisco helps us all prepare for its exams.

Although the exam objectives 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 objectives, 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

Table I-1 lists the exam topics for the ICND1 exam, with the ICND2 exam topics following in Table I-2. Although Cisco's posted exam topics are not numbered, Cisco Press numbers the exam topics for easier reference. Table I-1 also notes the book parts in which each exam topic is covered. Because it is possible that the exam topics may change over time, it may

be worth the time to double-check the exam topics as listed on Cisco's website (www.cisco.com/go/ccna). If Cisco does happen to add exam topics at a later date, note that Appendix C, "ICND2 Exam Updates: Version 1.0," describes how to go to www.ciscopress.com and download additional information about those newly added topics.

Table I-1 *ICND1 Exam Topics*

Reference Number	Book Parts (ICND1 Book)	Exam Topic
		Describe the operation of data networks
1	I	Describe the purpose and functions of various network devices
2	I	Select the components required to meet a given network specification
3	I, II, III, IV	Use the OSI and TCP/IP models and their associated protocols to explain how data flows in a network
4	I	Describe common networking applications including web applications
5	I	Describe the purpose and basic operation of the protocols in the OSI and TCP models
6	I	Describe the impact of applications (Voice over IP and Video over IP) on a network
7	I–V	Interpret network diagrams
8	I–V	Determine the path between two hosts across a network
9	I, III, IV, V	Describe the components required for network and Internet communications
10	I–V	Identify and correct common network problems at Layers 1, 2, 3 and 7 using a layered model approach
11	II, III, IV	Differentiate between LAN/WAN operation and features
		Implement a small switched network
12	II	Select the appropriate media, cables, ports, and connectors to connect switches to other network devices and hosts
13	II	Explain the technology and media access control method for Ethernet technologies
14	II	Explain network segmentation and basic traffic management concepts
15	II	Explain the operation of Cisco switches and basic switching concepts
16	II	Perform, save, and verify initial switch configuration tasks, including remote access management
17	II	Verify network status and switch operation using basic utilities (including ping, traceroute, telnet, SSH, arp, ipconfig), **show** and **debug** commands

Table I-1 *ICND1 Exam Topics (Continued)*

Reference Number	Book Parts (ICND1 Book)	Exam Topic
18	II	Implement and verify basic security for a switch (port security, deactivate ports)
19	II	Identify, prescribe, and resolve common switched network media issues, configuration issues, autonegotiation, and switch hardware failures
		Implement an IP addressing scheme and IP services to meet network requirements for a small branch office
20	I, III	Describe the need and role of addressing in a network
21	I, III	Create and apply an addressing scheme to a network
22	III, IV	Assign and verify valid IP addresses to hosts, servers, and networking devices in a LAN environment
23	IV	Explain the basic uses and operation of NAT in a small network connecting to one ISP
24	I, IV	Describe and verify DNS operation
25	III	Describe the operation and benefits of using private and public IP addressing
26	III, V	Enable NAT for a small network with a single ISP and connection using SDM and verify operation using CLI and ping
27	IV	Configure, verify, and troubleshoot DHCP and DNS operation on a router (including CLI/SDM)
28	IV	Implement static and dynamic addressing services for hosts in a LAN environment
29	III	Identify and correct IP addressing issues
		Implement a small routed network
30	I, III, IV	Describe basic routing concepts (including packet forwarding, router lookup process)
31	IV	Describe the operation of Cisco routers (including router bootup process, POST, router components)
32	I, IV	Select the appropriate media, cables, ports, and connectors to connect routers to other network devices and hosts
33	IV	Configure, verify, and troubleshoot RIPv2
34	IV	Access and utilize the router CLI to set basic parameters
35	IV	Connect, configure, and verify operation status of a device interface
36	IV	Verify device configuration and network connectivity using ping, traceroute, telnet, SSH, or other utilities

Table I-1 *ICND1 Exam Topics (Continued)*

Reference Number	Book Parts (ICND1 Book)	Exam Topic
37	IV	Perform and verify routing configuration tasks for a static or default route given specific routing requirements
38	IV	Manage IOS configuration files (including save, edit, upgrade, restore)
39	IV	Manage Cisco IOS
40	IV	Implement password and physical security
41	IV	Verify network status and router operation using basic utilities (including ping, traceroute, telnet, SSH, arp, ipconfig), **show** and **debug** commands
		Explain and select the appropriate administrative tasks required for a WLAN
42	II	Describe standards associated with wireless media (including IEEE, WI-FI Alliance, ITU/FCC)
43	II	Identify and describe the purpose of the components in a small wireless network (including SSID, BSS, ESS)
44	II	Identify the basic parameters to configure on a wireless network to ensure that devices connect to the correct access point
45	II	Compare and contrast wireless security features and capabilities of WPA security (including open, WEP, WPA-1/2)
46	II	Identify common issues with implementing wireless networks
		Identify security threats to a network and describe general methods to mitigate those threats
47	I	Explain today's increasing network security threats and the need to implement a comprehensive security policy to mitigate the threats
48	I	Explain general methods to mitigate common security threats to network devices, hosts, and applications
49	I	Describe the functions of common security appliances and applications
50	I, II, IV	Describe security recommended practices including initial steps to secure network devices
		Implement and verify WAN links
51	V	Describe different methods for connecting to a WAN
52	V	Configure and verify a basic WAN serial connection

ICND2 Exam Topics

Table I-2 lists the exam topics for the ICND2 (640-816) exam, along with the book parts in the *CCNA ICND2 Official Exam Certification Guide* in which each topic is covered.

Table I-2 *ICND2 Exam Topics*

Reference Number	Book Parts	Exam Topic
		Configure, verify, and troubleshoot a switch with VLANs and interswitch communications
101	I	Describe enhanced switching technologies (including VTP, RSTP, VLAN, PVSTP, 802.1q)
102	I	Describe how VLANs create logically separate networks and the need for routing between them
103	I	Configure, verify, and troubleshoot VLANs
104	I	Configure, verify, and troubleshoot trunking on Cisco switches
105	II	Configure, verify, and troubleshoot interVLAN routing
106	I	Configure, verify, and troubleshoot VTP
107	I	Configure, verify, and troubleshoot RSTP operation
108	I	Interpret the output of various **show** and **debug** commands to verify the operational status of a Cisco switched network
109	I	Implement basic switch security (including port security, unassigned ports, trunk access, etc.)
		Implement an IP addressing scheme and IP services to meet network requirements in a medium-size enterprise branch office network
110	II	Calculate and apply a VLSM IP addressing design to a network
111	II	Determine the appropriate classless addressing scheme using VLSM and summarization to satisfy addressing requirements in a LAN/WAN environment
112	V	Describe the technological requirements for running IPv6 (including protocols, dual stack, tunneling, etc.)
113	V	Describe IPv6 addresses
114	II, III	Identify and correct common problems associated with IP addressing and host configurations
		Configure and troubleshoot basic operation and routing on Cisco devices
115	III	Compare and contrast methods of routing and routing protocols
116	III	Configure, verify, and troubleshoot OSPF
117	III	Configure, verify, and troubleshoot EIGRP
118	II, III	Verify configuration and connectivity using ping, traceroute, and telnet or SSH
119	II, III	Troubleshoot routing implementation issues

Table I-2 *ICND2 Exam Topics (Continued)*

Reference Number	Book Parts	Exam Topic
120	II, III, IV	Verify router hardware and software operation using **show** and **debug** commands
121	II	Implement basic router security
		Implement, verify, and troubleshoot NAT and ACLs in a medium-size enterprise branch office network
122	II	Describe the purpose and types of access control lists
123	II	Configure and apply access control lists based on network filtering requirements
124	II	Configure and apply an access control list to limit telnet and SSH access to the router
125	II	Verify and monitor ACL's in a network environment
126	II	Troubleshoot ACL implementation issues
127	V	Explain the basic operation of NAT
128	V	Configure Network Address Translation for given network requirements using CLI
129	V	Troubleshoot NAT implementation issues
		Implement and verify WAN links
130	IV	Configure and verify Frame Relay on Cisco routers
131	IV	Troubleshoot WAN implementation issues
132	IV	Describe VPN technology (including importance, benefits, role, impact, components)
133	IV	Configure and very PPP connection between Cisco routers

CCNA 640-802 Exam Topics

The CCNA 640-802 exam actually covers everything from both the ICND1 and ICND2 exams, at least based on the published exam topics. As of publication, the CCNA exam topics include all topics in Tables I-1 and I-2, except those topics that are highlighted in light gray in those tables. However, note that the gray topics are still covered on the CCNA 640-802 exam; those topics are just not listed in the CCNA exam topics because one of the other exam topics refers to the same topic. In short, CCNA = ICND1 + ICND2.

ICND1 and ICND2 Course Outlines

Another way to get some direction about the topics on the exams is to look at the course outlines for the related courses. Cisco offers two authorized CCNA-related courses:

Interconnecting Cisco Network Devices 1 (ICND1) and Interconnecting Cisco Network Devices 2 (ICND2). Cisco authorizes Certified Learning Solutions Providers (CLSP) and Certified Learning Partners (CLP) to deliver these classes. These authorized companies can also create unique custom course books using this material, in some cases to teach classes geared toward passing the CCNA exam.

About the *CCNA ICND1 Official Cert Guide* and *CCNA ICND2 Official Cert Guide*

As previously mentioned, Cisco separated the content covered by the CCNA exam into two parts: topics typically used by engineers that work in a small enterprise network (ICND1), with the additional topics commonly used by engineers in medium-sized enterprises being covered by the ICND2 exam. Likewise, the Cisco Press CCNA Exam Certification Guide series includes two books for CCNA: the *CCENT/CCNA ICND1 Official Cert Guide* and the *CCNA ICND2 Official Cert Guide*. These books cover the breadth of topics on each exam, typically a bit more in-depth than what is required for the exams, just to ensure the books prepare you for the more difficult exam questions.

This section lists the variety of book features in both this book and the *CCENT/CCNA ICND1 Official Cert Guide*. Both books have the same basic features, so if you are reading both this book and the ICND1 book, there is no need to read the Introduction to that book. Also, for those of you using both books to prepare for the CCNA 640-802 exam (rather than taking the two-exam option), the end of this Introduction lists a suggested reading plan.

Objectives and Methods

The most important and somewhat obvious objective of this book is to help you pass the ICND2 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 key methodologies to help you discover the exam topics on which you need more review, to help you fully understand and remember those details, and to help you prove to yourself 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 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 via test questions on the DVD

Book 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 configuration 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
  - **Key Topics Review**: The Key Topics 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, which allows you to complete the table or list.
  - **Definition of Key Terms**: Although the exams may be 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 the 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 you remember what all the commands do.

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 ICND2 exams, as well as simulated CCNA exams, with the DVD and activation code included in this book. (You can take simulated ICND1 and CCNA exams with the DVD in *CCENT/CCNA ICND1 Official Cert Guide*.)

- **CCNA Simulator Lite**: This lite version of the best-selling CCNA Network Simulator from Pearson provides you with a means, right now, to experience the Cisco command-line interface (CLI). No need to go buy real gear or buy a full simulator to start learning the CLI. Just install it from the DVD in the back of this book. (Note: To determine when to use each lab, refer to this book's web page, and look for the link for Simulator. www.ciscopress.com/title/15872044355)

- **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 *CCNA ICND2 640-816 Official Cert Guide Premium Edition* eBook and Practice Test at a 70 percent discount off the list price. In addition to two versions of the eBook (PDF and EPUB), 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 how to calculate various facts about IP addressing and subnetting, in particular using the shortcuts described in this book.

- **VLSM, summarization, and ACL practice**: The companion DVD contains three appendices (D through F) that correspond to Chapters 5, 6, and 7, respectively. Each appendix contains a set of practice problems related to a corresponding chapter.

- **ICND1 subnetting chapters:** The DVD also includes a menu section that lists copies of all the subnetting elements from *CCENT/CCNA ICND1 640-822 Official Cert Guide*. These include the printed subnetting chapters from that book and the DVD-only practice appendices from that book.

- **DVD-based practice scenarios**: Appendix G, "Additional Scenarios," on the companion DVD, contains several networking scenarios for additional study. These scenarios describe various networks and requirements, taking you through conceptual design, configuration, and verification. These scenarios are useful for building your hands-on skills, even if you do not have lab gear.

- **Companion website**: The website www.ciscopress.com/title/1587204355 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.

  If you are looking for more hands-on practice, you might want to consider purchasing the *CCNA 640-802 Network Simulator*. You can purchase a copy of this software from Pearson at www.pearsonitcertification.com/networksimulator or other retail outlets. To help you with your studies, I have created a mapping guide that maps each of the 250 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. The site lists information to help you build your own lab, study pages that correspond to each chapter of this book and the ICND1 book, and links to the author's CCENT Skill blog and CCNA Skills blog. Start at www.certskills.com; check the tabs for study and blogs in particular.

How This Book Is Organized

This book contains 20 core chapters—Chapters 1 through 20, with Chapter 20 including some summary materials and suggestions for how to approach the actual exams. Each core chapter covers a subset of the topics on the ICND2 exam. The core chapters are organized into sections. The core chapters cover the following topics:

Part I: LAN Switching

- **Chapter 1, "Virtual LANs,"** explains the concepts and configuration surrounding virtual LANs, including VLAN trunking and VLAN Trunking Protocol.

- **Chapter 2, "Spanning Tree Protocol,"** dives deeply into the concepts behind the original Spanning Tree Protocol (STP), as well as the newer Rapid STP (RSTP), including concepts, configuration, and troubleshooting.

- **Chapter 3, "Troubleshooting LAN Switching,"** explains some general ideas about how to troubleshoot networking problems, with most of the chapter focusing on the forwarding process used by LAN switches.

Part II: IP Routing

- **Chapter 4, "IP Routing: Static and Connected Routes,"** examines how routers add both static routes and connected routes to the routing table, while also reviewing the concepts behind how routers route, or forward, packets.
- **Chapter 5, "Variable Length Subnet Masks,"** defines VLSM and explains the common pitfalls that may occur when designing and deploying IP addresses when using different masks in the same network.
- **Chapter 6, "Route Summarization,"** examines the idea of manual route summarization, with which an engineer can make a router advertise a route for one larger subnet rather than multiple routes for many smaller subnets. It also discusses the idea of automatic route summarization at the boundaries between classful networks.
- **Chapter 7, "Basic IP Access Control Lists,"** examines how standard IP ACLs can filter packets based on the source IP address so that a router will not forward the packet.
- **Chapter 8, "Advanced IP Access Control Lists,"** examines both named and numbered ACLs, emphasizing 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 9, "Troubleshooting IP Routing,"** shows a structured plan for how to isolate problems related to two hosts that should be able to send packets to each other, but cannot. The chapter also includes a variety of tips and tools for helping attack routing problems.

Part III: Routing Protocols

- **Chapter 10, "Routing Protocol Theory,"** explains the theory behind distance vector and link-state protocols.
- **Chapter 11, "OSPF,"** examines OSPF, including more detail about link-state theory as implemented by OSPF, and OSPF configuration.
- **Chapter 12, "EIGRP,"** examines EIGRP, including a description of the theory behind EIGRP, as well as EIGRP configuration and verification.
- **Chapter 13, "Troubleshooting Routing Protocols,"** explains some of the typical reasons why routing protocols fail to exchange routing information, showing specific examples of common problems with both OSPF and EIGRP.

Part IV: Wide-Area Networks

- **Chapter 14, "Point-to-Point WANs,"** reviews the basics of WANs and examines PPP, including CHAP, in more detail.
- **Chapter 15, "Frame Relay Concepts,"** focuses on the terminology and theory behind the Frame Relay protocol, including the IP addressing options when using Frame Relay.
- **Chapter 16, "Frame Relay Configuration,"** shows a variety of configuration options for Frame Relay, including both point-to-point and multipoint subinterfaces. It also explains how to best use **show** commands to isolate the root cause of common Frame Relay problems.
- **Chapter 17, "Virtual Private Networks,"** examines the concepts and protocols used to create secure VPNs over the Internet. This chapter includes the basics of IPsec.

Part V: Scaling the IP Address Space

- **Chapter 18, "Network Address Translation,"** 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.
- **Chapter 19, "IP Version 6,"** introduces the basics of IPv6, including the 128-bit address format, OSPF and EIGRP support for IPv6, and basic native IPv6 configuration. It also introduces the concept of IPv6 tunneling and migration strategies.

Part VI: Final Preparation

- **Chapter 20, "Final Preparation,"** 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 VII: Appendixes (In Print)

- **Appendix A, "Answers to the 'Do I Know This Already?' Quizzes,"** includes the answers to all the questions from Chapters 1 through 19.
- **Appendix B, "Numeric Reference Tables,"** lists several tables of numeric information, including a binary-to-decimal conversion table and a list of powers of 2.

- **Appendix C, "ICND2 Exam Updates: Version 1.0,"** covers a variety of short topics that either clarify or expand upon topics covered earlier in this book. This appendix is updated from time to time and posted at www.ciscopress.com/ccna, with the most recent version available at the time of printing included here as Appendix C. (The first page of the appendix includes instructions on how to check whether a later version of Appendix C is available online.)
- The **Glossary** contains definitions for all the terms listed in the "Definitions of Key Terms" section at the conclusion of Chapters 1–19.

Part VIII: Appendices (on the DVD)

The following appendixes are available in PDF format on the DVD that accompanies this book:

- **Appendix D, "Practice for Chapter 5: Variable Length Subnet Masks,"** lists extra practice problems related to VLSM, as originally explained in Chapter 5.
- **Appendix E, "Practice for Chapter 6: Route Summarization,"** lists extra practice problems related to manual route summarization, as originally explained in Chapter 6.
- **Appendix F, "Practice for Chapter 7: Basic IP Access Control Lists,"** lists extra practice problems related to IP ACLs, as originally explained in Chapter 7.
- **Appendix G, "Additional Scenarios"**—One method to improve your troubleshooting and network analysis skills is to examine as many unique network scenarios as is possible, think about them, and then get some feedback as to whether you came to the right conclusions. This appendix provides several such scenarios.
- **Appendix H, "Video Reference"**—The DVD includes several subnetting videos that show how to perform various subnetting tasks. This appendix contains copies of the key elements from those videos, which can be useful when watching the videos (so that you do not have to keep moving back and forth in the video).
- **Appendix I, "ICND1 Chapter 23: WAN Configuration,"** is a duplicate of Chapter 23 from *CCENT/CCNA ICND1 Official Cert Guide*. Chapter 14 of this book (ICND2), "Point-to-Point WANs," suggests to review a few prerequisite points as listed in this chapter. This chapter is included in this book for those of you who do not have a copy of *CCENT/CCNA ICND1 Official Cert Guide*.
- **Appendix J, "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 K, "Memory Tables Answer Key,"** contains the answer key for the exercises in Appendix J.
- **Appendix L, "ICND2 Open-Ended Questions,"** is a holdover from previous editions of this book. The older edition had some open-ended questions for the purpose of helping you study for the exam, but the newer features make these questions unnecessary. For convenience, the old questions are included here, unedited since the last edition.

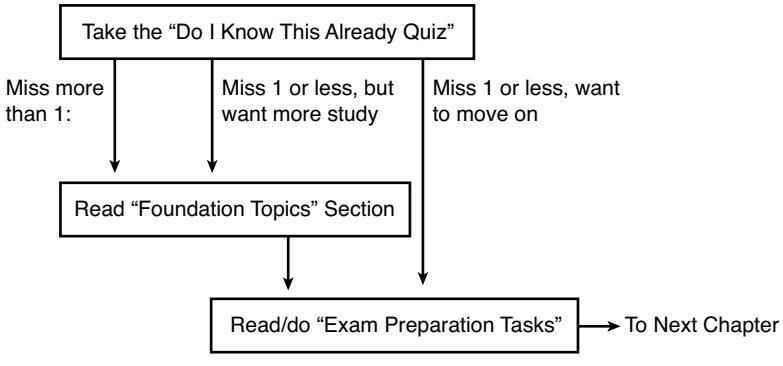
Note that in addition to the appendices listed here, the DVD also includes a menu section that lists copies of all the subnetting elements from *CCENT/CCNA ICND1 640-822 Official Cert Guide*. These include the printed subnetting chapters from that book and the DVD-only practice appendices from that book.

How to Use This Book to Prepare for the ICND2 and CCNA Exams

This book was designed with two primary goals in mind: to help you study for the ICND2 exam and to help you study for the CCNA exam by using both this book and the *ICND1 Official Cert Guide*. Using this book to prepare for the ICND2 exam is pretty straightforward: read each chapter in succession, and follow the study suggestions in Chapter 20.

For the core chapters of this book (Chapters 1–19), you have some choices as to how much of the chapter you read. In some cases, you may already know most or all of the information covered in a given chapter. To help you decide how much time to spend on each chapter, the chapters begin with a "Do I Know This Already?" quiz. If you get all the quiz questions correct, or just miss one question, you may want to skip to the end of the chapter and the "Exam Preparation Tasks" section, and do those activities. Figure I-2 shows the overall plan.

Figure I-2 *How to Approach Each Chapter of This Book*



When you complete Chapters 1–19, you can then use the guidance listed in Chapter 20 to detail the rest of the exam preparation tasks. That chapter includes the following suggestions:

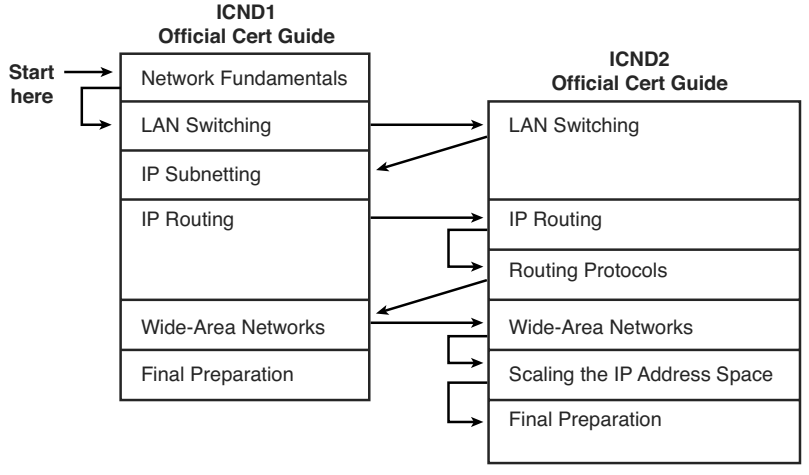
- Check www.ciscopress.com for the latest copy of Appendix C, which may include additional topics for study.
- Practice subnetting using the tools available in the DVD appendices.
- Repeat the tasks in all chapters' "Exam Preparation Tasks" chapter-ending sections.
- Review the scenarios in DVD Appendix G.
- Review all "Do I Know This Already?" questions using the exam engine.
- Practice the exam using the exam engine.

How to Use These Books to Prepare for the CCNA 640-802 Exam

If you plan to get your CCNA certification using the one-exam option of taking the CCNA 640-802 exam, you can use this book with the *CCENT/CCNA ICND1 Official Cert Guide*. If you've not yet bought either book, you can generally get the pair cheaper by buying both books as a two-book set, called the *CCNA Certification Library.*

These two books were designed to be used together when studying for the CCNA exam. There are basically two good options for the order in which to read the two books. The first and most obvious option is to read the ICND1 book first, and then read this book. The other option is to read all of ICND1's coverage of one topic area, and then read ICND2's coverage of the same topics, and then go back to ICND1 again. Figure I-3 outlines my suggested option for reading the two books.

Figure I-3 *Reading Plan When Studying for CCNA Exam*



Both reading plan options have some benefits. Moving back and forth between books helps you to focus on one general topic at a time. However, there is some overlap between the two exams, so there is some overlap between the two books. From reader comments about the previous edition of these books, those readers new to networking tended to do better by completing the first book, and then moving on to the second, while readers who had more experience and knowledge before starting the books tended to prefer to follow a reading plan like the one shown in Figure I-3.

Note that, for final preparation, you can use the final chapter (Chapter 24) of the ICND1 book instead of Chapter 20 of this book. Both of these chapters mention the same details.

In addition to the flow shown in Figure I-3, when studying for the CCNA exam (rather than the ICND1 and ICND2 exams), it is important to study and practice IP subnetting before moving on to the IP routing and routing protocol parts of this book. This book does not review subnetting or the underlying math, assuming that you know how to find the answers. Some chapters in this book, particularly Chapter 5, "Variable Length Subnet Masks," will be much easier to understand if you can do the related subnetting math pretty easily.

For More Information

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

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

The CCNA certification is arguably the most important Cisco certification, with the newer CCENT certification slowly gaining in popularity. CCNA certainly is the most popular Cisco certification, is required for several other certifications, and is the first step in distinguishing yourself as someone who has proven knowledge of Cisco.

The *CCNA ICND2 Official Cert Guide* helps you attain CCNA certification. This is the CCNA ICND2 certification book from the only Cisco-authorized publisher. We at Cisco Press believe that this book certainly can help you achieve CCNA certification, but the real work is up to you! I trust that your time will be well spent.

Cisco Published ICND2 Exam Topics* Covered in This Part

Configure, verify, and troubleshoot a switch with VLANs and interswitch communications

- Describe enhanced switching technologies (including: VTP, RSTP, VLAN, PVSTP, 802.1q)
- Describe how VLANs create logically separate networks and the need for routing between them
- Configure, verify, and troubleshoot VLANs
- Configure, verify, and troubleshoot trunking on Cisco switches
- Configure, verify, and troubleshoot VTP
- Configure, verify, and troubleshoot RSTP operation
- Interpret the output of various show and debug commands to verify the operational status of a Cisco switched network
- Implement basic switch security (including: port security, unassigned ports, trunk access, etc.)

* Always recheck Cisco.com for the latest posted exam topics.

This chapter covers the following subjects:

VLSM Concepts and Configuration: This section explains the issues and solutions when designing an internetwork that uses VLSM.

Finding VLSM Overlaps: This section is the first of three that focus on applying VLSM concepts in a particular way. In this case, it focuses on analyzing a deployed internetwork to find cases in which the subnets' address ranges overlap, which causes IP routing problems.

Adding New Subnets to an Existing VLSM Design: This section examines how to choose new subnets, based on an existing design plus the requirements for the new subnets. This section emphasizes how to avoid mistakenly choosing subnets that overlap.

Designing a Subnetting Plan Using VLSM: This section discusses cases in which you start with no design at all, but instead with a set of requirements and an IP network. Your job: choose a number of masks, the number of subnets that use each mask, and the specific subnet IDs to use with each mask.

CHAPTER 5

Variable Length Subnet Masks

Most of the IP addresses and subnetting content sits inside the ICND1 part of the CCNA puzzle. This chapter explores the one pure addressing topic in the ICND2 part of the mix: variable length subnet masks (VLSM).

VLSM builds on the subnetting concepts in ICND1. If you have a good handle on those details, great! If you are still a little unsure, it may be a good time to review and practice subnetting. For instance, to do some of the exercises in this chapter, you need to remember how and why you would pick a particular mask, given the need for a subnet to support some number of host IP addresses. You also need to be able to find all the subnet IDs of a single classful network when using a single mask. Using both sets of skills, this chapter expands on those concepts when using multiple masks. Look at this chapter as an opportunity to learn VLSM, as well as to review and strengthen your subnetting skills.

"Do I Know This Already?" Quiz

The "Do I Know This Already?" quiz allows you to assess whether you should read the entire chapter. If you miss no more than one of these six self-assessment questions, you might want to move ahead to the section, "Exam Preparation Tasks." Table 5-1 lists the major headings in this chapter and the "Do I Know This Already?" quiz questions covering the material in those headings so that you can assess your knowledge of these specific areas. The answers to the "Do I Know This Already?" quiz appear in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes."

Table 5-1 *"Do I Know This Already?" Foundation Topics Section-to-Question Mapping*

Foundations Topics Section	Questions
VLSM Concepts and Configuration	1, 2
Finding VLSM Overlaps	3, 4
Adding a New Subnet to an Existing VLSM Design	5
Designing a Subnetting Plan Using VLSM	6

1. Which of the following routing protocols support VLSM?
   a. RIP-1
   b. RIP-2
   c. EIGRP
   d. OSPF
2. What does the acronym VLSM stand for?
   a. Variable length subnet mask
   b. Very long subnet mask
   c. Vociferous longitudinal subnet mask
   d. Vector-length subnet mask
   e. Vector loop subnet mask
3. R1 has configured interface Fa0/0 with the **ip address 10.5.48.1 255.255.240.0** command. Which of the following subnets, when configured on another interface on R1, would not be considered an overlapping VLSM subnet?
   a. 10.5.0.0 255.255.240.0
   b. 10.4.0.0 255.254.0.0
   c. 10.5.32.0 255.255.224.0
   d. 10.5.0.0 255.255.128.0
4. R4 has a connected route for 172.16.8.0/22. Which of the following answers lists a subnet that overlaps with this subnet?
   a. 172.16.0.0/21
   b. 172.16.6.0/23
   c. 172.16.16.0/20
   d. 172.16.11.0/25

5. A design already includes subnets 192.168.1.0/26, 192.168.1.128/30, and 192.168.1.160/29. Which of the following subnets is the numerically lowest subnet ID that could be added to the design, if you wanted to add a subnet that uses a /28 mask?

   a. 192.168.1.144/28

   b. 192.168.1.112/28

   c. 192.168.1.64/28

   d. 192.168.1.80/28

   e. 192.168.1.96/28

6. An engineer is following a VLSM design process of allocating the largest subnets first, as the numerically lowest subnets, and then subdividing the next subnet into smaller pieces for the next smaller size of subnet. In this case, the engineer has reserved the first three /20 subnets of 172.16.0.0 to be used in an internetwork: 172.16.0.0/20, 172.16.16.0/20, and 172.16.32.0/20. The next smaller size subnets to be allocated will be subnets with mask /25; this design requires 10 such subnets. Assuming the engineer continues to allocate subnets in sequence, which answers lists the tenth of these /25 subnets?

   a. 172.16.48.0/25

   b. 172.16.64.0/25

   c. 172.16.52.128/25

   d. 172.16.68.128/25

Foundation Topics

VLSM Concepts and Configuration

VLSM occurs when an internetwork uses more than one mask for different subnets of a single Class A, B, or C network. Figure 5-1 shows an example of VLSM used in Class A network 10.0.0.0.

Figure 5-1 *VLSM in Network 10.0.0.0: Masks /24 and /30*

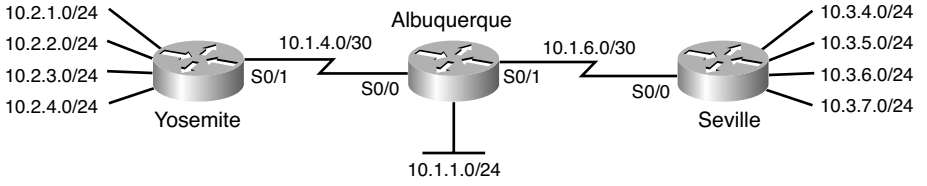


Figure 5-1 shows a typical choice of using a /30 prefix (mask 255.255.255.252) on point-to-point serial links, with mask /24 (255.255.255.0) on the LAN subnets. All subnets are of Class A network 10.0.0.0, with two masks being used, therefore meeting the definition of VLSM.

Oddly enough, a common mistake occurs when people think that VLSM means "using more than one mask in some internetwork," rather than "using more than one mask *in a single classful network*." For example, if in one internetwork diagram, all subnets of network 10.0.0.0 use a 255.255.240.0 mask, and all subnets of network 11.0.0.0 use a 255.255.255.0 mask, the design uses two different masks. However, Class A network 10.0.0.0 uses only one mask, and Class A network 11.0.0.0 uses only one mask. In that case, the design does not use VLSM.

VLSM provides many benefits for real networks, mainly related to how you allocate and use your IP address space. Because a mask defines the size of the subnet (the number of host addresses in the subnet), VLSM allows engineers to better match the need for addresses with the size of the subnet. For example, for subnets that need fewer addresses, the engineer uses a mask with fewer host bits, so the subnet has fewer host IP addresses. This flexibility reduces the number of wasted IP addresses in each subnet. By wasting fewer addresses, more space remains to allocate more subnets.

VLSM can be helpful for both public and private IP addresses, but the benefits are more dramatic with public networks. With public networks, the address savings help engineers

avoid having to obtain another registered IP network number from regional IP address assignment authorities. With private networks, as defined in RFC 1918, running out of addresses is not as big a negative, because you can always grab another private network from RFC 1918 if you run out.

Classless and Classful Routing Protocols

Before you can deploy a VLSM design created on paper, you must first use a routing protocol that supports VLSM. To support VLSM, the routing protocol must advertise the mask along with each subnet. Without mask information, the router receiving the update would be confused.

For instance, if a router learned a route for 10.1.8.0, but with no mask information, what does that mean? Is that subnet 10.1.8.0/24? 10.1.8.0/23? 10.1.8.0/30? The dotted-decimal number 10.1.8.0 happens to be a valid subnet number with a variety of masks, and because multiple masks may be used with VLSM, the router has no good way to make an educated guess. To effectively support VLSM, the routing protocol needs to advertise the correct mask along with each subnet, so the receiving router knows the exact subnet that is being advertised.

By definition, *classless routing protocols* advertise the mask with each advertised route, and *classful routing protocols* do not. The classless routing protocols, as noted in Table 5-2, are the newer, more advanced routing protocols. And not only do these more advanced classless routing protocols support VLSM, they also support manual route summarization, a feature discussed in Chapter 6, "Route Summarization."

Table 5-2 *Classless and Classful Interior IP Routing Protocols*

Routing Protocol	Is It Classless?	Sends Mask in Updates	Supports VLSM	Supports Manual Route Summarization
RIP-1	No	No	No	No
IGRP	No	No	No	No
RIP-2	Yes	Yes	Yes	Yes
EIGRP	Yes	Yes	Yes	Yes
OSPF	Yes	Yes	Yes	Yes

Beyond VLSM itself, the routing protocols do not have to be configured to support VLSM or to be classless. There is no command to enable or disable the fact that classless routing protocols include the mask with each route. The only configuration choice you must make

is to use a classless routing protocol, which among the IGPs discussed for CCNA, are RIP-2, EIGRP, and OSPF.

VLSM Configuration and Verification

Cisco routers do not configure VLSM, enable or disable it, or need any configuration to use it. From a configuration perspective, VLSM is simply a side effect of the **ip address** interface subcommand. Routers collectively configure VLSM by virtue of having IP addresses in the same classful network but with different masks.

For instance, Example 5-1 shows a simple example with two of the interfaces from router Yosemite from Figure 5-1. The example shows the IP address assignments on two interfaces, one with a /24 mask and one with a /30 mask, both with IP addresses in Class A network 10.0.0.0.

Example 5-1 *Configuring Two Interfaces on Yosemite, Resulting in VLSM*

```
Yosemite#configure terminal
Yosemite(config)#interface Fa0/0
Yosemite(config-if)#ip address 10.2.1.1 255.255.255.0
Yosemite(config-if)#interface S0/1
Yosemite(config-if)#ip address 10.1.4.1 255.255.255.252
```

When a router detects VLSM being used in a network, IOS lists the mask per route in the output of the **show ip route** command, rather than simply listing the mask only in the header line for that network. Example 5-2 lists an example of the routing table on Albuquerque from Figure 5-1; Albuquerque uses two masks inside network 10.0.0.0, as noted in the highlighted line in the example.

Example 5-2 *Albuquerque Routing Table with VLSM*

```
Albuquerque#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 11 subnets, 2 masks
D       10.2.1.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.2.2.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.2.3.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
```

Example 5-2 *Albuquerque Routing Table with VLSM (Continued)*

```
D       10.2.4.0/24 [90/2172416] via 10.1.4.1, 00:00:34, Serial0/0
D       10.3.4.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.5.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.6.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
D       10.3.7.0/24 [90/2172416] via 10.1.6.2, 00:00:56, Serial0/1
C       10.1.1.0/24 is directly connected, FastEthernet0/0
C       10.1.6.0/30 is directly connected, Serial0/1
C       10.1.4.0/30 is directly connected, Serial0/0
```

So ends the discussion of VLSM as an end to itself. This chapter is devoted to VLSM, but it took a mere 3–4 pages to fully describe it. Why the whole VLSM chapter? Well, to work with VLSM, to find problems with it, to add subnets to an existing design, and to design using VLSM from scratch—in other words, to apply VLSM to real networks—takes skill and practice. To do these same tasks on the exam requires skill and practice. The rest of this chapter examines the skills to apply VLSM and provides some practice for these three key areas:

- Finding VLSM overlaps
- Adding new VLSM subnets without overlaps
- Designing subnetting using VLSM

Finding VLSM Overlaps

Regardless of whether a design uses VLSM or not, the subnets used in any IP internetwork design should not overlap their address ranges. When subnets in different locations overlap their addresses, a router's routing table entries overlap. As a result, hosts in different locations may be assigned the same IP address. Routers clearly cannot route packets correctly in these cases. In short, a design that uses overlapping subnets is considered to be an incorrect design and should not be used.

NOTE Although I've not seen the term used in other places, just to have a term to contrast with VLSM, this book refers to the non-use of VLSM—in other words, using a single mask throughout a classful network—as static length subnet masks (SLSM).

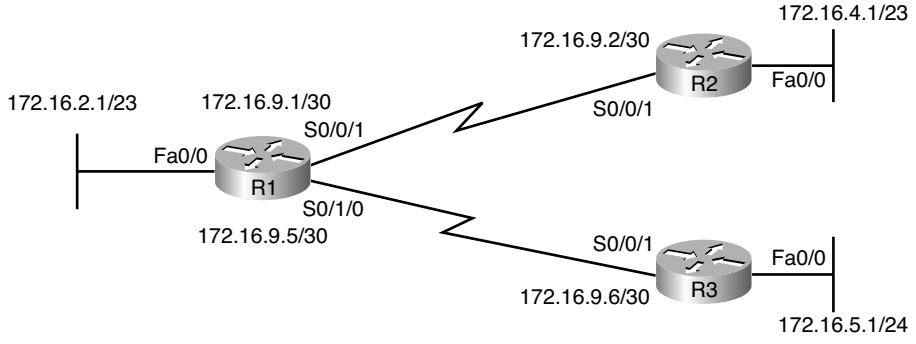
These address overlaps are easier to see when using SLSM than when using VLSM. With SLSM, overlapped subnets have identical subnet IDs, so to find overlaps, you just have to look at the subnet IDs. With VLSM, overlapped subnets may not have the same subnet ID. To find these overlaps, you have to look at the entire range of addresses in each subnet, from

subnet ID to subnet broadcast address, and compare the range to the other subnets in the design.

An Example of Finding a VLSM Overlap

For example, imagine that a practice question for the CCNA exam shows Figure 5-2. It uses a single Class B network (172.16.0.0), with VLSM, because it uses three different masks: /23, /24, and /30.

Figure 5-2 *VLSM Design with Possible Overlap*



Now imagine that the exam question shows you the figure, and either directly or indirectly asks whether overlapping subnets exist. This type of question might simply tell you that some hosts cannot ping each other, or it might not even mention that the root cause could be that some of the subnets overlap. To answer such a question, you could follow this simple but possibly laborious process:

Key Topic

Step 1 Calculate the subnet ID and subnet broadcast address of each subnet, which gives you the range of addresses in that subnet.

Step 2 List the subnet IDs in numeric order (along with their subnet broadcast addresses).

Step 3 Scan the list top to bottom, comparing each pair of adjacent entries, to see if their range of addresses overlaps.

For example, Table 5-3 completes the first two steps based on Figure 5-2, listing the subnet IDs and subnet broadcast addresses, in numeric order based on the subnet IDs.

Table 5-3 *Subnet IDs and Broadcast Addresses, in Numeric Order, from Figure 5-2*

Subnet	Subnet Number	Broadcast Address
R1 LAN	172.16.2.0	172.16.3.255
R2 LAN	172.16.4.0	172.16.5.255
R3 LAN	172.16.5.0	172.16.5.255
R1-R2 serial	172.16.9.0	172.16.9.3
R1-R3 serial	172.16.9.4	172.16.9.7

Step 3 states the somewhat obvious step of comparing the address ranges to see whether any overlaps occur. You could just scan the list overall, but if you order the list, you can also methodically scan the list looking at each adjacent pair.

First, look closely just at the subnet number column in Table 5-3. Note that, in this case, none of the subnet numbers are identical, but two entries (highlighted) do overlap.

Next, look closely at the R2 LAN and R3 LAN subnets. All the addresses in the 172.16.5.0/24 subnet are also part of the 172.16.4.0/23 subnet. In this case, the design is invalid because of the overlap, and one of these two subnets would need to be changed.

As far as the three-step process works, note that if two adjacent entries in the list overlap, compare three entries at the next step. The two subnets already marked as overlapped may overlap with the next subnet in the list. For example, imagine a case where you had the following three subnets in a list that you were examining for VLSM overlaps:

10.1.0.0/16 (subnet ID 10.1.0.0, broadcast 10.1.255.255)

10.1.200.0/24 (subnet ID 10.1.200.0, broadcast 10.1.200.255)

10.1.250.0/24 (subnet ID 10.1.250.0, broadcast 10.1.250.255)

If you compare entries 1 and 2, clearly, an overlap occurs, because all the addresses in subnet 10.1.200.0/24 sit inside subnet 10.1.0.0/16. If you then compare only entries 2 and 3, those entries do not overlap. However, entries 1 and 3 do overlap. So what does this mean for the process? Any time you find an overlap, compare all of those overlapped subnets with the next line in the list of subnets until you find one that doesn't overlap.

Practice Finding VLSM Overlaps

As typical of anything to with applying IP addressing and subnetting, practice helps. To that end, Table 5-4 lists three practice problems. Just start with the five IP addresses listed in a single column, and then follow the three-step process outlined in the previous section to find any VLSM overlaps. The answers can be found near the end of this chapter, in the section, "Answers to Earlier Practice Problems."

Table 5-4 *VLSM Overlap Practice Problems*

Problem 1	Problem 2	Problem 3
10.1.34.9/22	172.16.126.151/22	192.168.1.253/30
10.1.29.101/23	172.16.122.57/27	192.168.1.113/28
10.1.23.254/22	172.16.122.33/30	192.168.1.245/29
10.1.17.1/21	172.16.122.1/30	192.168.1.125/30
10.1.1.1/20	172.16.128.151/20	192.168.1.122/30

Adding a New Subnet to an Existing VLSM Design

The task described in this section happens frequently in real networks: choosing new subnets to add to an existing design. In real life, you may use tools that help you choose a new subnet so that you do not cause an overlap. However, for both real life and for the CCNA exam, you need to be ready to do the mental process and math of choosing a subnet that both has the right number of host IP addresses and does not create an overlapped VLSM subnet condition. In other words, you need to pick a new subnet and not make a mistake!

For example, consider the internetwork in Figure 5-2, with classful network 172.16.0.0. An exam question might suggest that a new subnet, with a /23 prefix length, needs to be added to the design. The question might also say, "Pick the numerically lowest subnet number that can be used for the new subnet." In other words, if both 172.16.4.0 and 172.16.6.0 would work, use 172.16.4.0.

So, you really have a couple of tasks: to find all the subnet IDs that could be used, rule out the ones that would cause an overlap, and then check to see if the question guides you to pick either the numerically lowest (or highest) subnet ID. This list outlines the specific steps:

Step 1 Pick the subnet mask (prefix length) for the new subnet, based on the design requirements (if not already listed as part of the question).

Step 2 Calculate all possible subnet numbers of the classful network using the mask from Step 1, along with the subnet broadcast addresses.

Step 3 Make a list of existing subnet IDs and matching subnet broadcast addresses.

Step 4 Rule out overlapping new subnets by comparing the lists from the previous two steps.

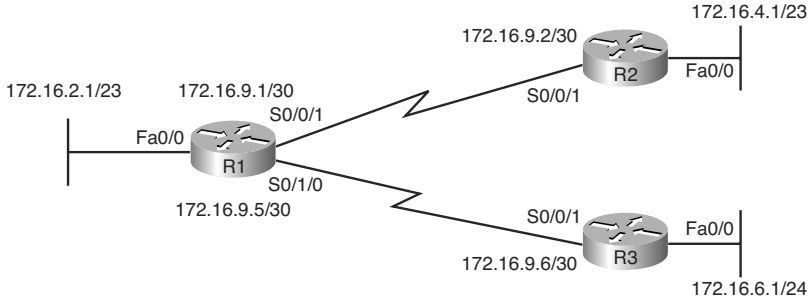
Step 5 Choose the new subnet ID from the remaining subnets identified at Step 4, paying attention to whether the question asks for the numerically lowest or numerically highest subnet ID.

An Example of Adding a New VLSM Subnet

For example, Figure 5-3 shows an existing internetwork that uses VLSM. In this case, you need to add a new subnet to support 300 hosts. Imagine that the question tells you to use the smallest subnet (least number of hosts) to meet that requirement. You use some math and logic you learned earlier in your study to choose mask /23, which gives you 9 host bits, for $2^9 - 2 = 510$ hosts in the subnet.

> **NOTE** If the logic and process in the previous paragraph was unfamiliar, it may be useful to take some time to review the ICND1 book's Chapter 15, "Analyzing Existing Masks," and Chapter 16, "Designing Subnet Masks." These chapters are also on the DVD in the back of this book. Likewise, if finding the subnet ID and subnet broadcast address is unfamiliar, review ICND1 Chapter 17, "Analyzing Existing Subnets," and Chapter 18, "Finding All Subnet IDs."

Figure 5-3 *Internetwork to Which You Need to Add a /23 Subnet, Network 172.16.0.0*



At this point, just follow the steps listed before Figure 5-3. For Step 1, you have already been given the mask (/23). For Step 2, you need to list all the subnet numbers and broadcast

addresses of 172.16.0.0 assuming the /23 mask. You will not use all these subnets, but you need the list for comparison to the existing subnets. Table 5-5 shows the results, at least for the first five possible /23 subnets.

Table 5-5 *First Five Possible /23 Subnets*

Subnet	Subnet Number	Subnet Broadcast Address
First (zero)	172.16.0.0	172.16.1.255
Second	172.16.2.0	172.16.3.255
Third	172.16.4.0	172.16.5.255
Fourth	172.16.6.0	172.16.7.255
Fifth	172.16.8.0	172.16.9.255

Next, at Step 3, list the existing subnet numbers and broadcast addresses, as seen earlier in Figure 5-3. To do so, do the usual math to take an IP address/mask to then find the subnet ID and subnet broadcast address. Table 5-6 summarizes that information, including the locations, subnet numbers, and subnet broadcast addresses.

Table 5-6 *Existing Subnet IDs and Broadcast Addresses from Figure 5-3*

Subnet	Subnet Number	Subnet Broadcast Address
R1 LAN	172.16.2.0	172.16.3.255
R2 LAN	172.16.4.0	172.16.5.255
R3 LAN	172.16.6.0	172.16.6.255
R1-R2 serial	172.16.9.0	172.16.9.3
R1-R3 serial	172.16.9.4	172.16.9.7

At this point, you have all the information you need to look for the overlap at Step 4. Simply compare the range of numbers for the subnets in the previous two tables. Which of the possible new /23 subnets (Table 5-5) overlap with the existing subnets (Table 5-6)? In this case, the second, third, and fifth subnets in Table 5-5 overlap, so rule those out as candidates to be used. (Table 5-5 denotes those subnets with gray highlights.)

Step 5 has more to do with the exam than with real network design, but it is still worth listing as a separate step. Multiple-choice questions sometimes need to force you into a single answer, and asking for the numerically lowest or highest subnet does that. This

particular example asks for the numerically lowest subnet number, which in this case is 172.16.0.0/23.

NOTE The answer, 172.16.0.0/23, happens to be a zero subnet. For the exam, the zero subnet should be avoided if (a) the question implies the use of classful routing protocols, or (b) the routers are configured with the **no ip subnet-zero** global configuration command. Otherwise, assume that the zero subnet can be used.

Practice Adding New VLSM Subnets

Your boss wants you to add a subnet to an existing design. The existing design already has these five subnets:

10.0.0.0/24
10.0.1.0/25
10.0.2.0/26
10.0.3.0/27
10.0.6.0/28

The boss cannot decide among five competing subnet masks. However, the boss wants you to practice VLSM and plan the subnet ID he would use for each of those five possible masks. He tells you that the new subnet ID must be part of class A network 10.0.0.0, that the new subnet must not overlap with the original five subnets, and that the new subnet ID must be the numerically lowest possible subnet ID (without breaking the other rules). Pick the one subnet ID you would plan to use based on each of the following mask choices by the boss:

1. /24
2. /23
3. /22
4. /25
5. /26

You can find the answers in the section, "Answers to Practice Problems."

Designing a Subnetting Plan Using VLSM

CCENT/CCNA ICND1 Official Cert Guide explains several important subnetting design concepts and tasks, but they all assume a single subnet mask is used in each classful network. To perform the similar but more involved design work when using VLSM, you need to apply those same skills in new ways.

For instance, you should understand by now how to design or choose a subnet mask so that a subnet supports a stated number of host IP addresses. You should also know how to list

all the subnets of a classful network, assuming one specific mask is used throughout that classful network.

This section discusses how to apply those same concepts when you allow the use of multiple masks.

For example, when assuming SLSM in the ICND1 book, a problem might use Class B network 172.16.0.0, and the design might call for ten subnets, with the largest subnet containing 200 hosts. Mask 255.255.255.0 meets the requirements for that largest subnet, with 8 subnet bits and 8 host bits, supporting 256 subnets and 254 hosts per subnet. (Other masks also meet that requirement.) If using that one mask throughout the network, the subnet numbers would be 172.16.0.0, 172.16.1.0, 172.16.2.0, and so on, counting by one in the third octet.

NOTE To review subnetting design when using static-length subnet masks (SLSM), refer to *CCENT/CCNA ICND1 Official Cert Guide*, Chapters 16 and 18. Both chapters also exist on this book's DVD.

To create a subnet plan with VLSM, you have to rethink the choice of subnet masks and the choice of allowed subnets. Additionally, you always have to avoid choosing subnets that overlap. This section walks through the VLSM subnet design process, beginning with mask design, and moving on to choosing subnets to use for a particular topology.

Choosing VLSM Masks

With SLSM design, you typically choose the one mask based on the needs of the largest subnet—in other words, the subnet that requires the largest number of host IP addresses. With VLSM design, you can instead choose to use many different masks. You could literally use every mask from /8 through /30 inside a single classful network.

Although using a dozen masks might let you save lots of addresses, it would also create extra complexity. So, the VLSM design choice for how many masks to use, and which ones, requires some compromise and tradeoffs between saving addresses while keeping things simple. Many companies settle on somewhere between two and four different masks as a compromise.

To choose the masks in real life, you need to look at the requirements for each subnet in the design. How many host IP addresses do you need in each case? How much growth do you expect? How many subnets do you need of each size?

In the more theoretical world of exam preparation, you can typically expect a cleaner view of the world, which makes the discussion in this book more objective. For instance, consider Figure 5-4, which lists requirements for two ultra-large data center subnets on the left, several branch office LAN subnets on the right, and a number of typical serial links.

Figure 5-4 *Requirements that Feed into a VLSM Design*

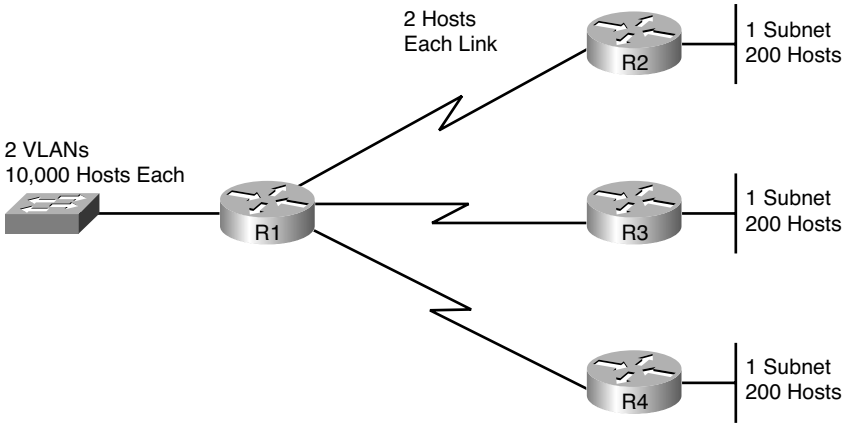


Figure 5-4 shows requirements for the number of host IP addresses; all you have to do then is pick a mask to meet the requirements for each size subnet as a separate problem, and note the number of subnets you need to create for each size. For the exam, the question might give some guidance that leads you to a single answer, like asking you to choose a mask that meets the goal and uses the least host bits. With Figure 5-4, using the least host bits, you would choose these three masks:

/18: 14 host bits, $2^{14} - 2 = 16{,}382$ hosts/subnet

/24: 8 host bits, $2^8 - 2 = 254$ hosts/subnet

/30: 2 host bits, $2^2 - 2 = 2$ hosts/subnet

In summary, to choose the masks to use in VLSM, analyze the requirements. Find subnets with requirements for similar numbers of hosts, like the three sizes of subnets in Figure 5-4. The, choose a small number of masks to use for those different sizes of subnets, as summarized in the list for this particular example.

Assigning the Largest Subnet IDs First

VLSM subnet assignment first occurs on paper, when the network engineer looks at a list of subnet IDs and chooses which subnet ID to use for which need in the network topology. For example, Figure 5-4 shows the need for two subnets with a /18 mask, three subnets with a /24 mask, and three subnets with a /30 mask. What specific subnets did the engineer

choose? Which subnets could the engineer have chosen? This section explores how to answer these questions and how to go about choosing subnets.

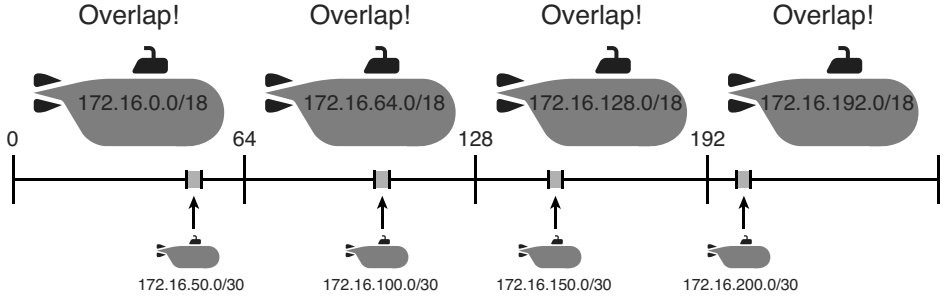
Key Topic

When assigning subnets, follow this strategy: Choose the largest subnets first.

To show you why, we continue the example based in part on Figure 5-4. In that company, the LAN team will assign the subnets for the /18 and /24 subnets, and the WAN team will assign all the /30 subnets. The WAN team has already deployed some WAN links, and they have the political power and are unwilling to change. The WAN team has already used subnets 172.16.50.0/30, 172.16.100.0/30, 172.16.150.0/30, and 172.16.200.0/30.

Although the four WAN subnets have consumed a mere 16 addresses, unfortunately, those subnets have already busted the VLSM design. The four small subnet assignments have created an overlap with all four possible /18 subnets of network 172.16.0.0. Figure 5-5 shows the idea, with the four possible /18 subnets at the top and the overlapping WAN subnets at the bottom.

Figure 5-5 *Overlaps Caused by Unfortunate Assignments of Smaller Subnets*



When using mask /18, with Class B network 172.16.0.0, only four possible subnets exist: 172.16.0.0, 172.16.64.0, 172.16.128.0, and 172.16.192.0. The four small /30 WAN subnets each overlap with one of these four, as shown in Figure 5-5. How can you avoid making such mistakes? Either assign the smaller subnets from a much tighter range or assign the larger subnet IDs first, as suggested in this chapter. In this case, the LAN team could have allocated the first two /18 subnets first, and made the WAN team avoid using IP addresses from the first half of class B network 172.16.0.0.

Admittedly, the WAN team could not have been any more shortsighted in this contrived example. Regardless, it shows how a small subnet assignment can prevent you from having a larger subnet available. You should always strive to keep large holes open in your address space in anticipation of assigning large subnets in the future.

An Example of VLSM Subnet Design

Other than a general strategy to assign the larger subnets first, what specific steps should you take? Rather than start with a formal process, this section shows an example. In short, the process finds and allocates the largest subnets. Then it takes one of those unused subnets and further subdivides it—sub-subnets it if you prefer—to make the next smaller size of subnets.

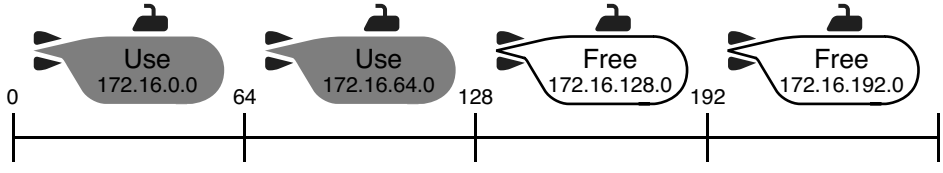
> **NOTE** To use this process, you really need to be comfortable with the idea of looking at a classful network number, one subnet mask, and finding all subnet IDs. As previously mentioned, to review the process to find all subnet IDs using a single mask, refer to *CCENT/CCNA ICND1 Official Cert Guide*, Chapter 18, which is found on this book's DVD.

This example uses the following requirements; they are the same requirements shown earlier in Figure 5-4.

2 subnets with mask /18
3 subnets with /24
3 subnets with /30

To begin, calculate all possible subnets of network 172.16.0.0 using a /18 mask (the largest subnets). Then, pick two subnets, because the requirements say that you need two. Figure 5-6 shows a representation of these four subnets and the fact that two are allocated for use.

Figure 5-6 *Four /18 Subnets Listed, with Two Allocated for Use*



The allocation of the first two of these large subnets removes a large set of IP addresses from the pool. When choosing subnets for the next smaller size subnet, you have to avoid the range of addresses in these subnets. In this case, these two subnets consume half the Class B network: addresses 172.16.0.0 – 172.16.127.255. The numerically lowest subnet ID that could possibly be used for the next to-be-allocated subnet, and not overlap, is 172.16.128.0.

For the next step, you take one of the currently free subnets from the list of large subnets and further subdivide it (or "sub-subnet it") to create the smaller sized subnet. For instance, in this case, the next large subnet ID in sequence is 172.16.128.0/18. You take this range of addresses, and you find all subnets in this range using the next smaller subnet size, which

in this example are the subnets that use the /24 mask. You can find all subnets of Class B network 172.16.0.0 using the /24 mask, but you really only have to start at 172.16.128.0. Figure 5-7 shows the idea of what subnets exist in this range, using /24 masks.

Figure 5-7 *Subdividing 172.16.128.0/18 into 64 Subnets Using /24 Mask*

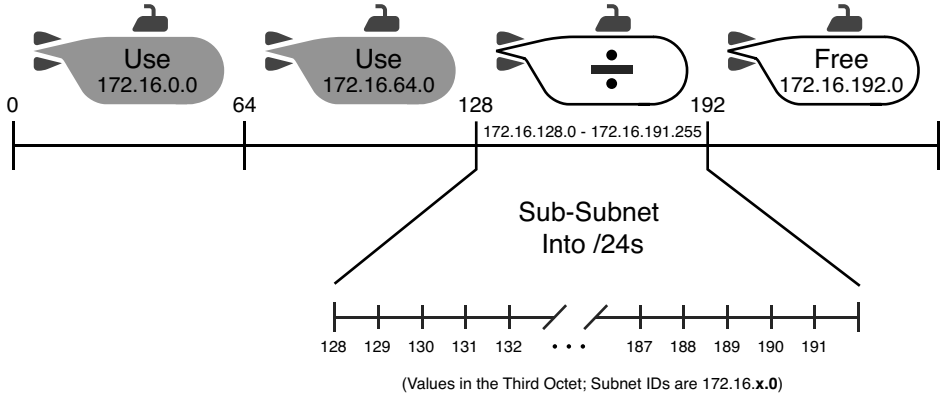


Figure 5-7 shows a representation of the fact that the subnets 172.16.128.0/24, 172.16.129.0/24, 172.16.130.0/24, and so on, through 172.16.191.0/24, all fit inside the range of addresses of the subdivided larger 172.16.128.0/18 subnet. Although the figure does not show all 64 of these /24 subnets because of space constraints, it shows enough to see the pattern.

To summarize what actions we took so far in choosing and assigning subnets on paper in this example, we

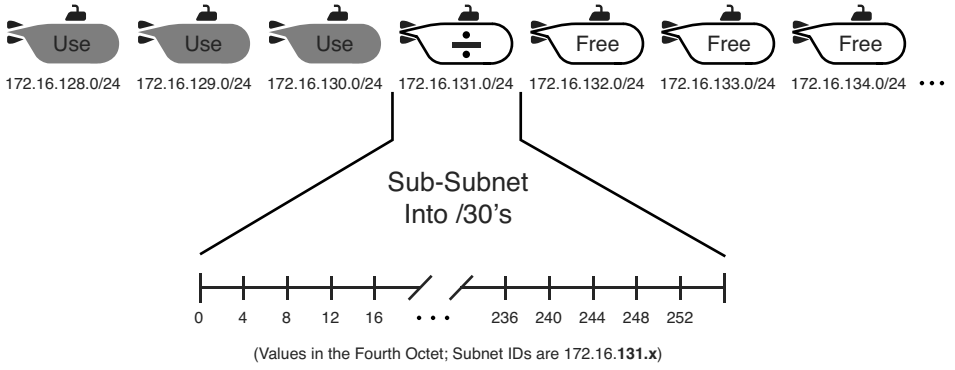
- Calculated the four possible subnets of Class B network 172.16.0.0 using mask /18
- Allocated the first two subnets for use in the internetwork
- Marked the third of four /18 subnets (172.16.128.0/18) to be sub-subnetted into smaller subnets
- Listed all subnets using mask /24 that could exist inside 172.16.128.0/18

To continue the exercise, the requirements asked for three /24 subnets, so you need to pick three subnets from the list in Figure 5-7. Using the first three makes sense: 172.16.128.0/24, 172.16.129.0/24, and 172.16.130.0/24.

The process continues until you go through every different mask. In this example, only one other mask was chosen (/30). To proceed, pick one of the currently free /24 subnets, mark it as one to be sub-subnetted, and proceed to subnet it into /30 subnets. Figure 5-8 updates

the idea, showing the three allocated /24 subnets, and the next /24 subnet in sequence (172.16.131.0/24) marked as the one to subnet further to create the /30 subnets.

Figure 5-8 *The Three Allocated /24 Subnets and the Next Subnet to Divide Further*



The process continues with the same logic as before, subnetting the address range implied by 172.16.131.0/24 using a /30 mask. That is, finding these possible /30 subnets within this range:

172.16.131.0/30
172.16.131.4/30
172.16.131.8/30
172.16.131.12/30
And so on, up through 172.16.131.252/30

If you again pick the first three subnets (you pick three because the requirements stated that you needed three subnets with a /30 mask), you would mark the first three in this list as allocated or used. At this point, the process is complete, other than picking exactly where to use each subnet.

Summary of the Formal VLSM Subnet Design Process

The process seems long because it takes time to work through each step. However, you essentially repeat the same process you would use to find and allocate subnets when using a single mask, just repeating the process for each successively longer mask (in other words,

from the largest subnets to smallest subnets). For completeness, the following list summarizes the steps:

Step 1 Analyze the requirements for the number of hosts and subnets, choose the masks to use, and list the number of subnets needed using each mask.

Step 2 For the shortest prefix mask (largest subnets):

- **a** Calculate, on paper, all possible subnets, using that one mask.
- **b** Mark some subnets as allocated for use, per the requirements from step 1.
- **c** Pick an unallocated subnet to be further subdivided by the next step (step 3).

Step 3 Repeat Step 2 for each mask, moving to the next longer mask (next smaller sized subnet) each time.

Practice Designing VLSM Subnets

The biggest hurdle in designing with VLSM subnets is to get through the process of finding all the subnets using each mask, particularly after the first step, when you really only care about a more limited range of subnet numbers. The following practice problems help with that process.

Table 5-7 lists the problems. To answer these problems, choose subnet IDs, lowest to highest, first allocating subnets for the largest subnets, then for the next largest subnets, and so on. Always choose the numerically lowest subnet IDs if you want your answer to match what is listed at the end of this chapter.

Table 5-7 *VLSM Subnet Design Practice Problems*

Problem	Classful Network	First Requirement	Second Requirement	Third Requirement
1	172.20.0.0	3 subnets, /22	3 subnets, /25	3 subnets, /30
2	192.168.1.0	3 subnets, /27	3 subnets, /28	3 subnets, /30

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics from this chapter, noted with the Key Topics icon in the outer margin of the page. Table 5-8 lists a reference of these key topics and the page numbers on which each is found.

Table 5-8 *Key Topics for Chapter 5*

Key Topic Element	Description	Page Number
Table 5-2	Classless and classful routing protocols listed and compared	203
List	Steps to analyze an existing design to discover any VLSM overlaps	206
List	Steps to follow when adding a new subnet to an existing VLSM design	209
Paragraph	Statement of the main VLSM subnet assignment strategy or assigning the largest subnets first	214
List	Steps to follow to design a subnet plan using VLSM	218

Complete the Tables and Lists from Memory

Print a copy of Appendix J, "Memory Tables," (found on the DVD) or at least the section for this chapter, and complete the tables and lists from memory. Appendix K, "Memory Tables Answer Key," also on the DVD, includes completed tables and lists to check your work.

Definitions of Key Terms

Define the following key terms from this chapter and check your answers in the Glossary:

classful routing protocol, classless routing protocol, overlapping subnets, variable length subnet masks (VLSM)

Read Appendix G Scenarios

Appendix G, "Additional Scenarios," contains five detailed scenarios that both give you a chance to analyze different designs, problems, and command output and show you how concepts from several different chapters interrelate. Appendix G Scenario 1, Part A, and all of Scenario 5 provide an opportunity to practice and develop skills with VLSM.

Appendix D Practice Problems

Appendix D, "Practice for Chapter 5: Variable Length Subnet Masks," lists additional practice problems and answers. You can find this appendix on the DVD as a printable PDF.

Answers to Earlier Practice Problems

Answers to Practice Finding VLSM Overlaps

This section lists the answers to the three practice problems in the section, "Practice Finding VLSM Overlaps," as listed earlier in Table 5-4. Note that the tables that list details of the answer reordered the subnets as part of the process.

In Problem 1, the second and third subnet IDs listed in Table 5-9 happen to overlap. The second subnet's range completely includes the range of addresses in the third subnet.

Table 5-9 *VLSM Overlap Problem 1 Answers (Overlaps Highlighted)*

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	10.1.1.1/20	10.1.0.0	10.1.15.255
2	10.1.17.1/21	10.1.16.0	10.1.23.255
3	10.1.23.254/22	10.1.20.0	10.1.23.255
4	10.1.29.101/23	10.1.28.0	10.1.29.255
5	10.1.34.9/22	10.1.32.0	10.1.35.255

In Problem 2, again, the second and third subnet IDs (listed in Table 5-10) happen to overlap, and again, the second subnet's range completely includes the range of addresses in

the third subnet. Also, the second and third subnet IDs are the same value, so the overlap is more obvious.

Table 5-10 *VLSM Overlap Problem 2 Answers (Overlaps Highlighted)*

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	172.16.122.1/30	172.16.122.0	172.16.122.3
2	172.16.122.57/27	172.16.122.32	172.16.122.63
3	172.16.122.33/30	172.16.122.32	172.16.122.35
4	172.16.126.151/22	172.16.124.0	172.16.127.255
5	172.16.128.151/20	172.16.128.0	172.16.143.255

In Problem 3, three subnets overlap. Subnet 1's range completely includes the range of addresses in the second and third subnets. Note that the second and third subnets do not overlap with each other, so for the process in this book to find all the overlaps, after you find that the first two subnets overlap, you should compare the next entry in the table (3) with both of the two known–to-overlap entries (1 and 2).

Table 5-11 *VLSM Overlap Problem 3 Answers (Overlaps Highlighted)*

Reference	Original Address and Mask	Subnet ID	Broadcast Address
1	192.168.1.113/28	192.168.1.112	192.168.1.127
2	192.168.1.122/30	192.168.1.120	192.168.1.123
3	192.168.1.125/30	192.168.1.124	192.168.1.127
4	192.168.1.245/29	192.168.1.240	192.168.1.247
5	192.168.1.253/30	192.168.1.252	192.168.1.255

Answers to Practice Adding VLSM Subnets

This section lists the answers to the five practice problems in the section, "Practice Adding VLSM Subnets."

All five problems for this section used the same set of five pre-existing subnets. Table 5-12 lists those subnet IDs and subnet broadcast addresses, which define the lower and higher ends of the range of numbers in each subnet.

Table 5-12 *Pre-Existing Subnets for the Add a VLSM Subnet Problems in This Chapter*

Subnet	Subnet Number	Broadcast Address
1	10.0.0.0/24	10.0.0.255
2	10.0.1.0/25	10.0.1.127
3	10.0.2.0/26	10.0.2.63
4	10.0.3.0/27	10.0.3.31
5	10.0.6.0/28	10.0.6.15

The rest of the explanations follow the five-step process outlined earlier in the section, "Adding New Subnets to an Existing VLSM Design," except that the explanations ignore Step 3 because Step 3's results in each case are already listed in Table 5-12.

Problem 1

Step 1 The problem statement tells us to use /24.

Step 2 The subnets would be 10.0.0.0, 10.0.1.0, 10.0.2.0, 10.0.3.0, 10.0.4.0, 10.0.5.0, and so on, counting by 1 in the third octet.

Step 4 The first four new possible subnets (10.0.0.0/24, 10.0.1.0/24, 10.0.2.0/24, and 10.0.3.0/24) all overlap with the existing subnets (see Table 5-12). 10.0.6.0/24 also overlaps.

Step 5 10.0.4.0/24 is the numerically lowest new subnet number that does not overlap with the existing subnets.

Problem 2

Step 1 The problem statement tells us to use /23.

Step 2 The subnets would be 10.0.0.0, 10.0.2.0, 10.0.4.0, 10.0.6.0, 10.0.8.0, and so on, counting by 2 in the third octet.

Step 4 Three of the first four new possible subnets (10.0.0.0/23, 10.0.2.0/23, and 10.0.6.0/23) all overlap with existing subnets.

Step 5 10.0.4.0/23 is the numerically lowest new subnet number that does not overlap with the existing subnets.

Problem 3

Step 1 The problem statement tells us to use /22.

Step 2 The subnets would be 10.0.0.0, 10.0.4.0, 10.0.8.0, 10.0.12.0, and so on, counting by 4 in the third octet.

Step 4 The first two new possible subnets (10.0.0.0/22, 10.0.4.0/22) overlap with existing subnets.

Step 5 10.0.8.0/22 is the numerically lowest new subnet number that does not overlap with the existing subnets.

Problem 4

The answer for this problem requires more detail than others, because the /25 mask creates a larger number of subnets that might overlap with the pre-existing subnets. For this problem, at Step 1, you already know to use mask /25. Table 5-13 shows the results of Step 2, listing the first 14 subnets of network 10.0.0.0 when using mask /25. For Step 4, Table 5-13 highlights the overlapped subnets. To complete the task at Step 5, search the table sequentially and find the first non-grayed subnet, 10.0.1.128/25.

Table 5-13 *First 14 Subnets of Network 10.0.0.0, Using /25 Mask*

Reference	Subnet Number	Broadcast Address
1	10.0.0.0	10.0.0.127
2	10.0.0.128	10.0.0.255
3	10.0.1.0	10.0.1.127
4	10.0.1.128	10.0.1.255
5	10.0.2.0	10.0.2.127
6	10.0.2.128	10.0.2.255
7	10.0.3.0	10.0.3.127
8	10.0.3.128	10.0.3.255
9	10.0.4.0	10.0.4.127
10	10.0.4.128	10.0.4.255
11	10.0.5.0	10.0.5.127
12	10.0.5.128	10.0.5.255
13	10.0.6.0	10.0.6.127
14	10.0.6.128	10.0.6.255

Problem 5

Like Problem 4, the answer for Problem 5 requires more detail, because the /26 mask creates a larger number of subnets that might overlap with the pre-existing subnets. For this problem, at Step 1, you already know to use mask /26. Table 5-14 shows the results of Step 2, listing the first 12 subnets of network 10.0.0.0 when using mask /26. For Step 4, Table 5-14 highlights the overlapped subnets. To complete the task at Step 5, search the table sequentially and find the first non-grayed subnet, 10.0.1.128/26.

Table 5-14 *First 12 Subnets of Network 10.0.0.0, Using /26 Mask*

Reference	Subnet Number	Broadcast Address
1	10.0.0.0	10.0.0.63
2	10.0.0.64	10.0.0.127
3	10.0.0.128	10.0.0.191
4	10.0.0.192	10.0.0.255
5	10.0.1.0	10.0.1.63
6	10.0.1.64	10.0.1.127
7	10.0.1.128	10.0.1.191
8	10.0.1.192	10.0.1.255
9	10.0.2.0	10.0.2.63
10	10.0.2.64	10.0.2.127
11	10.0.2.128	10.0.2.191
12	10.0.2.192	10.0.2.255

Answers to Practice Designing VLSM Subnets

This section lists the answers to the two practice problems in the section, "Practice Designing VLSM Subnets."

Answers for VLSM Subnet Design, Problem 1

For Problem 1, subnetting network 172.20.0.0 with mask /22 means that the subnets will all be multiples of 4 in the third octet: 172.20.0.0, 172.20.4.0, 172.20.8.0, and so on, through 172.20.252.0. Following the rule to choose the numerically lowest subnet IDs, you would allocate or use 172.20.0.0/22, 172.20.4.0/22, and 172.20.8.0/22. You would also then mark the next subnet, 172.20.12.0/22, to be sub-subnetted.

For the next mask, /25, all the subnet IDs will be either 0 or 128 in the last octet, and increments of 1 in the third octet. Starting at 172.20.12.0 per the previous paragraph, the first four such subnets are 172.20.12.0/25, 172.20.12.128/25, 172.20.13.0/25, and 172.20.13.128/25. Of these, you need to use three, so mark the first three as used. The fourth will be sub-subnetted at the next step.

For the third and final mask, /30, all the subnet IDs will increment by 4 in the fourth octet. Starting with the subnet ID that will be sub-subnetted (172.20.13.128), the next /30 subnet IDs are 172.20.13.128, 172.20.13.132, 172.20.13.136, 172.20.13.140, and so on. The first three in this list will be the three used per the requirements and rules for Problem 1.

Answers for VLSM Subnet Design, Problem 2

For Problem 2, subnetting network 192.168.1.0 with mask /27 means that the subnets will all be multiples of 32 in the fourth octet: 192.168.1.0, 192.168.1.32, 192.168.1.64, 192.168.1.96, and so on, through 192.168.1.224. Following the rule to choose the numerically lowest subnet IDs, you would allocate or use 192.168.1.0/27, 192.168.1.32/27, and 192.168.1.64/27. You would also then mark the next subnet, 192.168.1.96/27, to be sub-subnetted.

For the next mask, /28, all the subnet IDs will be multiples of 16 in the last octet. Starting at 192.168.1.96 per the previous paragraph, the first four such subnets are 192.168.1.96, 192.168.1.112, 192.168.1.128, and 192.168.1.144. Of these, you need to use three, so mark the first three as used. The fourth will be sub-subnetted at the next step.

For the third and final mask, /30, all the subnet IDs will increment by 4 in the fourth octet. Starting with the subnet ID that will be sub-subnetted (192.168.1.144), the next /30 subnet IDs are 192.168.1.144, 192.168.1.148, 192.168.1.152, 192.168.1.156, and so on. The first three in this list will be the three used per the requirements and rules for Problem 2.

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