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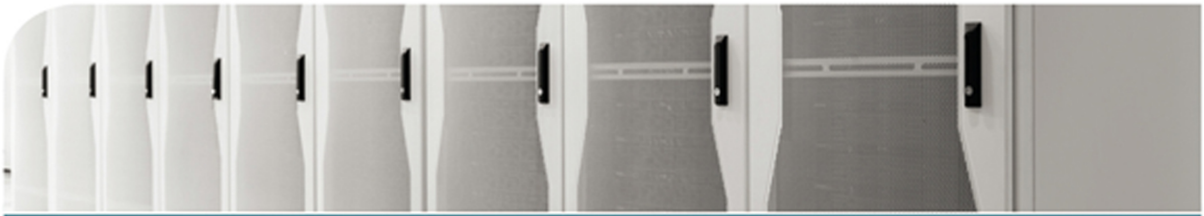

CCNA Data Center DCICN 200-150

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Dedications

Chad Hintz: This booked is dedicated to my loving wife and my two children, Tyler and Evan. You are my inspiration, and without your love and support, I would have never been able to complete this project. This book is also dedicated to my late father, Edward Hintz: You inspire me every day to be a better husband, father, and friend. I miss you every day.

Cesar Obediente: I dedicate this book to my loving wife, Jackie, for the support and understanding she has given me throughout my career; to my two daughters, Yvette and Veronica, for the joy they bring to my life; and to my parents—especially my late mom—who taught me the value of life and family.

Ozden Karakok: To my loving husband, Tom, for his endless support, encouragement, and love. Merci beaucoup, Askim.

To Remi and Mira, for being the most incredible miracles of my life and being my number-one source of happiness.

To my wonderful parents, who supported me in every chapter of my life and are an inspiration for life.

To my awesome sisters, Gulden and Cigdem, for their unconditional support and loving me just the way I am.

Acknowledgments

It just so happens that Cisco begins its first Data Center certifications with CCNA Data Center. Cisco requires you to pass two exams to achieve CCNA Data Center certification, with this book discussing the first such exam—the Introducing Cisco Data Center Networking (DCICN) exam.

Eleanor Bru did a phenomenal job of keeping us authors on track for book features, style, and organization. Thank you, Ellie, for your support by being the editor of this book!

The technical editor for this book, Jason Viera, did an excellent job reviewing the manuscript. Jason's great understanding in data center helped us make sure that we covered what was needed and also focused on ease of understanding from a reader's perspective. It is always a pleasure working with you Jason; thank you for the great job!

Mary Beth Ray served as executive editor on the book. No matter the issue, Mary Beth was always there and ready to help figure out the right course of action. It is great to have her steady hand keeping us on track, from the original idea to publication and beyond. Thanks, Mary Beth.

A big thank you to the entire Cisco Press team for all their support in getting this book published.

To the extended teams at Cisco: Thank you for being patient while our minds were in the book. Thank you for believing in and supporting us on this journey. Thank you for the innovative organization and development team at Cisco.

To all extended family and friends: Thank you for your patience and endless support.

Contents at a Glance

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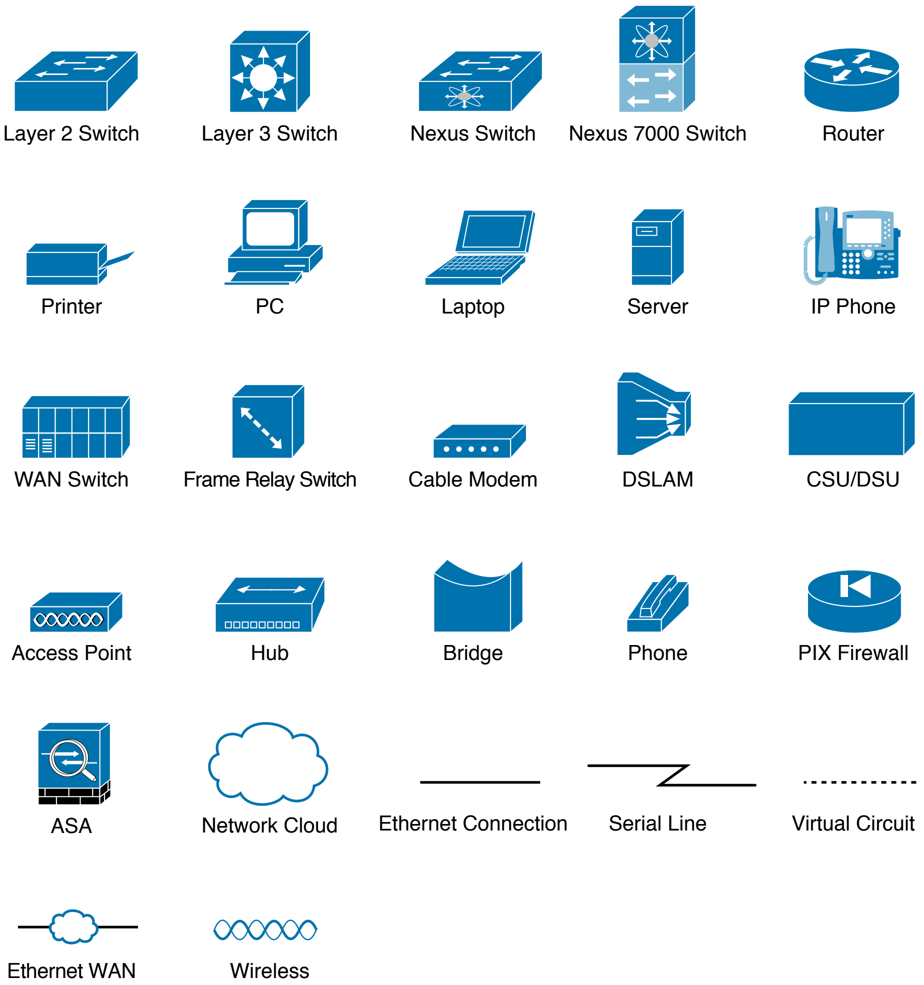

Command Syntax Conventions

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

About the Exam

Congratulations! If you are reading far enough to look at this book's Introduction, you've probably already decided to go for your Cisco CCNA Data Center certification, and that begins with the Introducing Cisco Data Center Networking (DCICN 200-150) exam. Cisco dominates the networking marketplace, and in a few short years after entering the data center server marketplace, they have achieved significant market share and become one of the primary vendors of data center server hardware as well. If you want to succeed as a technical person in the networking industry, and in data centers in particular, you need to know Cisco. Getting your CCNA Data Center certification is a great first step toward building your skills and becoming respected by others in the data center field.

CCNA Data Center and the Other CCNA Certifications

Cisco offers a wide variety of Cisco Certified Network Associate certifications. Cisco first offered CCNA back in 1998, using the name CCNA, with the certification focusing on routing and switching. Since that time, Cisco has added the CCNA certifications for various technology areas, as listed in Figure I-2. Cisco even renamed the original CCNA to CCNA Routing & Switching, so each and every CCNA certification's topic area is part of the name.

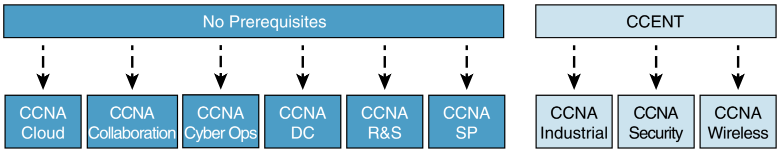

Figure I-2 *Cisco CCNA Certifications: CCENT Prerequisite or Not*

** The CCNA R&S has two different exam paths. One begins with CCENT, whereas the other allows you to get CCNA R&S certified using one exam: the CCNA 200-125 exam. With the single-exam path, CCENT is technically not a prerequisite; however, the single exam includes coverage of the topics in CCENT, so you still need to know CCENT content to achieve CCNA R&S.*

Interestingly, Cisco uses the Cisco Certified Entry Networking Technician (CCENT) certification as the minimum prerequisite for some of the CCNA certifications, but not all. As you can see in Figure I-2, CCNA Data Center, and five others, do not require you to first achieve CCENT (or some other more advanced routing and switching certification). Why? All six of these CCNA certifications that have no prerequisites cover the required routing and switching topics within the certification already. For instance, almost all the concepts discussed in this book are included in the scope of the ICND1 100-101 exam.

NOTE Always check www.cisco.com/go/certifications for current prerequisites. Cisco sometimes changes the prerequisites with the introduction of a new version of an exam or certification.

The Exams That Help You Achieve CCNA Data Center Certification

The Cisco CCNA Data Center certification is the most basic Cisco Data Center certification, and it acts as a prerequisite for the other Cisco Data Center certifications. CCNA Data Center itself has no other prerequisites. To achieve the CCNA Data Center cert, you simply have to pass two exams: Introducing Cisco Data Center Networking (DCICN) and Introducing Cisco Data Center Technologies (DCICT), as shown in Figure I-1.

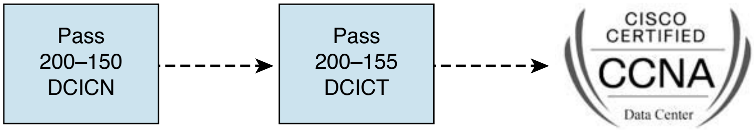

Figure I-1 *Path to Cisco CCNA Data Center Certification*

The DCICN and DCICT differ quite a bit in terms of the topics covered. DCICN focuses on networking technology. In fact, it overlaps quite a bit with the topics in the ICND1 100-101 exam, which leads to the Cisco Certified Entry Network Technician (CCENT) certification. DCICN explains the basics of networking, focusing on Ethernet switching and IP routing. The only data center focus in DCICN happens to be the fact that all the configuration and verification examples use Cisco Nexus switches, which Cisco builds specifically for use in the data center.

The DCICT exam instead focuses on technologies specific to the data center. These technologies include storage networking, Unified Computing (the term used by Cisco for its server products and services), and data networking features unique to the Nexus model series of switches.

Basically, DCICN touches on concepts that you might see in all parts of a corporate network (including the data center), and DCICT then hits the topics specific to data centers.

Types of Questions on the Exams

Cisco certification exams follow the same general format. At the testing center, you sit in a quiet room with a PC. Before the exam timer begins, you have a chance to do a few other tasks on the PC. 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.

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

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

The first three items in the list are all actually multiple-choice questions. The multiple-choice format simply requires that you point and click a circle beside the correct answer(s). Cisco traditionally tells you how many answers you need to choose, and the testing software prevents you from choosing too many answers. The testlet asks you several multiple-choice questions, all based on the same larger scenario.

DND questions require you to move some items around on the graphical user interface (GUI). You left-click and hold, move a button or icon to another area, and release the clicker to place the object somewhere else (usually into a list). Or, you might see a diagram, and you have to click and drag the icons in the figure to the correct place to answer a question. 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, sim and simlet questions, both use a network simulator. 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. Basically, these questions begin with a broken configuration, and you have to fix the configuration to answer the question.

Simlet questions also use a network simulator, but instead of you answering the question by changing the configuration, the simlet includes one or more multiple-choice questions that require you to use the simulator to examine the current behavior of a network and interpret the output of any **show** commands that you can remember to answer the question. Whereas sim questions require you to troubleshoot problems related to a configuration, simlets require you to analyze both working and broken networks as well as correlate **show** command output with your knowledge of networking theory and configuration commands.

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

What's on the DCICN Exam?

Everyone wants to know what is on the test, for any test, ever since the early days of school. Cisco tells the world the topics on each of its exams. For every Cisco certification exam, Cisco wants the public to know the variety of topics as well as to have an idea about the kinds of knowledge and skills required for each topic. To that end, Cisco publishes a set of exam topics for each exam.

While each exam topics lists the specific topics, such as IP addressing, OSPF, and VLANs, the verb in the exam topic is just as important. The verb tells us to what degree the topic must be understood and what skills are required. The topic also implies the kinds of skills required for that topic. For example, one topic might start with "Describe…," another with "Configure…," another with "Verify…," and another might begin with "Troubleshoot…." That last topic has the highest required skill level, because to troubleshoot, you must understand the topic, be able to configure it (to see what is wrong with the configuration), and verify it (to find the root cause of the problem). By listing the topics and skill levels, Cisco helps us all prepare for its exams.

Cisco's posted exam topics, however, are only guidelines. Cisco's disclaimer language mentions that fact. Cisco makes the effort to keep the exam questions within the confines of the stated exam topics, and I know from talking to those involved that every question is analyzed for whether it fits within the stated exam topics.

DCICN 200-150 Exam Topics

You can easily find exam topics for both the DCICN and DCICT exams with a simple search at Cisco.com. Alternatively, you can go to www.cisco.com/go/ccna, which gets you to the page for CCNA Routing and Switching, and then easily navigate to the nearby CCNA Data Center page.

Over time, Cisco has begun making two stylistic improvements to the posted exam topics. In the past, the topics were simply bulleted lists, with some indentation to imply subtopics under a major topic. More and more often today, including for the DCICN and DCICT exam topics, Cisco also numbers the exam topics, making it easier to refer to specific topics. In addition, Cisco lists the weighting for each of the major topic headings. The weighting tells you the percentage of points from your exam that should come from each major topic area. The DCICN contains five major headings, with the weightings shown in Table I-1.

Table I-1 Four Major Topic Areas in the DCICN 200-150 Exam

Number	Exam Topic	Weighting
1.0	Data Center Physical Infrastructure	15%
2.0	Basic Data Center Networking Concepts	23%
3.0	Advanced Data Center Networking Concepts	23%
4.0	Basic Data Center Storage	19%
5.0	Advanced Data Center Storage	20%

Note that while the weighting of each topic area tells you something about the exam, in the authors' opinion, the weighting probably does not change how you study. All five topic areas hold enough weighting so that if you completely ignore one topic, you will likely not pass. Also, networking requires that you put many concepts together, so you need all the pieces before you can understand the whole network. The weightings might tell you where to spend a little more of your time during the last days before taking the exam, but otherwise, plan on studying for all the exam topics.

Tables I-2 through I-6 list the details of the exam topics, with one table for each of the major topic areas listed in Table I-1. Note that these tables also list the book chapters that discuss each of the exam topics.

Table I-2 Exam Topics in the First Major DCICN Exam Topic Area

Number	Exam Topic	Chapter
1.0	Data Center Physical Infrastructure	1
1.1	Describe different types of cabling, uses, and limitations	1
1.2	Describe different types of transceivers, uses, and limitations	1
1.3	Identify physical components of a server and perform basic troubleshooting	1
1.4	Identify physical port roles	1
1.5	Describe power redundancy modes	1

Table I-3 Exam Topics in the Second Major DCICN Exam Topic Area

Number	Exam Topic	Chapter
2.0	Basic Data Center Networking Concepts	2, 3, 5, 6, 8, 10
2.1	Compare and contrast the OSI and the TCP/IP models	2
2.2	Describe Classic Ethernet fundamentals	3
2.2.a	Forward	3
2.2.b	Filter	3
2.2.c	Flood	3
2.2.d	MAC address table	3
2.3	Describe switching concepts and perform basic configuration	10
2.3.a	STP	8
2.3.b	802.1q	6
2.3.c	Port channels	3
2.3.d	Neighbor discovery	3
2.3.d.1	CDP	3
2.3.d.2	LLDP	3
2.3.e	Storm control	3

Table I-4 Exam Topics in the Third Major DCICN Exam Topic Area

Number	Exam Topic	Chapter
3.0	Advanced Data Center Networking Concepts	1, 11, 16, 17, 20, 21
3.1	Basic routing operations	16
3.1.a	Explain and demonstrate IPv4/IPv6 addressing	11
3.1.b	Compare and contrast static and dynamic routing	16

Number	Exam Topic	Chapter
3.1.c	Perform basic configuration of SVI/routed interfaces	17
3.2	Compare and contrast the First-Hop Redundancy Protocols	20
3.2.a	VRRP	20
3.2.b	GLBP	20
3.2.c	HSRP	20
3.3	Compare and contrast common data center network architectures	1
3.3.a	2 Tier	1
3.3.b	3 Tier	1
3.3.c	Spine-leaf	1
3.4	Describe the use of access control lists to perform basic traffic filtering	21
3.5	Describe the basic concepts and components of authentication, authorization, and accounting	21

Table I-5 Exam Topics in the Fourth Major DCICN Exam Topic Area

Number	Exam Topic	Chapter
4.0	Basic Data Center Storage	22
4.1	Differentiate between file- and block-based storage protocols	22
4.2	Describe the roles of FC/FCoE port types	22
4.3	Describe the purpose of a VSAN	22
4.4	Describe the addressing model of block-based storage protocols	22
4.4.a	FC	22
4.4.b	iSCSI	22

Table I-6 Exam Topics in the Fifth Major DCICN Exam Topic Area

Number	Exam Topic	Chapter
5.0	Advanced Data Center Storage	23
5.1	Describe FCoE concepts and operations	23
5.1.a	Encapsulation	23
5.1.b	DCB	23
5.1.c	vFC	23
5.1.d	Topologies	23

Number	Exam Topic	Chapter
5.1.d.1	Single hop	23
5.1.d.2	Multihop	23
5.1.d.3	Dynamic	23
5.2	Describe node port virtualization	23
5.3	Describe zone types and their uses	23
5.4	Verify the communication between the initiator and target	23
5.4.a	FLOGI	23
5.4.b	FCNS	23
5.4.c	Active zoneseset	23

NOTE Because it is possible that the exam topics may change over time, it may be worth double-checking the exam topics as listed on the Cisco website (go to www.cisco.com/go/certifications and navigate to the CCNA Data Center page). In the unlikely event that Cisco does happen to add exam topics at a later date, note that Appendix B, "DCICN Exam Updates," describes how to go to www.ciscopress.com and download additional information about those newly added topics.

About the Book

This book discusses the content and skills needed to pass the 200-150 DCICN exam.

Book Features and Exam Preparation Methods

This book uses several key methodologies to help you discover the exam topics for 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. Therefore, this book does not try to help you pass the exams only by memorization, but by truly learning and understanding the topics.

The book includes many features that provide different ways to study so you can be ready for the exam. If you understand a topic when you read it, but do not study it any further, you probably will not be ready to pass the exam with confidence. The features included in this book give you tools that help you determine what you know, review what you know, better learn what you don't know, and be well prepared for the exam. These tools include the following:

- **"Do I Know This Already?" Quizzes:** Each chapter begins with a quiz that helps you determine the amount of time you need to spend studying that chapter.
- **Foundation Topics:** These are the core sections of each chapter. They explain the protocols, concepts, and configurations for the topics in that chapter.

- **Exam Preparation Tasks:** The "Exam Preparation Tasks" section lists a series of study activities that should be done after reading the "Foundation Topics" section. Each chapter includes the activities that make the most sense for studying the topics in that chapter. The activities include the following:
  - **Key Topics Review:** The Key Topic icon appears 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 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. Review these topics carefully.
  - **Definition of Key Terms:** Although certification exams might be unlikely to ask a question such as "Define this term…," the DCICN 200-150 and DCICT 200-155 exams require you to learn and know a lot of terminology. This section lists some of the most important terms from the chapter, asking you to write a short definition and compare your answer to the Glossary.
  - **End of Chapter Review Questions:** Confirm that you understand the content you just covered.

Book Organization, Chapters, and Appendixes

This book contains 23 core chapters (Chapters 1 through 23), with Chapter 24 including some suggestions for how to approach the actual exams. Each core chapter covers a subset of the topics on the DCICN exam. The core chapters are organized into sections. The core chapters cover the following topics.

Part I: Networking Fundamentals

- **Chapter 1, "Introduction to Nexus Data Center Infrastructure and Architecture:"** Introduces the Cisco Nexus product lines and their capabilities and also discusses the evolution of data center network design.
- **Chapter 2, "The TCP/IP and OSI Networking Models:"** Introduces the terminology surrounding two different networking architectures, namely Transmission Control Protocol/Internet Protocol (TCP/IP) and Open Systems Interconnection (OSI).
- **Chapter 3, "Fundamentals of Ethernet LANs:"** Covers the concepts and terms used for the most popular option for the data link layer for local area networks (LANs), namely Ethernet.
- **Chapter 4, "Fundamentals of IPv4 Addressing and Routing:"** IP is the main network layer protocol for TCP/IP. This chapter introduces the basics of IP Version 4 (IPv4), including IPv4 addressing and routing.

Part II: Data Center Nexus Switching & Routing Fundamentals

- **Chapter 5, "Installing and Operating Nexus Switches:"** Explains how to access, examine, and configure Cisco Nexus switches.
- **Chapter 6, "VLAN and Trunking Concepts:"** Explains the concepts surrounding virtual LANs, including VLAN trunking and the VLAN Trunking Protocol (VTP).
- **Chapter 7, "VLAN Trunking and Configuration:"** Explains the configuration surrounding VLANs, including VLAN trunking and VTP.

- **Chapter 8, "Spanning Tree Protocol Concepts:"** Discusses the concepts behind the IEEE Spanning Tree Protocol (STP) and how it makes some switch interfaces block frames to prevent frames from looping continuously around a redundant switched LAN.
- **Chapter 9, "Cisco Nexus Spanning Tree Protocol Implementation:"** Shows how to configure, verify, and troubleshoot STP implementation on Cisco switches.
- **Chapter 10, "Configuring Ethernet Switching:"** Shows how to configure a variety of Nexus switch features, including duplex and speed, port security, securing the command-line interface (CLI), and the switch IP address.

Part III: IPv4/IPv6 Subnetting

- **Chapter 11, "Perspectives on IPv4 Subnetting:"** Walks through the entire concept of subnetting, from starting with a Class A, B, or C network to analyzing requirements, making choices, calculating the resulting subnets, and assigning those on paper—all in preparation to deploy and use those subnets by configuring the devices.
- **Chapter 12, "Analyzing Classful IPv4 Networks:"** IPv4 addresses originally fell into several classes, with unicast IP addresses being in Class A, B, and C. This chapter explores all things related to address classes and the IP network concept created by those classes.
- **Chapter 13, "Analyzing Subnet Masks:"** In most jobs, someone else came before you and chose the subnet mask used in a network. What does that mean? What does that mask do for you? This chapter focuses on how to look at the mask (and IP network) to discover key facts, such as the size of a subnet (number of hosts) and the number of subnets in the network.
- **Chapter 14, "Analyzing Existing Subnets:"** Most troubleshooting of IP connectivity problems starts with an IP address and mask. This chapter takes that paired information and shows you how to find and analyze the subnet in which that IP address resides, including finding the subnet ID, range of addresses in the subnet, and subnet broadcast address.
- **Chapter 15, "Fundamentals of IP Version 6:"** Surveys the big concepts, addressing, and routing created by the new version of IP: IP Version 6 (IPv6). This chapter attempts to show the similarities with IPv4, as well as the key differences—in particular the differences in IPv6 addresses.

Part IV: IPv4 Routing

- **Chapter 16, "IPv4 Routing Concepts:"** Looks at the IPv4 packet-forwarding process. It shows how a pure router forwards packets. This chapter also breaks down the multilayer switches (which include Cisco Nexus switches), including the Layer 3 routing logic in the same device that does Layer 2 Ethernet switching.
- **Chapter 17, "Cisco Nexus IPv4 Routing Configuration:"** Discusses how to implement IPv4 on Nexus switches. This chapter includes the details of configuring IPv4 addresses, static IPv4 routes, and multilayer switching.
- **Chapter 18, "IPv4 Routing Protocol Concepts:"** Examines a variety of protocols available to routers and multilayer switches to dynamically learn routes for the IP

subnets in an internetwork. This chapter focuses on the routing protocol theory that applies to any routing device, with discussion of RIP, OSPF, and EIGRP.

- **Chapter 19, "Nexus Routing Protocol Configuration:"** Explains how to implement IPv4 routing protocols on Cisco Nexus switches, specifically for RIP, OSPF, and EIGRP.
- **Chapter 20, "Nexus First-Hop Redundancy Protocols and Configurations:"** Discusses the different types of FHRPs and how to configure them using Cisco Nexus product lines.
- **Chapter 21, "IPv4 Access Control Lists on Cisco Nexus Switches:"** Discusses the basic concept of how an access control list (ACL) can filter packets as well as the implementation of IPv4 ACLs with Nexus switches.

Part V: Data Center Storage Technologies

- **Chapter 22, "Introduction to Storage and Storage Networking:"** Provides an overview of the data center storage-networking technologies. It compares Small Computer System Interface (SCSI), Fibre Channel, network-attached storage (NAS) connectivity for remote server storage, and storage-area network (SAN). It covers Fibre Channel, Internet Small Computer System Interface (iSCSI), and Fibre Channel over Ethernet protocols and operations in detail. The edge/core layer of the SAN design is also included.
- **Chapter 23, "Advanced Storage Area Network (SAN) Technologies and Configurations:"** Provides an overview of how to configure Cisco MDS 9000 Series multilayer switches. It also describes how to verify virtual storage-area networks (VSANs), zoning, the fabric login, fabric domain, VSAN trunking, and setting up an ISL port using the command-line interface. It discusses node port virtualization and storage virtualization concepts. It introduces principles behind IEEE data center bridging standards and various options for multihop FCoE topologies to extend the reach of Unified Fabric beyond the single-hop boundary.

Part VI: Final Preparation

- **Chapter 24, "Final Review:"** Suggests a plan for final preparation once you have finished the core parts of the book, in particular explaining the many study options available in the book.

Part VII: Appendices (In Print)

- **Appendix A, "Answers to the 'Do I Know This Already?' Quizzes:"** Includes the answers to all the questions from Chapters 1 through 23.
- **Appendix B, "DCICN Exam Updates:"** Covers a variety of short topics that either clarify or expand upon topics covered earlier in the book. This appendix is updated from time to time and posted at www.ciscopress.com/title/9781587205965, with the most recent version available at the time of printing included here as Appendix B. (The first page of the appendix includes instructions on how to check to see whether a later version of Appendix B is available online.)
- **Glossary:** Contains definitions for all of the terms listed in the "Definitions of Key Terms" section at the conclusion of Chapters 1 through 23.

Part VII: Appendices (Online)

- **Appendix C, "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 D, "Memory Tables Answer Key:"** Contains the answer key for the exercises in Appendix I.
- **Appendix E, "Practice for Chapter 12: Analyzing Classful IPv4 Networks:"** Lists practice problems associated with Chapter 12. In particular, the practice questions ask you to find the classful network number in which an address resides, and all other facts about that network.
- **Appendix F, "Practice for Chapter 13: Analyzing Subnet Masks:"** Lists practice problems associated with Chapter 13. In particular, the practice questions ask you to convert masks between the three formats, and to examine an existing mask, determine the structure of the IP addresses, and calculate the number of hosts per subnet and the number of subnets.
- **Appendix G, "Practice for Chapter 14: Analyzing Existing Subnets:"** Lists practice problems associated with Chapter 14. In particular, the practice questions ask you to take an IP address and mask and find the subnet ID, subnet broadcast address, and range of IP addresses in the subnet.
- **Appendix H, "Practice for Chapter 21: IPv4 Access Control Lists on Cisco Nexus Switches:"** Lists practice problems associated with Chapter 21. In particular, the practice questions give you a chance to practice working with access control list (ACL) wildcard masks.
- **Appendix I, "Numeric Reference Tables:"** Lists several tables of numeric information, including a binary-to-decimal conversion table and a list of powers of 2.
- **Appendix J, "Nexus Lab Guide:"** Gives some advice on options for building hands-on skills with NX-OS, the operating system on Cisco Nexus switches.
- **Appendix K, "Study Planner:"** A spreadsheet with major study milestones, where you can track your progress.

Companion Website

Register this book to get access to the Pearson IT Certification test engine and other study materials, plus additional bonus content. Check this site regularly for new and updated postings written by the authors that provide further insight into the more troublesome topics on the exam. Be sure to check the box that you would like to hear from us to receive updates and exclusive discounts on future editions of this product or related products.

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Pearson IT Certification Practice Test Engine and Questions

The companion website includes the Pearson IT Certification Practice Test engine—software that displays and grades a set of exam-realistic multiple-choice questions. Using the Pearson IT Certification Practice Test engine, you can either study by going through the questions in Study Mode or take a simulated exam that mimics real exam conditions. You can also serve up questions in a Flash Card Mode, which will display just the question and no answers, challenging you to state the answer in your own words before checking the actual answers to verify your work.

The installation process requires two major steps: installing the software and then activating the exam. The website has a recent copy of the Pearson IT Certification Practice Test engine. The practice exam (the database of exam questions) is not on this site.

NOTE The cardboard sleeve in the back of this book includes a piece of paper. The paper lists the activation code for the practice exam associated with this book. Do not lose the activation code. On the opposite side of the paper from the activation code is a unique, one-time-use coupon code for the purchase of the Premium Edition eBook and Practice Test.

Install the Software

The Pearson IT Certification Practice Test is a Windows-only desktop application. You can run it on a Mac using a Windows virtual machine, but it was built specifically for the PC platform. The minimum system requirements are as follows:

- Windows 10, Windows 8.1, or Windows 7
- Microsoft .NET Framework 4.0 Client
- Pentium-class 1GHz processor (or equivalent)
- 512MB RAM
- 650MB disk space plus 50MB for each downloaded practice exam
- Access to the Internet to register and download exam databases

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

The following steps outline the installation process:

1. Download the exam practice test engine from the companion site.
2. Respond to Windows prompts, as with any typical software installation process.

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

Activate and Download the Practice Exam

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

1. Start the Pearson IT Certification Practice Test software from the Windows Start menu or from your desktop shortcut icon.
2. To activate and download the exam associated with this book, from the My Products or Tools tab, click the **Activate Exam** button.
3. At the next screen, enter the activation key from the paper inside the cardboard sleeve in the back of the book. Once this is entered, click the **Activate** button.
4. The activation process will download the practice exam. Click **Next** and then click **Finish**.

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

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

If you want to check for updates to the Pearson Cert Practice Test exam engine software, display the **Tools** tab and click the **Update Application** button. You can then ensure that you are running the latest version of the software engine.

Activating Other Exams

The exam software installation process, and the registration process, only has to happen once. Then, for each new exam, only a few steps are required. For instance, if you buy another Pearson IT Certification Cert Guide, extract the activation code from the cardboard sleeve in the back of that book; you do not even need the exam engine at this point. From there, all you have to do is start the exam engine (if not still up and running) and perform steps 2 through 4 from the previous list.

Assessing Exam Readiness

Exam candidates never really know whether they are adequately prepared for the exam until they have completed about 30 percent of the questions. At that point, if you are not prepared, it is too late. The best way to determine your readiness is to work through the "Do I Know This Already?" quizzes at the beginning of each chapter and review the Foundation Topics and Key Topics presented in each chapter. It is best to work your way through the entire book, unless you can complete each subject without having to do any research or look up any answers.

How to View Only DIKTA Questions by Part

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

To view these DIKTA (book) questions inside the PCPT software, follow these steps:

Step 1. Start the PCPT software.

Step 2. From the main (home) menu, select the item for this product, with a name like **DCICN 200-150 Official Cert Guide**, and click **Open Exam**.

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

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

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

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

How to View Only Part Review Questions by Part

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

To view these questions, follow the same process as you did with DIKTA/book questions, but select the part review database instead of the book database, as follows:

Step 1. Start the PCPT software.

Step 2. From the main (home) menu, select the item for this product, with a name like **DCICN 200-150 Official Cert Guide**, and click **Open Exam**.

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

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

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

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

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CHAPTER 3

Fundamentals of Ethernet LANs

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

Many types of LANs have existed over the years, but today's networks use two general types of LANs: Ethernet LANs and wireless LANs. Ethernet LANs happen to use cables for the links between nodes, and because many types of cables use copper wires, Ethernet LANs are often called *wired LANs*. In comparison, wireless LANs do not use wires or cables; instead, they use radio waves to communicate between nodes.

Data center networks make extensive use of Ethernet LAN technology. For example, most individual servers today have multiple Ethernet connections to Ethernet LAN switches. This chapter begins laying a foundation of Ethernet knowledge that you can apply to all uses of Ethernet LAN technology, with the chapters in Part II, "Data Center Nexus Switching and Routing Fundamentals," and Part III, "IPv4/IPv6 Subnetting," adding many more details.

"Do I Know This Already?" Quiz

Use the "Do I Know This Already?" quiz to help decide whether you might want to skim this chapter, or a major section, moving more quickly to the "Exam Preparation Tasks" section near the end of the chapter. Table 3-1 lists the major headings in this chapter and their corresponding "Do I Know This Already?" quiz questions. For thorough explanations, see Appendix A, "Answers to the 'Do I Know This Already?' Quizzes."

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

Foundation Topics Section	Questions
An Overview of LANs	1, 2
Building Physical Ethernet Networks	3, 4
Sending Data in Ethernet Networks	5–8

1. In the LAN for a small office, some user devices connect to the LAN using a cable, while others connect using wireless technology (and no cable). Which of the following is true regarding the use of Ethernet in this LAN?
   a. Only the devices that use cables are using Ethernet.
   b. Only the devices that use wireless are using Ethernet.
   c. Both the devices using cables and those using wireless are using Ethernet.
   d. None of the devices are using Ethernet.
2. Which of the following Ethernet standards defines Gigabit Ethernet over UTP cabling?
   a. 10GBASE-T.
   b. 100BASE-T.
   c. 1000BASE-T.
   d. None of the other answers is correct.
3. Which of the following is true about Ethernet crossover cables for Fast Ethernet?
   a. Pins 1 and 2 are reversed on the other end of the cable.
   b. Pins 1 and 2 on one end of the cable connect to pins 3 and 6 on the other end of the cable.
   c. Pins 1 and 2 on one end of the cable connect to pins 3 and 4 on the other end of the cable.
   d. The cable can be up to 1000 meters long to cross over between buildings.
   e. None of the other answers is correct.
4. Each answer lists two types of devices used in a 100BASE-T network. If these devices were connected with UTP Ethernet cables, which pairs of devices would require a straight-through cable? (Choose three answers.)
   a. PC and router
   b. PC and switch
   c. Hub and switch
   d. Router and hub
   e. Wireless access point (Ethernet port) and switch
5. Which of the following is true about the CSMA/CD algorithm?
   a. The algorithm never allows collisions to occur.
   b. Collisions can happen, but the algorithm defines how the computers should notice a collision and how to recover.
   c. The algorithm works with only two devices on the same Ethernet.
   d. None of the other answers is correct.

6. Which of the following is true about the Ethernet FCS field?

a. Ethernet uses FCS for error recovery.

b. It is 2 bytes long.

c. It resides in the Ethernet trailer, not the Ethernet header.

d. It is used for encryption.

7. Which of the following are true about the format of Ethernet addresses? (Choose three answers.)

a. Each manufacturer puts a unique OUI code into the first 2 bytes of the address.

b. Each manufacturer puts a unique OUI code into the first 3 bytes of the address.

c. Each manufacturer puts a unique OUI code into the first half of the address.

d. The part of the address that holds this manufacturer's code is called the MAC.

e. The part of the address that holds this manufacturer's code is called the OUI.

f. The part of the address that holds this manufacturer's code has no specific name.

8. Which of the following terms describe Ethernet addresses that can be used to send one frame that is delivered to multiple devices on the LAN? (Choose two answers.)

a. Burned-in address

b. Unicast address

c. Broadcast address

d. Multicast address

Foundation Topics

An Overview of LANs

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

Typical SOHO LANs

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

Figure 3-1 shows a drawing of a SOHO Ethernet LAN. The figure shows a single LAN switch, five cables, and five other Ethernet nodes: three PCs, a printer, and one network device called a *router*. (The router connects the LAN to the WAN—in this case, to the Internet.)

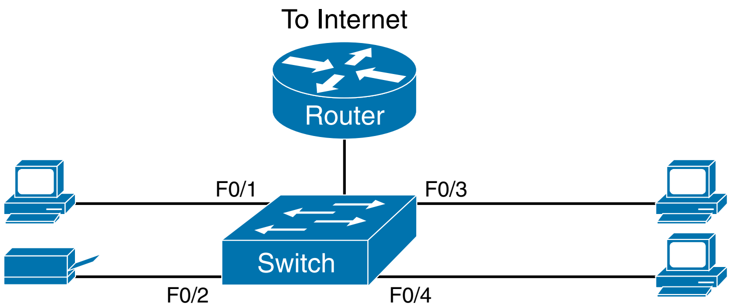

Figure 3-1 *Typical Small Ethernet-Only SOHO LAN*

Although Figure 3-1 shows a simple Ethernet LAN, many SOHO Ethernet LANs today combine the router and switch into a single device. Vendors sell consumer-grade integrated networking devices that work as a router and Ethernet switch, as well as perform other functions. These devices usually have "router" on the packaging, but many models also have four-port or eight-port Ethernet LAN switch ports built in to the device.

Typical SOHO LANs today also support wireless LAN connections. Ethernet defines wired LAN technology only; in other words, Ethernet LANs use cables. However, you can build one LAN that uses both Ethernet LAN technology as well as wireless LAN technology, which is also defined by the IEEE. Wireless LANs, defined by the IEEE using standards that begin with 802.11, use radio waves to send the bits from one node to the next.

Most wireless LANs rely on yet another networking device: a wireless LAN access point (*AP*). The AP acts somewhat like an Ethernet switch, in that all the wireless LAN nodes communicate with the Ethernet switch by sending and receiving data with the wireless AP. Of course, as a wireless device, the AP does not need Ethernet ports for cables, other than for a single Ethernet link to connect the AP to the Ethernet LAN, as shown in Figure 3-2.

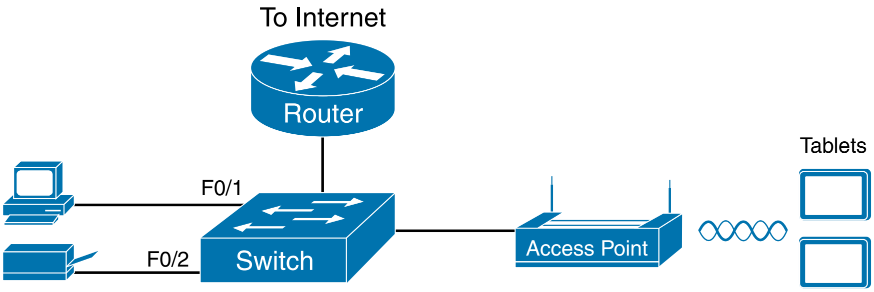

Figure 3-2 *Typical Small Wired and Wireless SOHO LAN*

Note that this drawing shows the router, Ethernet switch, and wireless LAN AP as three separate devices so that you can better understand the different roles. However, most SOHO networks today would use a single device, often labeled as a *wireless router*, that does all these functions.

Typical Enterprise Campus LANs

Companies (enterprises) need to support the devices used by their employees at the enterprise's business sites. Each site used by the enterprise might be only a few floors in an office building, or it might be the entire building, or even a campus with many buildings. Regardless, the term *campus* LAN refers to the LAN created to support the devices used by the people in an enterprise at a particular site.

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

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

Key Topic

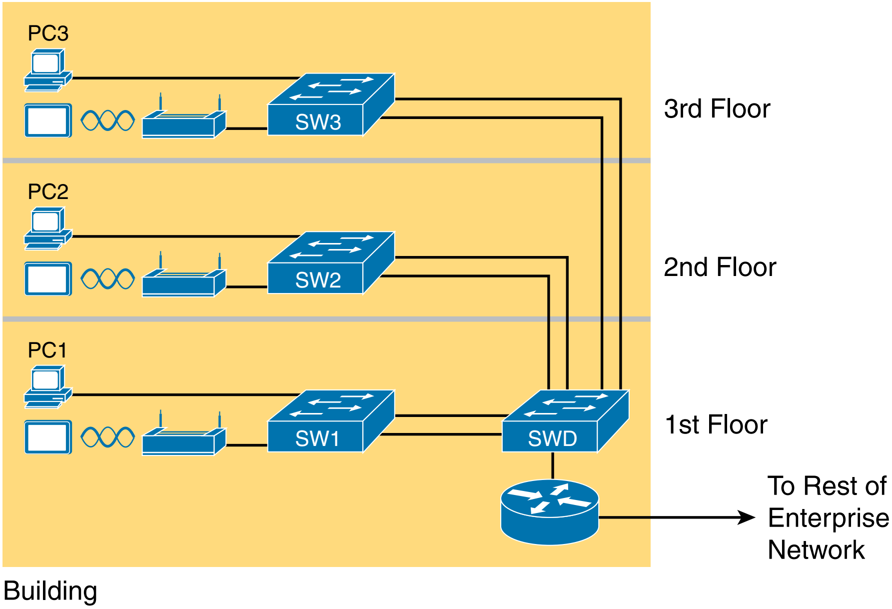

Figure 3-3 *Single-Building Enterprise Wired and Wireless LAN*

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

Typical Data Center Ethernet LAN

Data center Ethernet LANs use many of the same Ethernet technologies and concepts used in SOHO and campus LANs. However, the networking needs for data centers differ enough from SOHO and campus LANs for Cisco to offer an entirely different certification track (routing and switching) for core networking functions in the rest of the enterprise, as compared to the data center certification track that begins with the DCICN exam.

Whereas a campus or SOHO LAN connects to end-user devices, a data center LAN connects to servers that users never see with their own eyes. The data center holds a number of servers in a relatively small space, with the servers often sitting in equipment racks. Each server then connects to an Ethernet switch, with the switches connecting together so that the servers can communicate with each other, as well as with end-user devices. Figure 3-4 shows the general idea.

NOTE Figure 3-4 uses a slightly different switch icon than the previous figures. Cisco supplies a large variety of standard icons to use when drawing network diagrams. Figures 3-2 and 3-3 show the typical icon for a generic switch. The icons shown in Figure 3-4 are for any model of Cisco Nexus switch, with the Nexus switch product line being specifically built for data centers.

Key Topic

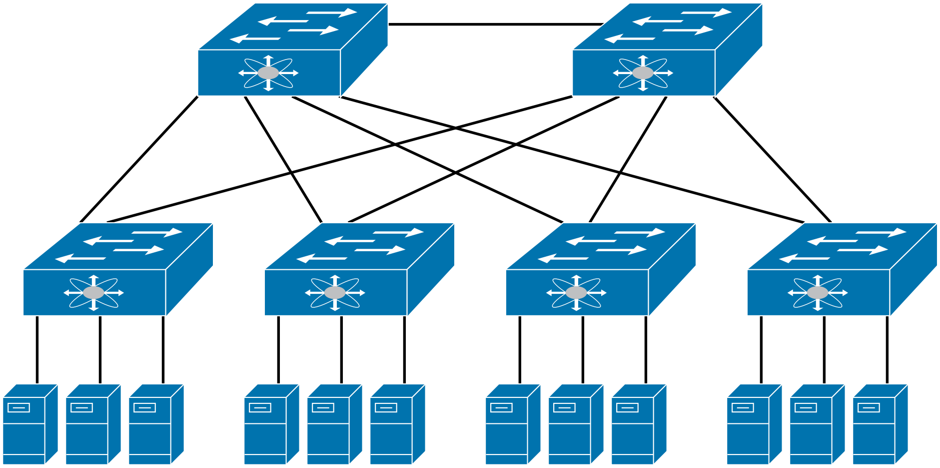

Figure 3-4 *Typical Data Center LAN Design with Four Racks*

No matter whether the Ethernet LAN is a single-room small office, a large data center, or some campus LAN, almost all LANs today use Ethernet as the primary LAN technology.

The rest of this chapter focuses on Ethernet in particular.

The Variety of Ethernet Physical Layer Standards

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

Ethernet supports a large variety of options for physical Ethernet links given its long history over the past 40 or so years. Today, Ethernet includes many standards for different kinds of optical and copper cabling, and for speeds from 10 megabits per second (Mbps) up to 100 gigabits per second (Gbps). The standards also differ as far as the types of cabling and the allowed length of the cabling.

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

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

Table 3-2 lists a few Ethernet physical layer standards. First, the table lists enough names so that you get a sense of the IEEE naming conventions. It also lists the four most common standards that use UTP cabling, because this book's discussion of Ethernet focuses mainly on the UTP options.

Key Topic

Table 3-2 Examples of Types of Ethernet

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

NOTE Fiber-optic cabling contains long, thin strands of fiberglass. The attached Ethernet nodes send light over the glass fiber in the cable, encoding the bits as changes in the light. For copper cabling, certain categories of cables are required; to reach 100m for 10G, please reference this guide: http://www.cisco.com/c/en/us/solutions/data-center-virtualization/10-gigabit-ethernet-technologies/index.html#~copper.

Consistent Behavior over All Links Using the Ethernet Data Link Layer

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

Whereas the physical layer standards focus on sending bits over a cable, the Ethernet data-link protocols focus on sending an *Ethernet frame* from source to destination Ethernet node. From a data-link perspective, nodes build and forward frames. As first defined in Chapter 2, "The TCP/IP and OSI Networking Models," the term *frame* specifically refers to the header and trailer of a data-link protocol, plus the data encapsulated inside that header and trailer. The various Ethernet nodes simply forward the frame, over all the required links, to deliver it to the correct destination.

Figure 3-5 shows an example of the process. In this case, PC1 sends an Ethernet frame to PC3. The frame travels over a UTP link to Ethernet switch SW1, then over fiber links to Ethernet switches SW2 and SW3, and finally over another UTP link to PC3. Note that the bits actually travel at four different speeds in this example: 10 Mbps, 1 Gbps, 10 Gbps, and 100 Mbps, respectively.

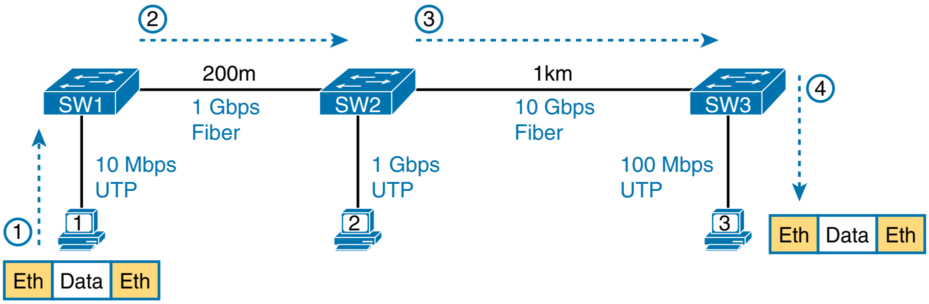

Figure 3-5 *Ethernet LAN Forwards a Data-Link Frame over Many Types of Links*

So, what is an Ethernet LAN? It is a combination of user devices, LAN switches, and different kinds of cabling. Each link can use different types of cables, at different speeds. However, they all work together to deliver Ethernet frames from the one device on the LAN to some other device.

The rest of this chapter takes these concepts a little deeper, first looking at the details of building the physical Ethernet network, followed by some discussion of the rules for forwarding an Ethernet frame from source to destination Ethernet node.

Building Physical Ethernet Networks with UTP

This second of three major sections of this chapter focuses on the individual physical links between any two Ethernet nodes. Before the Ethernet network as a whole can send Ethernet frames between user devices, each node must be ready and able to send data over an individual physical link. This section looks at some of the particulars of how Ethernet sends data over these links.

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

Transmitting Data Using Twisted Pairs

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

First, to create one electrical circuit, Ethernet defines how to use the two wires inside a single twisted pair of wires, as shown Figure 3-6. The figure does not show a UTP cable between two nodes, but instead shows two individual wires that are inside the UTP cable. An electrical circuit requires a complete loop, so the two nodes, using circuitry on their Ethernet ports, connect the wires in one pair to complete a loop, allowing electricity to flow.

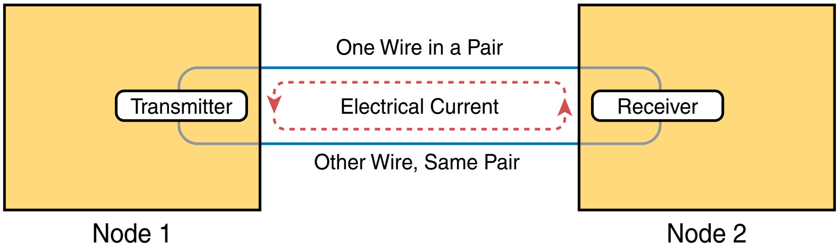

Figure 3-6 *Creating One Electrical Circuit over One Pair to Send in One Direction*

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

Note that in an actual UTP cable, the wires will be twisted together and not parallel, as shown in Figure 3-6. The twisting helps solve some important physical transmission issues. When electrical current passes over any wire, it creates electromagnetic interference (EMI) that obstructs the electrical signals in nearby wires, including the wires in the same cable. (EMI between wire pairs in the same cable is called *crosstalk*.) Twisting the wire pairs together helps cancel out most of the EMI, so most networking physical links that use copper wires use twisted pairs.

Breaking Down a UTP Ethernet Link

The term *Ethernet link* refers to any physical cable between two Ethernet nodes. To learn about how a UTP Ethernet link works, it helps to break down the physical link into those basic pieces, as shown in Figure 3-7: the cable itself, the connectors on the ends of the cable, and the matching ports on the devices into which the connectors will be inserted.

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

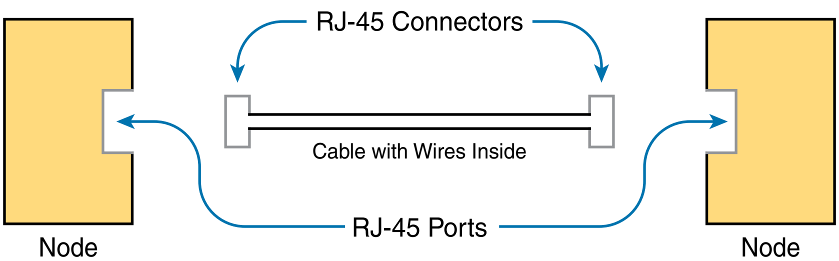

Figure 3-7 *Basic Components of an Ethernet Link*

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

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

To complete the physical link, each node needs an RJ-45 *Ethernet port* that matches the RJ-45 connectors on the cable so that the connectors on the ends of the cable can attach to each node. PCs often include this RJ-45 Ethernet port as part of a network interface card (NIC), which can be an expansion card on the PC or can be built in to the system itself. Switches typically have many RJ-45 ports because switches give user devices a place to connect to the Ethernet LAN.

Figure 3-8 shows photos of the cables, connectors, and ports.

NOTE The RJ-45 connector is slightly wider than, but otherwise similar to, the RJ-11 connectors commonly used for telephone cables in homes in North America.

The figure shows a connector on the left and ports on the right. The left shows the eight pin positions in the end of the RJ-45 connector. The upper right shows an Ethernet NIC that is not yet installed in a computer. The lower-right part of the figure shows the side of a Cisco 2960 switch, with multiple RJ-45 ports, allowing multiple devices to easily connect to the Ethernet network.

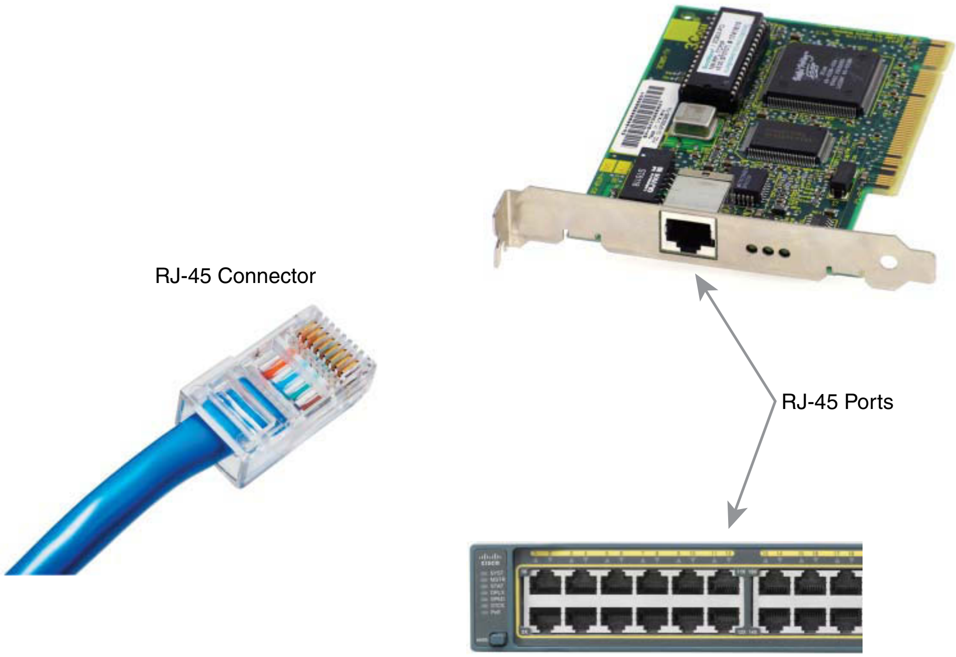

Figure 3-8 *RJ-45 Connectors and Ports (Ethernet NIC © Mark Jansen, LAN Cable © Mikko Pitkänen)*

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

To give customers flexibility as to the type of Ethernet links, Cisco switches include some physical ports whose port hardware can be changed later, after the switch has been purchased. One type of port is called a *gigabit interface converter* (GBIC), which happened to first arrive on the market around the same time as Gigabit Ethernet, so it was given the same "gigabit" name. More recently, improved and smaller types of removable interfaces, called *small form-factor pluggables* (SFPs), provide the same function of enabling users to swap hardware and change the type of physical link. Figure 3-9 shows a photo of a Cisco switch with an SFP sitting slightly outside the SFP slot.

Figure 3-9 *Gigabit Fiber SFP Sitting Just Outside a Switch SFP Port*

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

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

This next topic discusses conventions for 10BASE-T and 100BASE-T together because they use UTP cabling in similar ways (including the use of only two wire pairs). A short comparison of the wiring for 1000BASE-T (Gigabit Ethernet), which uses four pairs, follows.

Straight-Through Cable Pinout

10BASE-T and 100BASE-T use two pairs of wires in a UTP cable, one for each direction, as shown in Figure 3-10. The figure shows four wires, all of which sit inside a single UTP cable that connects a PC and a LAN switch. In this example, the PC on the left transmits using the top pair, and the switch on the right transmits using the bottom pair.

Key Topic

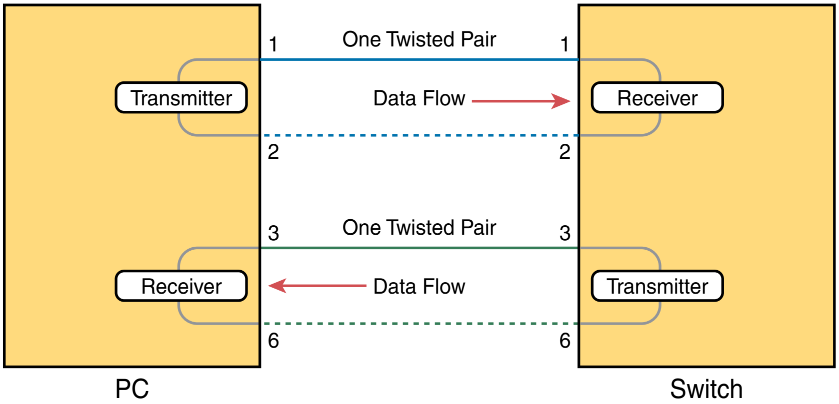

Figure 3-10 *Using One Pair for Each Transmission Direction with 10Mbps and 100Mbps Ethernet*

For correct transmission over the link, the wires in the UTP cable must be connected to the correct pin positions in the RJ-45 connectors. For example, in Figure 3-10, the transmitter on the PC on the left must know the pin positions of the two wires it should use to transmit. Those two wires must be connected to the correct pins in the RJ-45 connector on the switch so that the switch's receiver logic can use the correct wires.

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

To allow a PC NIC to communicate with a switch, the UTP cable must also use a *straight-through cable pinout*. The term *pinout* refers to the wiring of which color wire is placed in each of the eight numbered pin positions in the RJ-45 connector. An Ethernet straight-through cable connects the wire at pin 1 on one end of the cable to pin 1 at the other end of the cable; the wire at pin 2 needs to connect to pin 2 on the other end of the cable; pin 3 on one end connects to pin 3 on the other, and so on, as shown in Figure 3-11. Also, it uses the wires in one wire pair at pins 1 and 2, and another pair at pins 3 and 6.

Key Topic

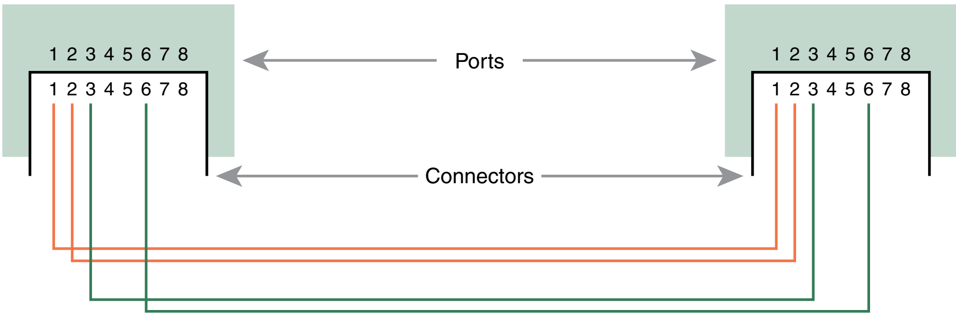

Figure 3-11 *10BASE-T and 100BASE-T Straight-Through Cable Pinout*

Figure 3-12 shows one final perspective on the straight-through cable pinout. In this case, PC Larry connects to a LAN switch. Note that the figure again does not show the UTP cable, but instead shows the wires that sit inside the cable, to emphasize the idea of wire pairs and pins.

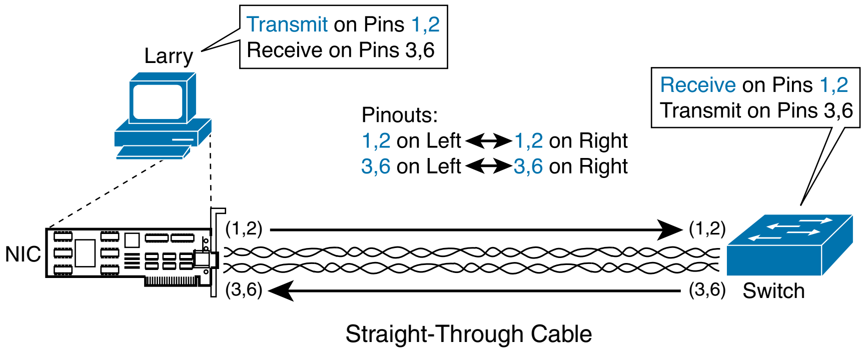

Figure 3-12 *Ethernet Straight-Through Cable Concept*

Crossover Cable Pinout

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

Although the previous sentence is true, this concept is much clearer with a figure, such as Figure 3-13. The figure shows what happens on a link between two switches. The two switches both transmit on the pair at pins 3 and 6, and they both receive on the pair at pins 1 and 2. So, the cable must connect a pair at pins 3 and 6 on each side to pins 1 and 2 on the other side, connecting to the other node's receiver logic. The top of the figure shows the literal pinouts, and the bottom half shows a conceptual diagram.

Key Topic

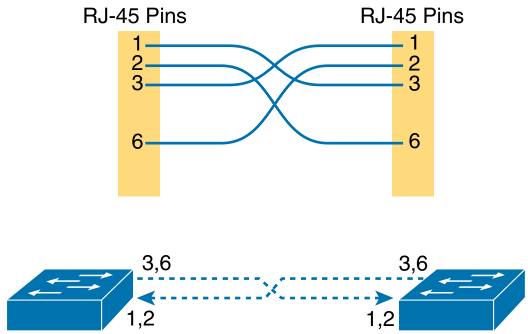

Figure 3-13 *Crossover Ethernet Cable*

Choosing the Right Cable Pinouts

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

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

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

Table 3-3 lists the devices mentioned in this book and the pin pairs they use, assuming that they use 10BASE-T and 100BASE-T.

Key Topic

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

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

For example, Figure 3-14 shows a campus LAN in a single building. In this case, several straight-through cables are used to connect PCs to switches. In addition, the cables connecting the switches require crossover cables.

Key Topic

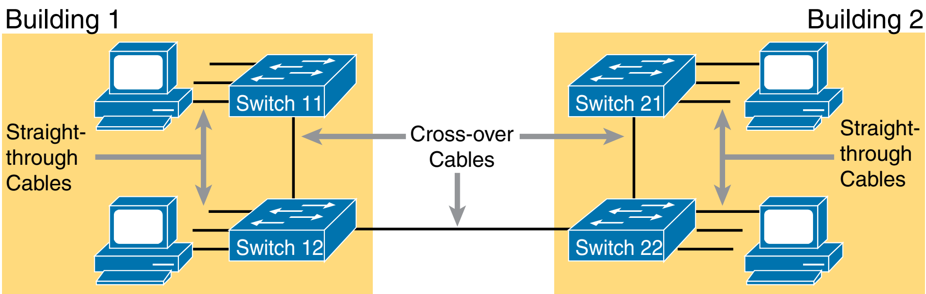

Figure 3-14 *Typical Uses for Straight-Through and Crossover Ethernet Cables*

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

UTP Cabling Pinouts for 1000BASE-T

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

The straight-through cable connects each pin with the same numbered pin on the other side, but it does so for all eight pins—pin 1 to pin 1, pin 2 to pin 2, up through pin 8. It keeps one pair at pins 1 and 2 and another at pins 3 and 6, just like in the earlier wiring. It adds a pair at pins 4 and 5 and the final pair at pins 7 and 8 (refer to Figure 3-13).

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

Sending Data in Ethernet Networks

Although physical layer standards vary quite a bit, other parts of the Ethernet standards work the same way, regardless of the type of physical Ethernet link. Next, this final major section of this chapter looks at several protocols and rules that Ethernet uses regardless of the type of link. In particular, this section examines the details of the Ethernet data link layer protocol, plus how Ethernet nodes, switches, and hubs forward Ethernet frames through an Ethernet LAN.

Ethernet Data-Link Protocols

One of the most significant strengths of the Ethernet family of protocols is that these protocols use the same data-link standard. In fact, the core parts of the data-link standard date back to the original Ethernet standards.

The Ethernet data-link protocol defines the Ethernet frame: an Ethernet header at the front, the encapsulated data in the middle, and an Ethernet trailer at the end. Ethernet actually defines a few alternate formats for the header, with the frame format shown in Figure 3-15 being commonly used today.

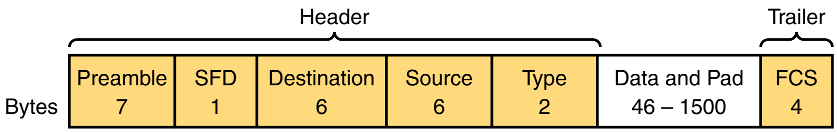

Figure 3-15 *Commonly Used Ethernet Frame Format*

All the fields in the frame matter, but some matter more to the topics discussed in this book. Table 3-4 lists the fields in the header and trailer, and it provides a brief description for reference, with the upcoming pages including more detail about a few of these fields.

Table 3-4 IEEE 802.3 Ethernet Header and Trailer Fields

Field	Field Length in Bytes	Description
Preamble	7	Synchronization.
Start Frame Delimiter (SFD)	1	Signifies that the next byte begins the Destination MAC Address field.

Field	Field Length in Bytes	Description
Destination MAC Address	6	Identifies the intended recipient of this frame.
Source MAC Address	6	Identifies the sender of this frame.
Type	2	Defines the type of protocol listed inside the frame; today, this most likely identifies IP version 4 (IPv4) or IP version 6 (IPv6).
Data and Pad*	46–1500	Holds data from a higher layer, typically an L3PDU (usually an IPv4 or IPv6 packet). The sender adds padding to meet the minimum length requirement for this field (46 bytes).
Frame Check Sequence (FCS)	4	Provides a method for the receiving NIC to determine whether the frame experienced transmission errors.

* The IEEE 802.3 specification limits the data portion of the 802.3 frame to a minimum of 46 bytes and a maximum of 1500 bytes. The term *maximum transmission unit* (MTU) defines the maximum Layer 3 packet that can be sent over a medium. Because the Layer 3 packet rests inside the data portion of an Ethernet frame, 1500 bytes is the largest IP MTU allowed over an Ethernet.

Ethernet Addressing

The source and destination Ethernet address fields play a big role in much of the Ethernet logic included in all the CCNA certifications (including DC). The general idea for each is relatively simple: The sending node puts its own address in the source address field and the intended Ethernet destination device's address in the destination address field. The sender transmits the frame, expecting that the Ethernet LAN, as a whole, will deliver the frame to that correct destination.

Ethernet addresses, also called *Media Access Control (MAC)* addresses, are 6-byte-long (48-bit-long) binary numbers. For convenience, most computers list MAC addresses as 12-digit hexadecimal numbers. Cisco devices typically add some periods to the number for easier readability as well; for example, a Cisco switch might list a MAC address as 0000.0C12.3456.

Most MAC addresses represent a single NIC or other Ethernet port, so these addresses are often called a *unicast* Ethernet address. The term *unicast* is simply a formal way to refer to the fact that the address represents one interface to the Ethernet LAN. (This term also contrasts with two other types of Ethernet addresses, *broadcast* and *multicast*, which are defined later in this section.)

The entire idea of sending data to a destination unicast MAC address works well, but it works only if all the unicast MAC addresses are unique. If two NICs try to use the same MAC address, there could be confusion. (The problem is like the confusion caused to the postal service if you and I both try to use the same mailing address. Would the postal service deliver mail to your house or to mine?) If two PCs on the same Ethernet try to use the same MAC address, to which PC should frames sent to that MAC address be delivered?

Ethernet solves this problem using an administrative process so that, at the time of manufacture, all Ethernet devices are assigned a universally unique MAC address. Before a manufacturer can build Ethernet products, it must ask the IEEE to assign the manufacturer a universally unique 3-byte code, called the *organizationally unique identifier* (OUI). The manufacturer agrees to give all NICs (and other Ethernet products) a MAC address that begins with its assigned 3-byte OUI. The manufacturer also assigns a unique value for the last 3 bytes, a number that manufacturer has never used with that OUI. As a result, the MAC address of every device in the universe is unique.

NOTE The IEEE also calls these universal MAC addresses global MAC addresses.

Figure 3-16 shows the structure of the unicast MAC address, with the OUI.

Key Topic

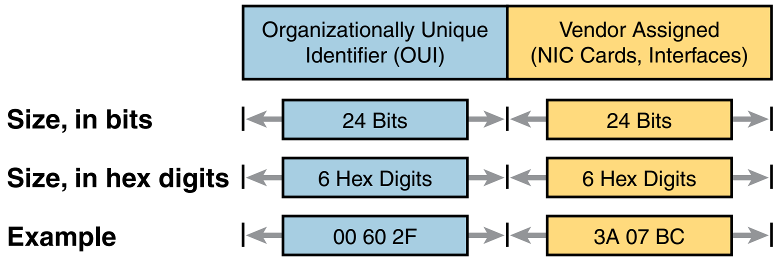

Figure 3-16 *Structure of Unicast Ethernet Addresses*

These addresses go by many names: LAN address, Ethernet address, hardware address, burned-in address, physical address, universal address, and MAC address. For example, the term *burned-in address* (BIA) refers to the idea that a permanent MAC address has been encoded (burned) into the ROM chip on the NIC. As another example, the IEEE uses the term *universal address* to emphasize the fact that the address assigned to a NIC by a manufacturer should be unique among all MAC addresses in the universe.

In addition to unicast addresses, Ethernet also uses group addresses. *Group addresses* identify more than one LAN interface card. A frame sent to a group address might be delivered to a small set of devices on the LAN, or even to all devices on the LAN. In fact, the IEEE defines two general categories of group addresses for Ethernet:

Broadcast address: Frames sent to this address should be delivered to all devices on the Ethernet LAN. It has a value of FFFF.FFFF.FFFF.

Multicast addresses: Frames sent to a multicast Ethernet address will be copied and forwarded to a subset of the devices on the LAN that volunteers to receive frames sent to a specific multicast address.

Table 3-5 summarizes most of the details about MAC addresses.

Table 3-5 LAN MAC Address Terminology and Features

LAN Addressing Term or Feature	Description
MAC	Media Access Control. 802.3 (Ethernet) defines the MAC sublayer of IEEE Ethernet.
Ethernet address, NIC address, LAN address	Other names often used instead of MAC address. These terms describe the 6-byte address of the LAN interface card.
Burned-in address	The 6-byte address assigned by the vendor making the card.
Unicast address	A term for a MAC address that represents a single LAN interface.
Broadcast address	An address that means "all devices that reside on this LAN right now."
Multicast address	On Ethernet, a multicast address implies some subset of all devices currently on the Ethernet LAN.

Identifying Network Layer Protocols with the Ethernet Type Field

Whereas the Ethernet header's address fields play an important and more obvious role in Ethernet LANs, the Ethernet Type field plays a more obscure role. The Ethernet Type field, or EtherType, sits in the Ethernet data link layer header, but its purpose is to directly help the network processing on routers and hosts. Basically, the Type field identifies the type of network layer (Layer 3) packet that sits inside the Ethernet frame.

First, think about what sits inside the data part of the Ethernet frame shown earlier in Figure 3-15. Typically, it holds the network layer packet created by the network layer protocol on some device in the network. Over the years, those protocols have included IBM Systems Network Architecture (SNA), Novell NetWare, Digital Equipment Corporation's DECnet, and Apple Computer's AppleTalk. Today, the most common network layer protocols are both from TCP/IP: IP version 4 (IPv4) and IP version 6 (IPv6).

The original host has a place to insert a value (a hexadecimal number) to identify the type of packet encapsulated inside the Ethernet frame. However, what number should the sender put in the header to identify an IPv4 packet as the type? Or an IPv6 packet? As it turns out, the IEEE manages a list of EtherType values, so that every network layer protocol that needs a unique EtherType value can have a number. The sender just has to know the list. (Anyone can view the list; just go to www.ieee.org and search for "*EtherType*.")

For example, a host can send one Ethernet frame with an IPv4 packet and the next Ethernet frame with an IPv6 packet. Each frame would have a different Ethernet Type field value, using the values reserved by the IEEE, as shown in Figure 3-17.

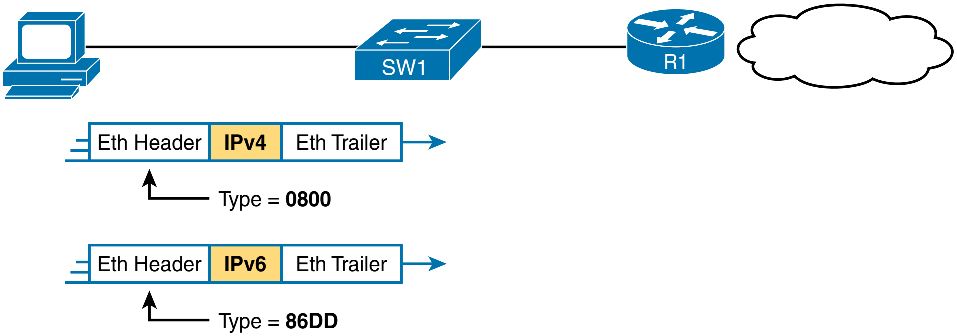

Figure 3-17 *Use of Ethernet Type Field*

Error Detection with FCS

Ethernet also defines a way for nodes to find out whether a frame's bits changed while crossing over an Ethernet link. (Usually, the bits could change because of some kind of electrical interference or a bad NIC.) Ethernet, like most every other data-link protocol covered on the CCNA exams, uses a field in the data-link trailer for the purpose of error detection.

The Ethernet Frame Check Sequence (FCS) field in the Ethernet trailer—the only field in the Ethernet trailer—gives the receiving node a way to compare results with the sender, to discover whether errors occurred in the frame. The sender applies a complex math formula to the frame before sending it, storing the result of the formula in the FCS field. The receiver applies the same math formula to the received frame. The receiver then compares its own results with the sender's results. If the results are the same, the frame did not change; otherwise, an error occurred, and the receiver discards the frame.

Note that *error detection* does not also mean *error recovery*. Ethernet does error detection so that if a frame's content has changed, the Ethernet device can simply discard the frame. Ethernet does not attempt to recover the lost frame. Other protocols, notably TCP, recover the lost data by noticing that it is lost and sending the data again.

Sending Ethernet Frames with Switches and Hubs

Ethernet LANs behave slightly differently depending on whether the LAN has mostly modern devices (in particular, LAN switches instead of some older LAN devices called *LAN hubs*). Basically, the use of more modern switches allows the use of full-duplex logic, which is much faster and simpler than half-duplex logic, which is required when using hubs. The final topic in this chapter looks at these basic differences.

Sending in Modern Ethernet LANs Using Full-Duplex

Modern Ethernet LANs use a variety of Ethernet physical standards, but with standard Ethernet frames that can flow over any of these types of physical links. Each individual link can run at a different speed, but each link allows the attached nodes to send the bits in the frame to the next node. They must work together to deliver the data from the sending Ethernet node to the destination node.

The process is relatively simple, on purpose; the simplicity lets each device send a large number of frames per second. Figure 3-18 shows an example in which PC1 sends an Ethernet frame to PC2.

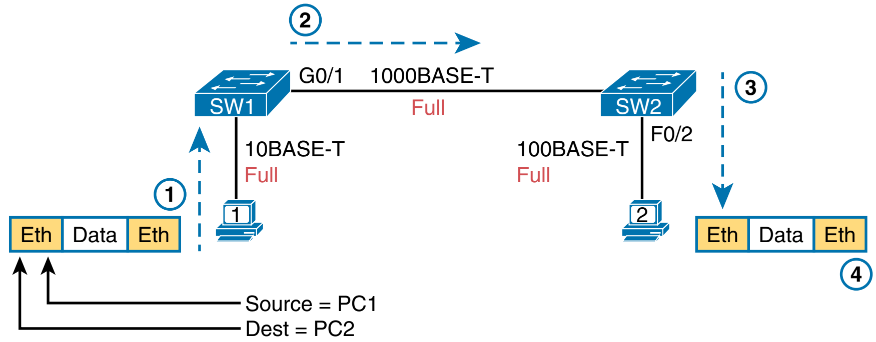

Figure 3-18 *Example of Sending Data in a Modern Ethernet LAN*

The following list details the steps in the figure:

1. PC1 builds and sends the original Ethernet frame, using its own MAC address as the source address and PC2's MAC address as the destination address.
2. Switch SW1 receives and forwards the Ethernet frame out its G0/1 interface (short for Gigabit interface 0/1) to SW2.
3. Switch SW2 receives and forwards the Ethernet frame out its F0/2 interface (short for Fast Ethernet interface 0/2) to PC2.
4. PC2 receives the frame, recognizes the destination MAC address as its own, and processes the frame.

The Ethernet network in Figure 3-18 uses full-duplex on each link, but the concept might be difficult to see. Full-duplex means that the NIC or switch port has no half-duplex restrictions. So, to understand full-duplex, you need to understand half-duplex, as follows:

Key Topic

Half-duplex: Logic in which a port sends data only when it is not also receiving data; in other words, it cannot send and receive at the same time.

Full-duplex: The absence of the half-duplex restriction.

So, with all PCs and LAN switches, and no LAN hubs, all the nodes can use full-duplex. All nodes can send and receive on their port at the same instant in time. For example, in Figure 3-18, PC1 and PC2 could send frames to each other simultaneously, in both directions, without any half-duplex restrictions.

Using Half-Duplex with LAN Hubs

To understand the need for half-duplex logic in some cases, you have to understand a little about an older type of networking device called a LAN hub. When the IEEE first introduced 10BASE-T in 1990, the Ethernet did not yet include LAN switches. Instead of switches, vendors created LAN hubs. The LAN hub provided a number of RJ-45 ports as a place to connect links to PCs, just like a LAN switch, but it used different rules for forwarding data.

LAN hubs forward data using physical layer standards and are therefore considered to be Layer 1 devices. When an electrical signal comes in one hub port, the hub repeats that electrical signal out all other ports (except the incoming port). By doing so, the data reaches all the rest of the nodes connected to the hub, so the data hopefully reaches the correct destination. The hub has no concept of Ethernet frames, of addresses, and so on.

The downside of using LAN hubs is that if two or more devices transmit a signal at the same instant, the electrical signal collides and becomes garbled. The hub repeats all received electrical signals, even if it receives multiple signals at the same time. For example, Figure 3-19 shows the idea, with PCs Archie and Bob sending an electrical signal at the same instant of time (Steps 1A and 1B) and the hub repeating both electrical signals out toward Larry on the left (Step 2).

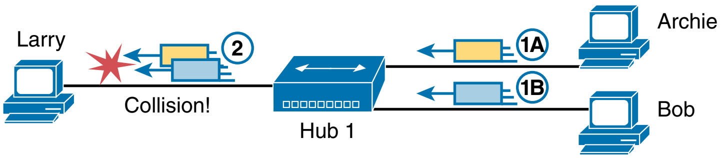

Figure 3-19 *Collision Occurring Because of LAN Hub Behavior*

NOTE For completeness, note that the hub floods each frame out all other ports (except the incoming port). So, Archie's frame goes to both Larry and Bob; Bob's frame goes to Larry and Archie.

If you replace the hub in Figure 3-19 with a LAN switch, the switch prevents the collision on the left. The switch operates as a Layer 2 device, meaning that it looks at the data-link header and trailer. A switch would look at the MAC addresses, and even if the switch needed to forward both frames to Larry on the left, the switch would send one frame and queue the other frame until the first frame was finished.

Now back to the issue created by the hub's logic: collisions. To prevent these collisions, the Ethernet nodes must use half-duplex logic instead of full-duplex logic. A problem only occurs when two or more devices send at the same time; half-duplex logic tells the nodes that if someone else is sending, wait before sending.

For example, back in Figure 3-19, imagine that Archie began sending his frame early enough so that Bob received the first bits of that frame before Bob tried to send his own frame. Bob, at Step 1B, would notice that he was receiving a frame from someone else, and using half-duplex logic, would simply wait to send the frame listed at Step 1B.

Nodes that use half-duplex logic actually use a relatively well-known algorithm called *carrier sense multiple access with collision detection* (CSMA/CD). The algorithm takes care of the obvious cases but also the cases caused by unfortunate timing. For example, two nodes could check for an incoming frame at the exact same instant, both realize that no other node is sending, and both send their frames at the exact same instant, thus causing a collision. CSMA/CD covers these cases as well, as follows:

Step 1. A device with a frame to send listens until the Ethernet is not busy.

Step 2. When the Ethernet is not busy, the sender begins sending the frame.

Step 3. The sender listens while sending to discover whether a collision occurs; collisions might be caused by many reasons, including unfortunate timing. If a collision occurs, all currently sending nodes do the following:

A. They send a jamming signal that tells all nodes that a collision happened.

B. They independently choose a random time to wait before trying again, to avoid unfortunate timing.

C. The next attempt starts again at Step 1.

3

Although most modern LANs do not often use hubs, and therefore do not need to use half-duplex, enough old hubs still exist in enterprise networks that you need to be ready to understand duplex issues. Each NIC and switch port has a duplex setting. For all links between PCs and switches, or between switches, full-duplex should be used. However, for any link connected to a LAN hub, the connected LAN switch and NIC port should use half-duplex. Note that the hub itself does not use half-duplex logic, instead just repeating incoming signals out every other port.

Figure 3-20 shows an example, with full-duplex links on the left and a single LAN hub on the right. The hub then requires SW2's F0/2 interface to use half-duplex logic, along with the PCs connected to the hub.

Key Topic

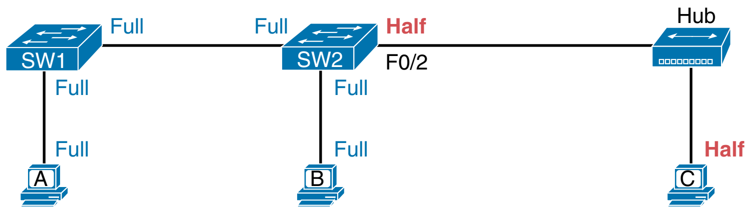

Figure 3-20 *Full- and Half-Duplex in an Ethernet LAN*

Traffic Storm Control in Ethernet Networks

A traffic storm happens when packets flood the LAN, creating excessive traffic and degrading network performance. You can use the traffic storm control feature to prevent disruptions on Layer 2 ports by a broadcast, multicast, or unicast traffic storm on physical interfaces.

Storm control allows you to monitor the levels of the incoming broadcast, multicast, and unicast traffic more than a 1-second interval. During this interval, the traffic level, which is a percentage of the total available bandwidth of the port, is compared with the traffic storm control level that you configured. If the ingress traffic reaches the storm control level that is configured on the port, traffic storm control drops the traffic until the interval ends.

Figure 3-21 shows the broadcast traffic patterns on a Layer 2 interface over a given interval. In this example, traffic storm control occurs between times T1 and T2 and between T4 and T5. During those intervals, the amount of broadcast traffic exceeded the configured threshold.

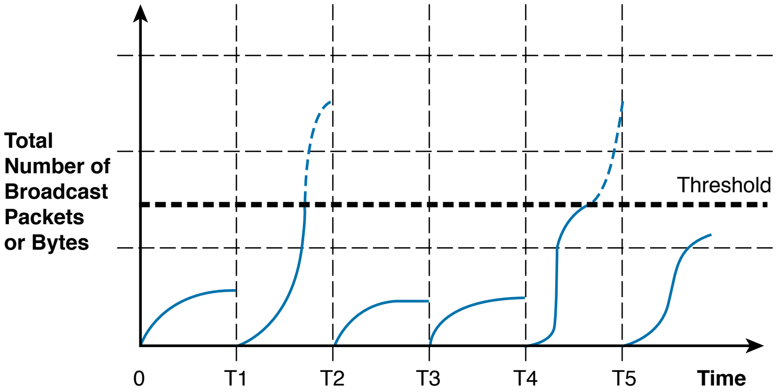

Figure 3-21 *Storm Control Intervals*

Exam Preparation Tasks

Review All Key Topics

Review the most important topics from this chapter, noted with the Key Topic icon in the outer margin of the page. Table 3-6 lists references for these key topics and the page number on which each is found.

Table 3-6 Key Topics for Chapter 3

Key Topic Element	Description	Page Number
Figure 3-3	Drawing of a typical wired and wireless enterprise LAN	116
Figure 3-4	Drawing of a typical data center LAN	117
Table 3-2	Several types of Ethernet LANs and some details about each	118
Figure 3-10	Conceptual drawing of transmitting in one direction, each over two different electrical circuits between two Ethernet nodes	123
Figure 3-11	10Mbps and 100Mbps Ethernet straight-through cable pinouts	123
Figure 3-13	10Mbps and 100Mbps Ethernet crossover cable pinouts	124
Table 3-3	List of devices that transmit on wire pair 1,2 and wire pair 3,6	125
Figure 3-14	Typical uses for straight-through and crossover Ethernet cables	125
Figure 3-16	Format of Ethernet MAC addresses	128
List	Definitions of half-duplex and full-duplex	131
Figure 3-20	Examples of which interfaces use full-duplex and which interfaces use half-duplex	133

Complete the Tables and Lists from Memory

Print a copy of Appendix C, “Memory Tables,” or at least the section for this chapter, and complete the tables and lists from memory. Appendix D, “Memory Tables Answer Key,” includes completed tables and lists for you to check your work.

Definitions of Key Terms

After your first reading of the chapter, try to define these key terms, but do not be concerned about getting them all correct at that time. Chapter 24, “Final Review,” directs you in how to use these terms for late-stage preparation for the exam.

Ethernet, IEEE, wired LAN, Ethernet frame, 10BASE-T, 100BASE-T, 1000BASE-T, Fast Ethernet, Gigabit Ethernet, Ethernet link, RJ-45, Ethernet port, network interface card (NIC), straight-through cable, crossover cable, Ethernet address, MAC address, unicast address, broadcast address, Frame Check Sequence

This chapter covers the following exam topics:

2.0. Basic data center networking concepts

2.1. Compare and contrast the OSI and the TCP/IP models