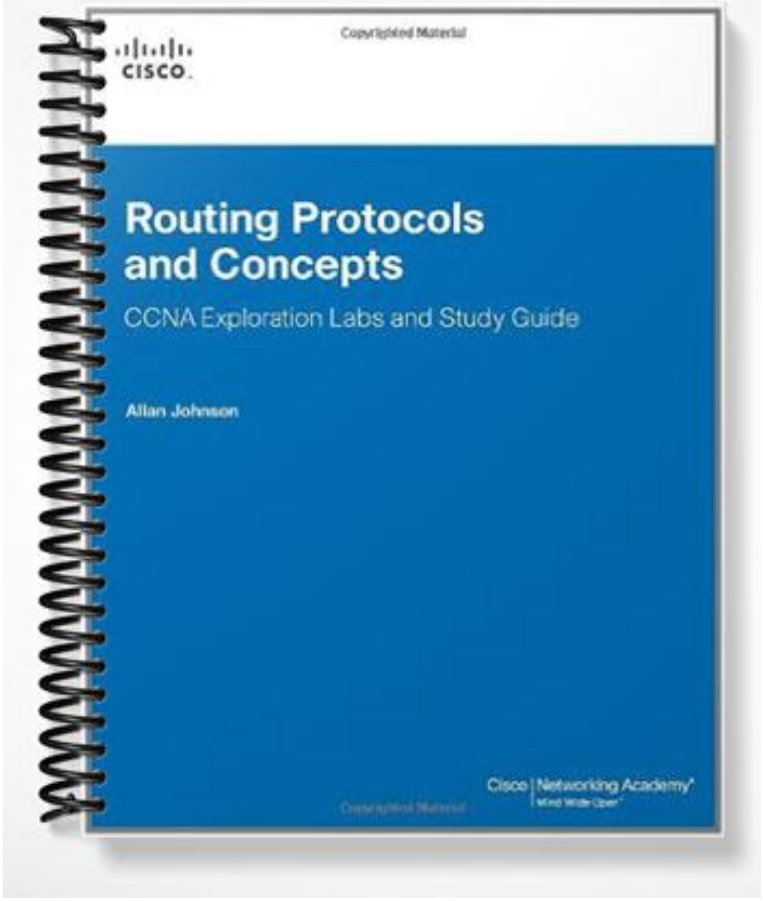
SOLUTIONS MANUAL



Routing Protocols and Concepts

CCNA Exploration Labs and Study Guide

Instructor Edition

Allan Johnson

Cisco Press

800 East 96th Street

Indianapolis, Indiana 46240 USA

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About the Author

Allan Johnson entered the academic world in 1999 after 10 years as a business owner/operator to dedicate his efforts to his passion for teaching. He holds both an M.B.A. and an M.Ed. in occupational training and development. He is an information technology instructor at Del Mar College in Corpus Christi, Texas. In 2003, Allan began to commit much of his time and energy to the CCNA Instructional Support Team, providing services to Networking Academy instructors worldwide and creating training materials. He now works full time for the Academy in Learning Systems Development.

About the Technical Reviewer

Tony Chen, CCNP and CCAI, manages Cisco Networking Academy for the College of DuPage in Glen Ellyn, Illinois, and teaches CCNA and CCNP classes at the college. As a manager for regional academy, he also trains and supports local Cisco networking academies. He also manages the computer network for the Ball Foundation. The Ball Foundation's motto is to discover and develop human potential. Tony Chen has a understanding wife, Joanne, and one wonderful daughter, Kylie.

Dedications

For my wife, Becky. Without the sacrifices you made during the project, this work would not have come to fruition. Thank you providing me the comfort and resting place only you can give.

—Allan Johnson

Acknowledgments

As technical editor, Tony Chen served admirably as my second pair of eyes, finding and correcting technical inaccuracies as well as grammatical errors. Tony's meticulous attention to detail helped to make this project a first-class production.

Mary Beth Ray, executive editor, you amaze me with your ability to juggle multiple projects at once, steering each from beginning to end. I can always count on you to make the tough decisions.

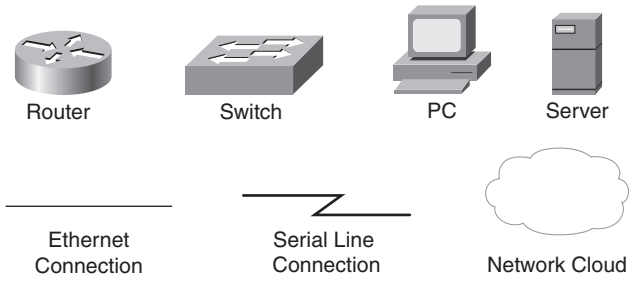
This is my third project with Christopher Cleveland as development editor. His dedication to perfection pays dividends in countless, unseen ways. Thank you again, Chris, for providing me with much-needed guidance and support. This book could not be a reality without your persistence.

Last, I cannot forget to thank all my students—past and present—who have helped me over the years to create engaging and exciting activities and labs. There is no better way to test the effectiveness of an activity or lab than to give it to a team of dedicated students. They excel at finding the obscurest of errors! I could have never done this without all your support.

Contents at a Glance

Contents

Icons Used in This Book



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).
- Italics indicate arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets [ ] indicate optional elements.
- Braces { } indicate a required choice.
- Braces within brackets [{ }] indicate a required choice within an optional element.

Introduction

The Cisco Networking Academy is a comprehensive e-learning program that provides students with Internet technology skills. A Networking Academy delivers web-based content, online assessment, student performance tracking, and hands-on labs to prepare students for industry-standard certifications. The CCNA curriculum includes four courses oriented around the topics of the Cisco Certified Network Associate (CCNA) certification.

Routing Protocols and Concepts, CCNA Exploration Labs and Study Guide is a supplement to your classroom and laboratory experience with the Cisco Networking Academy. To be successful on the exam and achieve your CCNA certification, you should do everything in your power to arm yourself with a variety of tools and training materials to support your learning efforts. This Labs and Study Guide is just such a collection of tools. Used to its fullest extent, it will help you gain the knowledge as well as practice the skills associated with the content area of the CCNA Exploration Routing Protocols and Concepts course. Specifically, this book will help you work on these main areas:

- Basic Routing and Packet-Forwarding Concepts
- Understanding and Configuring Static and Default Routes
- Distance Vector Routing Protocol Concepts
- RIPv1, RIPv2, and EIGRP Concepts and Configuration
- IP Addressing with VLSM
- Classful and Classless Routing
- Link-State Routing Protocol Concepts
- OSPF Concepts and Configuration
- Troubleshooting Routing Issues

Labs and Study Guides similar to this one are also available for the other three courses: *Network Fundamentals, CCNA Exploration Labs and Study Guide*; *LAN Switching and Wireless, CCNA Exploration Labs and Study Guide*; and *Accessing the WAN, CCNA Exploration Labs and Study Guide*.

A Word About Packet Tracer

Packet Tracer is a self-paced, visual, interactive teaching and learning tool developed by Cisco. Lab activities are an important part of networking education. However, lab equipment can be a scarce resource. Packet Tracer provides a visual simulation of equipment and network processes to offset the challenge of limited equipment. Students can spend as much time as they like completing standard lab exercises through Packet Tracer, and have the option to work from home. Although Packet Tracer is not a substitute for real equipment, it allows students to practice using a command-line interface. This "e-doing" capability is a fundamental component of learning how to configure routers and switches from the command line.

Packet Tracer v4.x is available only to Cisco Networking Academies through the Academy Connection website.

Goals and Methods

The most important goal of this book is to help you pass the CCNA exam (640-802). Passing this foundation exam means that you not only have the required knowledge of the technologies covered by the exam, but that you can also plan, design, implement, operate, and troubleshoot these technologies. In other words, these exams are rigorously application based. You can view the exam topics any time at http://www.cisco.com/go/certifications. The topics are divided into eight categories:

- Describe how a network works
- Configure, verify, and troubleshoot a switch with VLANs and interswitch communications
- Implement an IP addressing scheme and IP services to meet network requirements in a medium-size enterprise branch office network.
- Configure, verify, and troubleshoot basic router operation and routing on Cisco devices
- Explain and select the appropriate administrative tasks required for a WLAN
- Identify security threats to a network and describe general methods to mitigate those threats
- Implement, verify, and troubleshoot NAT and ACLs in a medium-size enterprise branch office network
- Implement and verify WAN links

The Routing Protocols and Concepts course focuses on the third and fourth bullets.

The Study Guide section offers exercises that help you learn the routing protocol concepts as well as the configurations crucial to your success as a CCNA exam candidate. Each chapter is slightly different and includes some or all of the following types of exercises:

- Vocabulary Matching and Completion
- Skill-Building Activities and Scenarios
- Configuration Scenarios
- Concept Questions
- Journal Entries
- Internet Research

In the configuration chapters, you'll find many Packet Tracer Activities that work with the Cisco Packet Tracer tool. Packet Tracer allows you to create networks, visualize how packets flow in the network, and use basic testing tools to determine whether the network would work. When you see this icon, you can use Packet Tracer with the listed file to perform a task suggested in this book. The activity files are available on this book's CD-ROM; Packet Tracer software, however, is available through the Academy Connection website. Ask your instructor for access to Packet Tracer.

The Labs and Activities sections include a Command Reference table, all the online Curriculum Labs, and a Packet Tracer Skills Integration Challenge Activity. The Curriculum Labs are divided into three categories:

- **Basic:** The Basic Labs are procedural in nature and assume that you have no experience configuring the technologies that are the topic of the lab.
- **Challenge:** The Challenge Labs are implementation in nature and assume that you have a firm enough grasp on the technologies to "go it alone." These labs often only give you a general requirement that you must implement fully without the details of each small step. In other

words, you must use the knowledge and skills you gained in the chapter text, activities, and Basic Lab to successfully complete the Challenge Labs. Avoid the temptation to work through the Challenge Lab by flipping back through the Basic Lab when you are not sure of a command. Do not try to short-circuit your CCNA training. You need a deep understanding of CCNA knowledge and skills to ultimately be successful on the CCNA exam.

- **Troubleshooting:** The Troubleshooting Labs will ask you to fix a broken network. These labs include corrupted scripts you purposefully load onto the routers. Then you use troubleshooting techniques to isolate problems and implement a solution. By the end of the lab, you should have a functional network with full end-to-end connectivity.

Each of the hands-on labs include Packet Tracer Companion Activities, where you can use Packet Tracer to complete a simulation of the lab.

Each chapter also includes a culminating activity called the Packet Tracer Skills Integration Challenge. These activities require you to pull together several skills learned from the chapter—as well as previous chapters and courses—to successfully complete one comprehensive exercise.

Audience for This Book

This book's main audience is anyone taking the CCNA Exploration Routing Protocols and Concepts course of the Cisco Networking Academy curriculum. Many Academies use this textbook as a required tool in the course, while other Academies recommend the Companion Guides as an additional source of study and practice materials.

The secondary audiences for this book include people taking CCNA-related classes from professional training organizations. This book can also be used for college- and university-level networking courses, as well as for anyone wanting to gain a detailed understanding of routing.

How This Book Is Organized

Because the content of *Routing Protocols and Concepts, CCNA Exploration Companion Guide* and the online curriculum is sequential, you should work through this Labs and Study Guide in order, beginning with Chapter 1.

The book covers the major topic headings in the same sequence as the online curriculum for the CCNA Exploration Routing Protocols and Concepts course. This book has 11 chapters, with the same numbers and similar names as the online course chapters.

Each routing protocol chapter and the static routing chapter begin with a single topology that is used throughout the chapter. The single topology per chapter allows better continuity and easier understanding of routing commands, operations, and outputs. However, the topology is different than the one used in the online curriculum and the Companion Guide. A different topology affords you the opportunity to practice your knowledge and skills without just simply recording the information you find in the text.

- **Chapter 1, "Introduction to Routing and Packet Forwarding":** This chapter begins with several exercises devoted to reinforcing your understanding of the basic hardware and software components of a router as well as testing your knowledge of basic routing and packet forwarding. Then you will practice the basic addressing and configuration skills that are crucial to all future chapters. The Study Guide portion of the chapter ends with a review of routing principles

as well as explains how a router determines the path and switches the packet. The Lab portion includes two versions of the Basic Lab, a Challenge Lab, and the Packet Tracer Skills Integration Challenge Activity.

- **Chapter 2, "Static Routing":** The exercises in the first part of this chapter will help you understand basic router configuration and verification as well as the concept of directly connected networks. Then the exercises cover, in detail, static routes, summary routes, and default routes. The Lab portion of the chapter includes a Basic Lab, a Challenge Lab, a Troubleshooting Lab, and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 3, "Introduction to Dynamic Routing Protocols":** The exercises in this chapter focus on the concepts of dynamic routing, including basic concepts and advantages, classification, metrics, administrative distance, and routing table elements. The Lab section includes six subnetting scenarios to help you hone your IP addressing design skills. The Lab section also includes a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 4, "Distance Vector Routing Protocols":** This chapter's exercises are devoted to the concepts of distance vector routing protocols, including their characteristics, how they maintain the routing table, and how they guard against routing loops. The Lab section includes a routing table interpretation activity and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 5, "RIP Version 1":** Exercises in this chapter focus on RIPv1 concepts, basic configuration, verification, troubleshooting, automatic summarization, and RIP default route propagation. The Lab portion of the chapter includes a Basic Lab, a Challenge Lab, a Troubleshooting Lab, and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 6, "VLSM and CIDR":** This chapter is a transition from classful routing to classless routing. Therefore, exercises focus on the concepts and skills necessary for implementing VLSM addressing schemes and CIDR. The Lab section includes three VLSM design scenarios and three route summarization scenarios. The Lab section also includes a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 7, "RIPv2":** The exercises in this chapter cover the concepts and configurations of the classless version of RIPv2. First, you explore how RIPv2 addresses the limitations of RIPv1. Then you configure, verify, and troubleshoot RIPv2. The Lab portion of the chapter includes a Basic Lab, a Challenge Lab, a Troubleshooting Lab, and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 8, "The Routing Table: A Closer Look":** This chapter represents a pivotal point in your studies of routing protocols and concepts as you delve into exercises that take you deep into the structure of the routing table. Understanding exactly how the routing table is constructed and then used by the IOS provides a valuable tool in verifying and troubleshooting networks. The Lab portion of the chapter includes two routing table labs and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 9, "EIGRP":** Exercises in this chapter focus on EIGRP concepts, basic configuration, verification, troubleshooting, metric calculation, and DUAL operation as well as some more advanced EIGRP configurations. The Lab portion of the chapter includes a Basic Lab, a Challenge Lab, a Troubleshooting Lab, and a Packet Tracer Skills Integration Challenge Activity.
- **Chapter 10, "Link-State Routing Protocols":** The exercises in this chapter help you transition from distance vector routing protocols to link-state routing protocols. There are no labs for this chapter. However, there is a Packet Tracer Skills Integration Challenge Activity.

- **Chapter 11, "OSPF":** This chapter concludes your studies of routing protocols with exercises focusing on basic OSPF concepts and configurations, including the OSPF metric calculation, OSPF multiaccess networks, and some advanced OSPF configurations for single-area OSPF implementations. The Lab portion of the chapter includes a Basic Lab, a Challenge Lab, a Troubleshooting Lab, and a Packet Tracer Skills Integration Challenge Activity.

About the CD-ROM

The CD-ROM included with this book has all the Packet Tracer Activity, Packet Tracer Companion, and Packet Tracer Challenge files that are referenced throughout the book as indicated by the Packet Tracer Activity, Packet Tracer Companion, and Packet Tracer Challenge icons.

Updates to these files can be obtained from the website for this book, http://www.ciscopress.com/title/1587132044. The files will be updated to cover any subsequent releases of Packet Tracer.

About the Cisco Press Website for This Book

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To register this book, go to http://www.ciscopress.com/bookstore/register.asp and enter the book's ISBN, which is located on its back cover. You'll then be prompted to log in or join ciscopress.com to continue registration.

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CHAPTER 1

Introduction to Routing and Packet Forwarding

The Study Guide portion of this chapter uses a combination of matching, fill-in-the-blank, multiple-choice, and open-ended question exercises to test your knowledge and skills of basic router concepts and configuration. The Lab Exercises portion of this chapter includes all the online curriculum labs to ensure that you have mastered the hands-on skills needed to understand basic IP addresing and router configuration.

As you work through this chapter, use Chapter 1 in *Routing Protocols and Concepts, CCNA Exploration Companion Guide* or use the corresponding Chapter 1 in the Exploration Routing Protocols and Concepts online curriculum for assistance.

Study Guide

Inside the Router

A router is a computer and has many of the common hardware components found on other types of computers. A router also includes an operating system. The exercises in this section will reinforce your understanding of the basic hardware and software components of a router. You will also gain a better understanding of the routing and packet-forwarding process.

Vocabulary Exercise: Matching

Match the definition on the left with a term on the right. This exercise is not necessarily a one-to-one matching. Some definitions might be used more than once, and some terms might have multiple definitions.

Definitions

a. Because routers do not necessarily have the same information in their routing tables, packets can traverse the network in one direction, using one path, and return through another path.

b. Routing protocols use _____ to evaluate what path will be the best for a packet to travel to a destination network.

c. Routing that depends on manually entered routes in the routing table.

d. A management port on the router.

e. A company that provides WAN technologies to connect the customer's local networks to the Internet and other remote networks.

f. Most common LAN technology.

g. Table of IP address–to–MAC address mappings used by routers that have Ethernet interfaces.

h. The fastest route to a certain destination, which is based on the routing protocol's metric.

i. A data link layer technology often used for WAN links.

j. A dynamic routing protocol used by routers to determine the best path for IP packets.

k. Port on the router that can be attached to a modem for remote management access.

l. A series of questions prompting the user for basic configuration information because the router did not locate a startup configuration file.

m. A form of permanent storage used by Cisco devices to store the bootstrap instructions, basic diagnostic software, and a scaled-down version of IOS.

n. A router's ability to use multiple paths to the same destination because the paths have the same metric value.

o. Identifies how many routers can be traversed by the datagram before being dropped.

p. Stores the instructions and data needed to be executed by the CPU.

q. An end device or node on the network that implies a computer system.

r. This router mode allows the user to make configuration changes. The router prompt will change from a ">" to a "#."

s. A router's ability to send packets over multiple networks, even when the metric is not the same.

t. Common process that occurs on most every computer during bootup to test the router hardware.

u. Used by the Cisco IOS as permanent storage for the startup configuration file.

v. Nonvolatile computer memory that is used as permanent storage for the operating system, Cisco IOS.

w. Port used to initially configure a router.

x. Used by the router to determine the best path to forward the packet.

y. Used by routers to automatically learn about remote networks and build their routing tables.

Terms

__g__ ARP cache

__a__ asymmetric routing

__i__ Asynchronous Transfer Mode

d, k auxiliary port

__h__ best path

__j__ BGP

d, w console port

__y__ dynamic routing protocols

__j__ EIGRP

__n__ equal-cost load balancing

__f__ Ethernet

__v__ flash

__i__ Frame Relay

__q__ hosts

__j__ IGRP

__e__ Internet service provider (ISP)

__j__ IS-IS

__b__ metric

__u__ NVRAM

__j__ OSPF

__t__ power-on self test (POST)

__i__ Point-to-Point Protocol (PPP)

__r__ privileged EXEC

__p__ RAM

__j__ RIP

__m__ ROM

__x__ routing table

__l__ setup mode

__c__ static routing

__o__ Time to Live (TTL)

__s__ unequal-cost load balancing

Vocabulary Exercise: Completion

Complete the paragraphs that follow by filling in the appropriate words and phrases.

Routers Are Computers

A router is a computer, just like any other computer including a PC. Routers have many of the same hardware and software components that are found in other computers including

- CPU
- RAM
- ROM
- Operating system

Each network that a router connects to typically requires a separate interface. These interfaces are used to connect a combination of both local-area networks (LAN) and wide-area networks (WAN). LANs are commonly Ethernet networks that contain devices such as PCs, printers, and servers. WANs are used to connect networks over a large geographical area and are commonly used to connect a LAN to the Internet service provider's (ISP) network.

The router's primary responsibility is to forward packets destined for local and remote networks by

- Determining the best path to send packets
- Forwarding packets toward their destination

The router uses its routing table to determine the best path to forward the packet. When a match is found, the router encapsulates the IP packet into the data-link frame of the outgoing or exit interface, and the packet is then forwarded towards its destination.

It is likely that a router will receive a packet encapsulated in one type of data-link frame, such as an Ethernet frame, and when forwarding the packet, encapsulate it in a different type of data-link frame.

Static routes and dynamic routing protocols are used by routers to learn about remote networks and build their routing tables.

Router CPU and Memory

Like a PC, the CPU in a router executes operating system instructions, such as system initialization, routing functions, and network interface control.

Similar to other computers, RAM stores the instructions and data needed to be executed by the CPU. It is volatile memory that loses its content when the router is powered down or restarted. For this reason, the router also contains permanent storage areas such as ROM, flash, and NVRAM.

ROM is a form of permanent storage. On Cisco devices, it stores

- The bootstrap instructions
- Basic diagnostic software
- Scaled-down version of IOS

In most models of Cisco routers, the IOS is permanently stored in flash memory and copied into RAM during the bootup process.

NVRAM is nonvolatile random-access memory that does not lose its information when power is turned off. NVRAM is used by the Cisco IOS as permanent storage for the startup configuration file.

Internetwork Operating System (IOS)

Like any operating system on any other computer, Cisco IOS is responsible for managing the hardware and software resources of the router. Although the Cisco IOS might appear to be the same on many routers, there are many different IOS images: a file that contains the entire IOS for that router.

Although some routers provide a GUI (graphical user interface), the CLI (command-line interface) is a much more common method of configuring Cisco routers.

Upon bootup, the startup-config file in NVRAM is copied into RAM and stored as the running-config file. Any changes entered by the network administrator are stored in the running-config file and immediately implemented by the IOS.

Router Bootup Process

Like all computers, a router uses a systematic process to boot up. The four phases are

1. POST: Testing the router hardware
2. Loading the bootstrap program
3. Locating and loading the IOS
4. Locating and loading the startup configuration file or entering setup mode

Power-on self test (POST) is a common process that occurs on most every computer during bootup. The POST process is used to test the router hardware.

After the POST, the bootstrap program is copied from ROM into RAM. Its job is to locate the Cisco IOS and load it into RAM.

After the IOS is loaded, it searches for the startup-config file. If this file is located, it is copied into RAM as the running-config file. The IOS executes the commands in the file one line at a time.

If the startup configuration file cannot be located, the router will prompt the user to enter setup mode, a series of questions prompting the user for basic configuration information. Setup mode will not be used in this course.

After the normal loading process is completed and the prompt is displayed, the router is now running the IOS with the current running configuration file. The network administrator can now begin using IOS commands on this router.

The **show version** command can be used to help verify and troubleshoot some of the basic hardware and software components of the router.

Router Ports and Interfaces

Routers have management ports, which are physical connectors used by the administrator to configure the router and are not used for packet forwarding. The most common of the management ports is the console port. It must be used during initial configuration of the router. Another management port is the auxiliary port, which can also be used to attach a modem.

The term *interface* on Cisco routers refers to a physical connector on the router whose main purpose is to receive and forward packets. Routers have multiple interfaces used to connect to multiple networks.

Every interface on the router is a member, a host on a different IP network. A router's Ethernet interface usually uses an RJ-45 jack that supports unshielded twisted-pair (UTP) cabling. When a router is connected to a switch, a straight-through cable is used. When a PC's network interface card (NIC) is

connected directly to a router's Ethernet interface, a crossover cable is used.

Similar to LAN interfaces, each WAN interface has its own IP address and subnet mask, making it a member of a specific network. Remember, MAC addresses are used only on Ethernet interfaces and are not on WAN interfaces.

Routers and the Network Layer

Key to understanding the role of a router in the network is to understand that a router is a Layer 3 device responsible for forwarding packets. However, a router also operates at Layers 1 and 2.

The main purpose of a router is to connect multiple networks and forward packets destined for its own networks or other networks. A router is considered a Layer 3 device because its primary forwarding decision is based on the information in the Layer 3 IP packet, specifically the destination IP address. This is known as routing.

When a router receives a packet, it examines the destination IP address. If the packet does not belong to any of the router's directly connected networks, the router must forward this packet to another router or drop the packet.

When forwarding a packet, the router will encapsulate the Layer 3 IP packet into the data portion of a Layer 2 data-link frame appropriate for the exit interface. The Layer 2 frame will then be encoded into the Layer 1 physical signals used to represent these bits over the physical link.

Label the External Components of a Router Exercise

Choose the correct label description for each number shown in Figure 1-1.

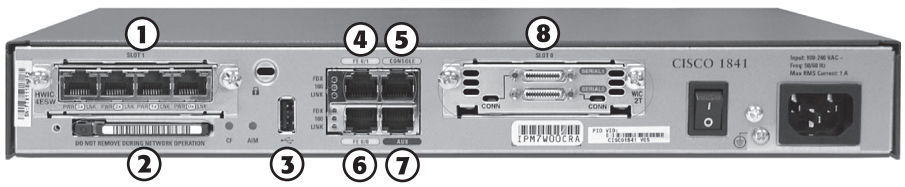


Figure 1-1 Rear View of an 1841 Cisco Router

Figure 1-1 Label Description:

7 Alternative management port that can support remote access through a modem

3 Single-slot USB port

1 4-port Cisco EtherSwitch 10BASE-T/100BASE-TX autosensing high-speed WAN interface card

6 FastEthernet port 0/0

8 High-speed WAN interface card with two serial interfaces

2 Compact flash module

5 Management port used for local access to the device; must be used for initial configuration

4 FastEthernet port 0/1

Label the Internal Components of a Router Exercise

Choose the correct label description for each number shown in Figure 1-2.

Figure 1-2 Logical Diagram of the Internal Components of an 1841 Cisco Router

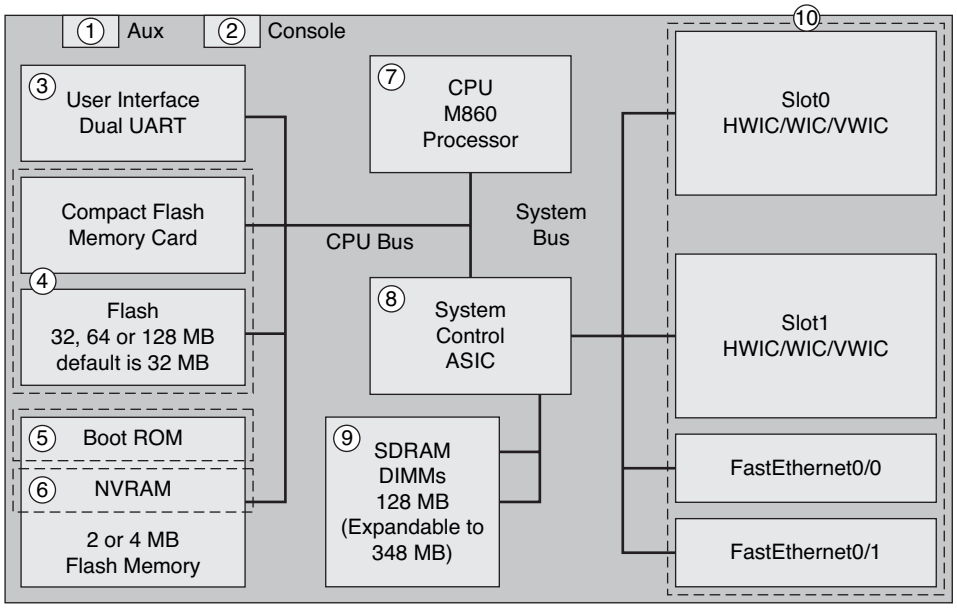


Figure 1-2 Label Description:

3 Universal asynchronous receiver/transmitter, which controls the dual access through the console and auxiliary ports

5 Holds the bootstrap program, ROM monitor, and possibly a scaled-down version of IOS software

10 Includes two modular slots and two built-in LAN interfaces

9 Holds running configuration, routing tables, and other data structures

6 Holds startup configuration

1 Management port used for remote configuration through a modem; not all routers have one of these

7 Loads instructions defined in Cisco IOS Software from the main processor memory and executes them

8 Controls the flow of data among memory, interfaces, and the CPU

2 Management port used for local configuration of the device

4 Stores the Cisco IOS Software image

Describe the Internal Components of a Router Exercise

Knowing the functions of the main internal components of a router is more important than knowing the locations of the physical components inside a particular model. Therefore, in your own words, provide a sufficiently detailed description of each component.

Component	Description
CPU	The central processing unit (CPU) executes the instructions of the operating system. Among these functions are system initialization, routing functions, and network interface control.
RAM	RAM is used for storing the IOS and for the working memory needed by the IOS. This includes the routing table, running configurations, and packet queues, which hold packets until the interface can be used to forward the packet. The contents of RAM are lost when the router loses power.
Flash	Flash memory is used for storage of a full Cisco IOS Software image. In most routers, a copy of the IOS is transferred to RAM from flash during the bootup process. Physically, flash memory consists of single in-line memory modules (SIMM) or PCMCIA cards, which can be upgraded to increase the amount of flash. Flash memory does not lose its contents when the router loses power.
NVRAM	NVRAM is used to store the startup configuration. As described in Chapter 2, "Static Routing," a router will copy the startup configuration from NVRAM into RAM when the router is initialized, and use the running configuration in RAM for normal router operation. NVRAM retains its contents when the router loses power.
Buses	Buses provide a physical means for the router to move bits between the different components of the router. Most routers contain a system bus and a CPU bus. The system bus is used to communicate between the CPU and the interfaces. For example, this bus transfers the packets to and from the interfaces. The CPU bus is used by the CPU for accessing router storage devices, like NVRAM and flash memory.
ROM	ROM holds the bootstrap program, the ROM Monitor software, and optionally a scaled-down version of the IOS. (Chapter 2 covers these types of software.) ROMs are not erasable and can only be upgraded by replacing the ROM chips, but ROM does retain its contents when the router loses power.
Power supply	The power supply converts the voltage and current of a standard power source to the voltage and current required by the devices in the router. The power supplies can be internal or external to the router chassis (the chassis is the metal box that holds the components of the router), and some routers have multiple power supplies for redundancy.

Another way to learn the internal components of a router is by listing the components' functions. For each component from the following list, indicate in the table that follows which component performs the listed function:

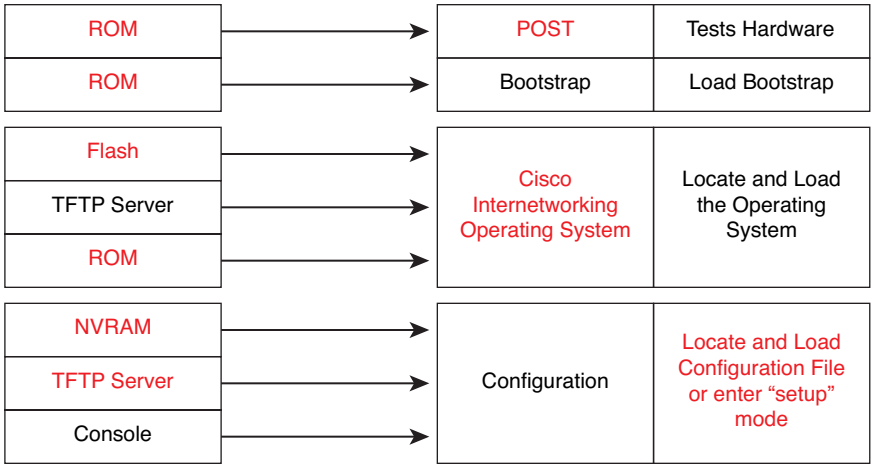
A. RAM
B. NVRAM
C. Flash
D. ROM
E. Interfaces

Answer	Function
A	Provides temporary memory for the configuration file of the router while the router is powered on
C	Allows software to be updated without removing and replacing chips on the processor
A	Stores routing tables
D	Maintains instructions for power-on self test (POST) diagnostics
E	Connects the router to the network for frame entry and exit
E	Can be on the motherboard or on a separate module
C	Is a type of electronically erasable programmable ROM (EEPROM)
B	Retains content when router is powered down or restarted
D	Stores bootstrap program and basic operating system software
A	Holds ARP cache
A	Loses content when router is powered down or restarted
B	Retains content when router is powered down or restarted
C	Holds the operating system image (IOS)
B	Provides storage for the startup configuration file
C	Can store multiple versions of IOS software

Router Bootup Process Exercise

Figure 1-3 displays an incomplete diagram of the default boot sequence of a router. Provide detail where information is missing.

Figure 1-3 Diagram of the Router Boot Sequence



Interpreting the show version Command Exercise

Figure 1-4 displays the output from the **show version** command with parts of the output numbered. Choose the correct label description for each number shown in the figure.

Figure 1-4 show version Command

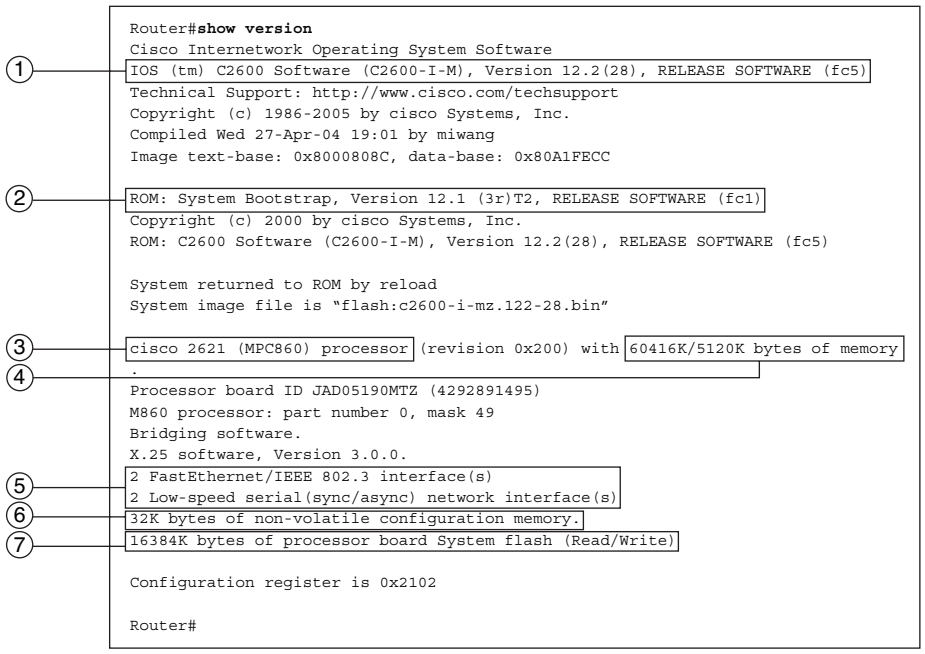


Figure 1-4 Label Description:

2 Bootstrap version

5 Number and type of interfaces

7 Amount of flash

3 Model and CPU

4 Amount of RAM

6 Amount of NVRAM

1 IOS version

CLI Configuration and Addressing

The basic addressing and configuration of Cisco devices were covered in a previous course. However, we will spend some time reviewing these topics as well as prepare you for the hands-on lab experience in this course.

Implementing Basic Addressing Schemes Exercise

When designing a new network or mapping an existing network, it is important to document the network. At a minimum, the documentation should include a topology map of the network and an addressing table that lists the following information:

- Device names
- Interface
- IP address and subnet mask
- Default gateway address for end devices such as PCs

Refer to the topology shown in Figure 1-5 and Table 1-1 that follows it. Using the following guidelines, fill in the addressing table with the correct information:

- The routers use the first address in each network for the LANs.
- R1 uses the first address and R2 uses the second address for the WAN.
- The PCs use the tenth address.

Figure 1-5 Chapter 1 Study Guide Topology

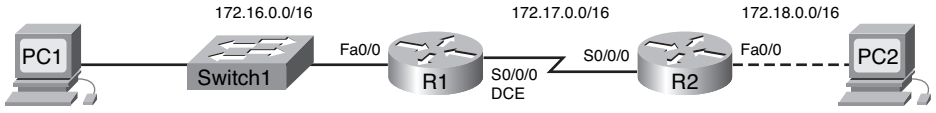


Table 1-1 Addressing Table for Chapter 1 Topology

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	172.16.0.1	255.255.0.0	—
	S0/0/0	172.17.0.1	255.255.0.0	—
R2	Fa0/0	172.18.0.1	255.255.0.0	—
	S0/0/0	172.17.0.2	255.255.0.0	—
PC1	NIC	172.16.0.10	255.255.0.0	172.16.0.1
PC2	NIC	172.18.0.10	255.255.0.0	172.18.0.1

Basic Router Configuration Exercise

When configuring a router, there are certain basic tasks that are performed, including

- Naming the router
- Setting passwords
- Configuring interfaces
- Configuring a banner
- Saving changes on a router
- Verifying basic configuration and router operations

The first prompt is at user mode and will allow you to view the state of the router. What major limitation does this mode have?

User mode will not allow you to modify the router configuration.

What is the router prompt for this mode?

Router>

The **enable** command is used to enter the privileged mode. What is the major difference between this mode and the previous mode?

Privileged mode allows the user to make configuration changes on the router.

What is the router prompt for this mode?

Router#

Basic Configuration Tasks

Table 1-2 lists the basic router configuration tasks in the left column. Fill in the right column with the correct command syntax for each of the tasks.

Table 1-2 Basic Router Configuration Command Syntax

Configuration Task	Command Syntax
Naming the router	`Router(config)# hostname name`
Setting passwords	`Router(config)# enable secret password`
	`Router(config)# line console 0`
	`Router(config-line)# password password`
	`Router(config-line)# login`
	`Router(config)# line vty 0 4`
	`Router(config-line)# password password`
	`Router(config-line)# login`
Configuring a message-of-the-day banner	`Router(config)# banner motd # message #`
Configuring an interface	`Router(config)# interface type number`
	`Router(config-if)# ip address address mask`
	`Router(config-if)# description description`
	`Router(config-if)# no shutdown`
Saving changes on a router	`Router# copy running-config startup-config`
Examining the output of **show** commands	`Router# show running-config`
	`Router# show ip route`
	`Router# show ip interface brief`
	`Router# show interfaces`

Applying a Basic Configuration

The following exercise will walk you through a basic configuration.

First, enter global configuration mode.

```
Router# config t
```

Next, apply a unique host name to the router. Use R1 for this example.

```
Router(config)# hostname R1
```

Now, configure the password that is to be used to enter privileged EXEC mode. Use class as the password.

```
Router(config)# enable secret class
```

Next, configure the console and Telnet lines with the password cisco. The console commands follow:

```
R1(config)# line console 0
R1(config-line)# password cisco
R1(config-line)# login
```

The Telnet lines use similar commands:

```
R1(config)# line vty 0 4
R1(config-line)# password cisco
R1(config-line)# login
```

From global configuration mode, configure the message-of-the-day banner. Use the following text: **Authorized Access Only**. A delimiting character, such as a #, is used at the beginning and at the end of the message.

```
R1(config)# banner motd # Authorized Access Only #
```

What is the purpose of the message of the day?

At a minimum, a banner should warn against unauthorized access. Never configure a banner that "welcomes" an unauthorized user.

Refer to Figure 1-5 for the correct interface designations. What is the command to enter interface configuration mode for R1's serial interface?

```
R1(config)# interface Serial0/0/0
```

Enter the command to configure the IP address using the address you specified in Table 1-1.

```
R1(config-if)# ip address 172.17.0.1 255.255.255.0
```

Describe the interface with the following text: **Link to R2**.

```
R1(config-if)# description Link to R2
```

Because R1 is on the data communications equipment (DCE) side, set the clocking signal to **64000**.

```
R1(config-if)# clock rate 64000
```

Activate the interface.

```
Router(config-if)# no shutdown
```

Now enter the commands to configure and activate the Fast Ethernet interface on R1. Use the following description text: **R1 LAN**.

```
R1(config)# interface FastEthernet0/0
R1(config-if)# ip address 172.16.0.1 255.255.255.0
R1(config-if)# description R1 LAN
R1(config-if)# no shutdown
```

What command will save the current configuration?

```
Router# copy running-config startup-config
```

Verifying Basic Router Configuration

Basic configurations can be verified using four basic **show** commands. In Table 1-3, list the command in the left column that fits the description in the right column.

Table 1-3 Basic Router Configuration Verification Commands

Command	Description
show running-config	Displays the current running configuration that is stored in RAM
show startup-config	Displays the startup configuration file stored in NVRAM
show ip route	Displays the routing table that the IOS is currently using to choose the best path to its destination networks

Command	Description
show interfaces	Displays all the interface configuration parameters and statistics
show ip interface brief	Displays abbreviated interface configuration information, including IP address and interface status

Packet Tracer Activity

Packet Tracer Exercise 1-1: Basic Router Configuration

Now you are ready to use Packet Tracer to apply your documented addressing scheme. Open file LSG02-0101.pka on the CD-ROM that accompanies this book to perform this exercise using Packet Tracer.

Note: The following instructions are also contained within the Packet Tracer Exercise.

Learning Objectives

- Add Devices and Connect Cables
- Configure PCs
- Configure R1
- Configure R2
- Save the Packet Tracer file

Scenario

In this exercise, you will practice configuring the Chapter 1 Study Guide Topology (Figure 1-1). Use the Addressing Table (Table 1-1) you completed in the section "Implementing Basic Addressing Schemes Exercise."

Task 1: Add Devices and Connect Cables

Step 1. Add two PCs: PC1 and PC2. Make sure that you name both PCs. Attach PC1 to S1 and PC2 to R2.

Step 2. Connect the devices. Attach R1 to S1. Attach R1 to R2. Make sure that R1 is the DCE side of the connection.

Step 3. Your completion percentage should be 11%. If not, click **Check Results** to see which required components are not yet completed.

Task 2: Configure PCs

Step 1. Configure PC1 and PC2 according to the addressing table you filled out in the section "Implementing Basic Addressing Schemes Exercise." If you have not completed that exercise, do so now.

Step 2. Check results. Both PCs should now be configured. Your completion percentage should be 21%. If not, click **Check Results** to see which required components are not yet completed.

Task 3: Configure R1

Step 1. Configure the host name, banner, enable secret password, console and Telnet lines according to the following guidelines:

- To avoid incorrect grading, make sure that all names and text strings are case sensitive, with no spacing before or after the name or text string.
- Use the host name **R1**.
- Use the following text for the banner: **Authorized Access Only**.
- For the secret password, use **class**. (Note: The activity does not grade this configuration.)
- For the console and Telnet lines, configure login access with the password **cisco**.
- Your completion percentage should be 46%. If not, click **Check Results** to see which required components are not yet completed.

Step 2. Configure the Fast Ethernet interface.

- Use the IP address and subnet mask according to the addressing table in the section "Implementing Basic Addressing Schemes Exercise."
- Describe the link as **R1 LAN**.
- Activate the interface.
- Your completion percentage should be 53%. If not, click **Check Results** to see which required components are not yet completed.

Step 3. Configure the serial interface.

- Use the IP address and subnet mask according to the addressing table in the section "Implementing Basic Addressing Schemes Exercise."
- Describe the link as **Link to R2**.
- R1 provides clocking at 64,000 bps.
- Activate the interface.
- R1 is now configured. Your completion percentage should be 61%. If not, click **Check Results** to see which required components are not yet completed.

Step 4. Save the configuration to R1.

Task 4: Configure R2

Step 1. Configure the host name, banner, enable secret password, and console and Telnet lines according to the following guidelines:

- To avoid incorrect grading, make sure that all names and text strings are case sensitive, with no spacing before or after the name or text string.
- Use the host name **R2**.
- Use the following text for the banner: **Authorized Access Only**.
- For the secret password, use **class**. (Note: The activity does not grade this configuration.)

- For the console and Telnet lines, configure login access with the password **cisco**.
- Your completion percentage should be 86%. If not, click **Check Results** to see which required components are not yet completed.

Step 2. Configure the Fast Ethernet interface.

- Use the IP address and subnet mask according to the addressing table in the section "Implementing Basic Addressing Schemes Exercise."
- Describe the link as **R2 LAN**.
- Activate the interface.
- Your completion percentage should be 93%. If not, click **Check Results** to see which required components are not yet completed.

Step 3. Configure the serial interface.

- Use the IP address and subnet mask according to the addressing table in the section "Implementing Basic Addressing Schemes Exercise."
- Describe the link as **Link to R1**.
- Activate the interface.
- R1 is now configured. Your completion percentage should be 100%. All the connectivity tests should show a status of "successful." If not, click **Check Results** to see which required components are not yet completed.

Step 4. Save the configuration to R2.

Task 5: Save the Packet Tracer File

Save your Packet Tracer file as LSG02-0101-end.pka. You will use this file to complete some of the remaining exercises in this chapter.

Building the Routing Table

The primary function of a router is to forward packets toward the destination network, the destination IP address of the packet. To do this, a router needs to search the routing information stored in its routing table. In this section, you will learn how a router builds the routing table. Then, you will learn the three basic routing principles.

Vocabulary Exercise: Completion

Complete the paragraphs that follow by filling in appropriate words and phrases.

Introducing the Routing Table

A routing table is a data file stored in RAM that is used to store route information about directly connected and remote networks.

There are two major types of routes in the routing table:

- A directly connected network: When a router's interface is configured with an IP address and subnet mask, the interface becomes a host on that attached network.

- A remote network: This is a network that can only be reached by sending the packet to another router. These networks are added to the routing table by using a dynamic routing protocol or by configuring static routes. Dynamic routes are routes to remote networks that were learned automatically by the router. Static routes are routes to networks that a network administrator manually configured.

show ip route *Command*

Describe the meaning of each part of the following route entry:

```
C    172.16.0.0/16 is directly connected, FastEthernet0/0
```

- **C:** The information in this column denotes the source of the route information, directly connected network, static route, or a dynamic routing protocol. The C represents a directly connected route.
- **172.16.0.0/24:** This is the network address and subnet mask of the directly connected or remote network.
- **FastEthernet 0/0:** The information at the end of the route entry represents the exit interface and/or the IP address of the next-hop router. In this example, both FastEthernet 0/0 and Serial 0/0/0 are the exit interfaces used to reach these networks.

Static Routing

When the IOS learns about a remote network and the interface it will use to reach that network, it adds that route to the routing table, as long as the exit interface is enabled.

Static routes are denoted with the code S in the routing table.

List and describe three situations in which static routes should be used.

- **A network consists of only a few routers.** Using a dynamic routing protocol in such a case does not present any substantial benefit. On the contrary, dynamic routing can add more administrative overhead.
- **A network is connected to the Internet only through a single ISP.** There is no need to use a dynamic routing protocol across this link because the ISP represents the only exit point to the Internet.
- **A large network is configured in a hub-and-spoke topology.** A hub-and-spoke topology consists of a central location (the hub) and multiple branch locations (spokes), with each spoke having only one connection to the hub. Using a dynamic routing protocol would be unnecessary because each branch only has one path to a given destination—through the central location.

Dynamic Routing

Dynamic routing protocols are used by routers to share information about the reachability and status of remote networks. Dynamic routing protocols perform several activities, including

- Network discovery, which is a routing protocol's ability to share information about the networks it knows about with other routers that are also using the same routing protocol
- Maintain routing tables, which is a routing protocol's ability to compensate for any topology changes without involving the network administrator

IP Routing Protocols

List the acronym and full name of the dynamic routing protocols for IP.

- RIP (Routing Information Protocol)
- IGRP (Interior Gateway Routing Protocol)
- EIGRP (Enhanced Interior Gateway Routing Protocol)
- OSPF (Open Shortest Path First)
- IS-IS (Intermediate System–to–Intermediate System)
- BGP (Border Gateway Protocol)

Routing Table Principles Exercise

In your own words, describe the three routing table principles according to Alex Zinin in his book *Cisco IP Routing*.[1]

Instructor note: The student should restate the principles. The following answers are examples.

Principle #1: Each router makes a routing decision solely based on information in its own routing table.

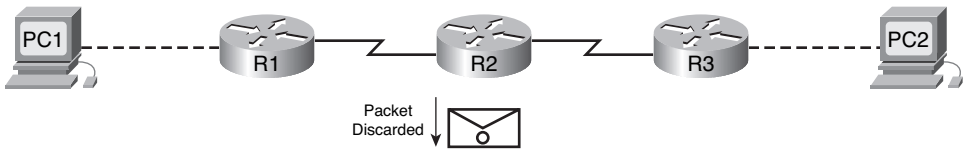
Principle #2: Just because the local router has a route in its table does not mean that other routers have the same route.

Principle #3: Even though a router can route to the destination does not mean that the same router can route a response back to the originating source.

Refer to Figure 1-6. R2 received a packet from R1 destined for PC2. R2 did not have a route for the network that PC2 belongs to, so R2 discarded the packet. Which routing principle does this illustrate?

Routing Principle #2

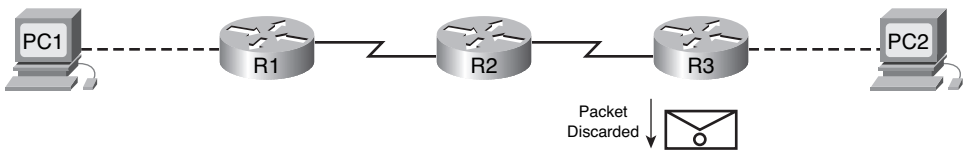
Figure 1-6 Routing Principles: Example 1



Refer to Figure 1-7. R3 received a packet from R2 destined for PC2. R3 sent the packet on to R2. But when R2 sent a response to PC1, R3 discarded the packet. Which routing principle does this illustrate?

Routing Principle #3

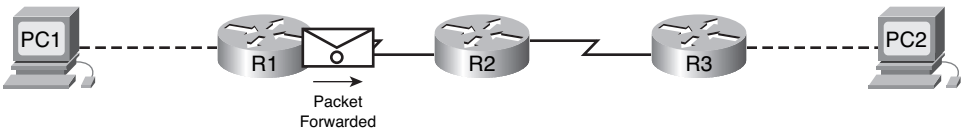
Figure 1-7 Routing Principles: Example 2



Refer to Figure 1-8. R1 received a packet from PC1 destined for PC2. R1 forwarded the packet to R2. Which routing principle does this illustrate?

Routing Principle #1

Figure 1-8 Routing Principles: Example 3



Path Determination and Switching Functions

The following sections use exercises to focus your attention on exactly what happens to data as it moves from source to destination. First, we review the packet and frame field specifications. Then, we discuss in detail how the frame fields change from hop to hop, whereas the packet fields remain unchanged.

Internet Protocol (IP) Packet Format Exercise

Figure 1-9 shows the structure of fields for the packet header. Fill in the missing field names.

Figure 1-9 Field Specification for the IP Header

Byte 1		Byte 2	Byte 3	Byte 4
Version	IHL	Type of Service	Packet Length	
Identification			Flags	Fragment Offset
Time to Live		Protocol	Header Checksum	
Source IP Address				
Destination IP Address				
Options				Padding

MAC Layer Frame Format Exercise

Figure 1-10 shows the two compatible version of Ethernet. Fill in the missing field names.

Figure 1-10 Field Specification for Ethernet Frames

Ethernet

Field Length in Bytes

8	6	6	2	46-1500	4
Preamble	Destination Address	Source Address	Type	Data	FCS

IEEE 802.3

Field Length in Bytes

7	1	6	6	2	46-1500	4
Preamble	SOF	Destination Address	Source Address	Length	802.2 Header and Data	FCS