Networking Essentials

Companion Guide

Cisco Networking Academy

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Cisco Press

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Contents at a Glance

Contents

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

Networking Essentials Companion Guide is the official supplemental textbook for the Cisco Networking Academy Networking Essentials version 2 course. Cisco Networking Academy is a comprehensive program that delivers information technology skills to students around the world. The curriculum emphasizes real-world practical application, while providing opportunities for you to gain the skills and hands-on experience needed to design, install, operate, and maintain networks in small- to medium-sized businesses as well as enterprise and service provider environments.

This book provides a ready reference to explain the same networking concepts, technologies, protocols, and devices as the online curriculum. The book emphasizes key topics, terms, and activities and provides some alternate explanations and examples as compared with the course. You can use the online curriculum as directed by your instructor and then use this Companion Guide's study tools to help solidify your understanding of all the topics.

Who Should Read This Book

The book, as well as the course, is designed to provide learners with a broad foundational understanding of networking. It is suitable for anyone interested in a career in information and communication technology (ICT) or a related career pathway. Networking Essentials is self-paced. The primary emphasis is on networking knowledge with a small amount of basic skills that are useful for a home or a small office/home office (SOHO) network. The online version of this course includes activities that expand on the course material presented. Upon completion of the online course, the end-of-course survey, and the end-of-course assessment, you will receive a Certificate of Completion. You will also receive a digital badge if you complete the course in an instructor-led class.

Online Course Enrollment

The online version of Networking Essentials version 2 is offered in two ways: self-paced or instructor led:

- To enroll for free in a self-paced version of Networking Essentials, visit https://skillsforall.com/course/networking-essentials.
- To find a location near you that offers instructor-led Cisco Networking Academy courses, visit https://www.netacad.com/portal/netacad_academy_search.

Book Features

The educational features of this book focus on supporting topic coverage, readability, and practice of the course material to facilitate your full understanding of the course material.

Topic Coverage

The following features give you a thorough overview of the topics covered in each chapter so that you can make constructive use of your study time:

- **Objectives:** Listed at the beginning of each chapter, the objectives reference the core concepts covered in the chapter. The objectives match the objectives stated in the corresponding chapters of the online curriculum; however, the question format in the Companion Guide encourages you to think about finding the answers as you read the chapter.
- **Notes:** These short sidebars point out interesting facts, time-saving methods, and important safety issues.
- **Chapter summaries:** At the end of each chapter is a summary of the chapter's key concepts. It provides a synopsis of the chapter and serves as a study aid.
- **Practice:** At the end of chapter, there is a full list of all the labs, class activities, and Packet Tracer activities to refer to for study time.

Readability

The following features assist your understanding of the networking vocabulary:

- **Key terms:** Each chapter begins with a list of key terms, along with a page-number reference from inside the chapter. This handy reference enables you to find a term, flip to the page where the term appears, and see the term used in context.
- **Glossary:** The Glossary defines all the highlighted key terms plus more.

Practice

Practice makes perfect. This Companion Guide offers you ample opportunities to put what you learn into practice. You will find the following features valuable and effective in reinforcing the instruction that you receive:

- **Check Your Understanding questions and answer key:** Review questions are presented at the end of each chapter as a self-assessment tool. These questions match the style of questions that you see in the online course. Appendix A, “Answers to the ‘Check Your Understanding’ Questions,” provides an answer key to all the questions and includes an explanation of each answer.

- **Labs and activities:** Throughout each chapter, you will be directed back to the online course to take advantage of the activities created to reinforce concepts. In addition, at the end of each chapter, a practice section collects a list of all the labs and activities to provide practice with the topics introduced in this chapter.

Interactive Graphic

- **Page references to online course:** After headings, you will see, for example, (1.1.2). This number refers to the page number in the online course so that you can easily jump to that spot online to view a video, practice an activity, perform a lab, or review a topic.

Video

About Packet Tracer Software and Activities

Packet Tracer ☐ Activity

Interspersed throughout the chapters, you’ll find a few Cisco Packet Tracer activities. 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 in the course. For self-enrolled courses on SkillsForAll.com, Packet Tracer software is available through a link in your course after you enroll. For instructor-led courses on the Cisco Networking Academy website (netacad.com), Packet Tracer software is available from the **Resources** menu.

How This Book Is Organized

This book corresponds closely to the Cisco Networking Academy Switching, Routing, and Wireless Essentials course and is divided into 20 chapters, one appendix, and a glossary of key terms:

- **Chapter 1, “Communications in a Connected World”:** This chapter explains the concept of network communication including the concept of a network, network data, network speed and capacity, the role of clients and servers, and the role of network infrastructure devices.

- **Chapter 2, “Online Connections”:** This chapter explains the basic requirements for getting online, including the different types of networks used by cell phones and mobile devices, the requirements for host connectivity, and the importance of network documentation.

- **Chapter 3, "Explore Networks with Packet Tracer":** This chapter explains how to create a simulated network using Packet Tracer, including the purpose and function of Packet Tracer, installing Packet Tracer on a local device, investigating the Packet Tracer user interface, configuring a Packet Tracer network, and creating a simulated network in Packet Tracer.
- **Chapter 4, "Build a Simple Network":** This chapter explains how to build a simple home network with common types of network cables including Ethernet twisted-pair, coaxial, and fiber-optic cabling. Also included is an explanation of how a twisted-pair cable transmits and receives signals. Finally, the chapter explains how to verify connectivity in a simple routed network.
- **Chapter 5, "Communication Principles":** This chapter explains the importance of standards and protocols in network communications, including network communication protocols and standards, the OSI and TCP/IP models, and the functions of Layer 1 and Layer 2 in an Ethernet network
- **Chapter 6, "Network Design and the Access Layer":** This chapter explains how communication occurs on Ethernet networks and describes the process of encapsulation and Ethernet framing, the function at each layer of the three-layer network design model, how to improve network communication at the access layer, and why it is important to contain broadcasts within a network.
- **Chapter 7, "Routing Between Networks":** This chapter explains how to configure devices on a LAN and the need for routing, as well as how routers use tables. The chapter then explains how to build a fully connected network.
- **Chapter 8, "The Internet Protocol":** This chapter explains the features of an IP address, including the purpose of an IPv4 address, how to calculate numbers between decimal and binary systems, how IPv4 addresses and subnets are used together; the different IPv4 address classes; public and private IPv4 address ranges; and unicast, multicast, and broadcast addresses.
- **Chapter 9, "Dynamic Addressing with DHCP":** This chapter explains static and dynamic IPv4 addressing and how to configure a DHCPv4 server to dynamically assign IPv4 addresses.
- **Chapter 10, "IPv4 and IPv6 Address Management":** This chapter explains the principles of IPv4 and IPv6 address management, including network boundaries, the purpose of Network Address Translation in small networks, why IPv6 addressing will replace IPv4 addressing, and some of the features of IPv6.
- **Chapter 11, "Transport Layer Services":** This chapter explains how clients access Internet services and also describes client and server interaction, TCP and UDP transport layer functions, and how TCP and UDP use port numbers.

- **Chapter 12, "Application Layer Services":** This chapter explains the function of common application layer services, including DNS, HTTP and HTML, FTP, Telnet and SSH, and email protocols.
- **Chapter 13, "Build a Home Network":** This chapter explains how to configure an integrated wireless router and wireless client to connect securely to the Internet. It also describes the components required to build a home network, the wired and wireless network technologies used, and how wireless traffic is controlled.
- **Chapter 14, "Connect to the Internet":** This chapter explains how to configure Wi-Fi settings on mobile devices to connect to the Internet, including ISP connectivity options. The chapter also explains the purpose and characteristics of network virtualization.
- **Chapter 15, "Security Considerations":** This chapter explains different types of network security threats, including social engineering attacks, various types of malicious software, and denial-of-service attacks. The chapter explains how security tools, software updates, and antimalware software mitigate network security threats.
- **Chapter 16, "Configure Network and Device Security":** This chapter explains how to configure basic network security, including basic ways to address wireless security vulnerabilities, configure encryption on a wireless router, and configure firewall settings.
- **Chapter 17, "Cisco Switches and Routers":** This chapter explains Cisco LAN switches and the Cisco LAN switch boot process. The chapter also explains Cisco small business routers and the Cisco router boot process. Finally, the chapter explains in-band and out-of-band management access.
- **Chapter 18, "The Cisco IOS Command Line":** This chapter explains how to use the Cisco IOS; it also covers the correct commands to navigate the Cisco IOS modes, how to navigate the Cisco IOS to configure network devices, and how to use show commands to monitor device operations.
- **Chapter 19, "Build a Small Cisco Network":** This chapter explains how to build a simple computer network using Cisco devices. In addition, it describes the initial settings on a Cisco switch and a Cisco router, how to configure the devices for secure remote management, and how to connect the devices together in a network.
- **Chapter 20, "Troubleshoot Common Network Problems":** This chapter explains some of the approaches used to troubleshoot networks, including the process of detecting physical layer problems and network troubleshooting utilities. The chapter also explains how to troubleshoot a wireless network problem, common Internet connectivity problems, and how to use outside sources and Internet resources for troubleshooting.

- **Appendix, "Answers to the 'Check Your Understanding' Questions":** This appendix lists the answers to the "Check Your Understanding" review questions that are included at the end of each chapter.
- **Glossary:** The Glossary provides definitions for all the key terms identified in each chapter, plus more terms you might encounter.

CHAPTER 5

Communication Principles

Objectives

Upon completion of this chapter, you will be able to answer the following questions:

- What are network communication protocols?
- What are network communication standards?
- What are the differences and similarities of the OSI and TCP/IP models?
- How do the OSI model's Layer 1 and Layer 2 function in an Ethernet network?

Key Terms

This chapter uses the following key terms. You can find the definitions in the Glossary.

Ethernet page 103

Institute of Electrical and Electronic Engineers (IEEE) page 104

International Organization for Standardization (ISO) page 99

Internet Engineering Task Force (IETF) page 96

protocol page 93

protocol suite page 99

reference model page 99

Request for Comments (RFC) page 96

Introduction (5.0.1)

When you talk with someone, you are communicating. When you mail a card to a relative, you are communicating. You probably don't think much about the rules of communication when you do these two things. But there are rules, and good communication happens only when all parties know and follow those rules. It is the same with devices on a network. This chapter explains the rules, which are called protocols, of network communication. When you understand the various protocols and how they work with other protocols, you not only will understand how networks and the Internet work but also be able to troubleshoot problems in your own network.

The Rules (5.1)

Before communicating with one another, individuals must use established rules or agreements to govern the conversation. Rules are also required for devices on a network to communicate.

The Three Elements (5.1.1)

The primary purpose of any network is to provide a method to communicate and share information. From the earliest primitive human societies to the most advanced technological societies of today, sharing information with others has been crucial for human advancement.

All communication begins with a message, or information, that must be sent from one individual or device to another. The methods used to send, receive, and interpret messages change over time as technology advances.

All communication methods have three elements in common. The first of these elements is the message source, or sender. Message sources are people or even electronic devices that need to communicate a message to other individuals or devices. The second element of communication is the destination, or receiver, of the message. The destination receives the message and interprets it. The third element is called a transmission medium, or channel. It provides the pathway over which the message can travel from source to destination.

For example, in Figure 5-1, two people can communicate face-to-face. Prior to communicating, they must agree on how to communicate. If the communication is using voice, they must first agree on the language. Next, when they have a message to share, they must be able to format that message in a way that is understandable. If someone uses the English language but poor sentence structure, the message can easily be misunderstood. Each of these tasks describes protocols that are used to accomplish communication.

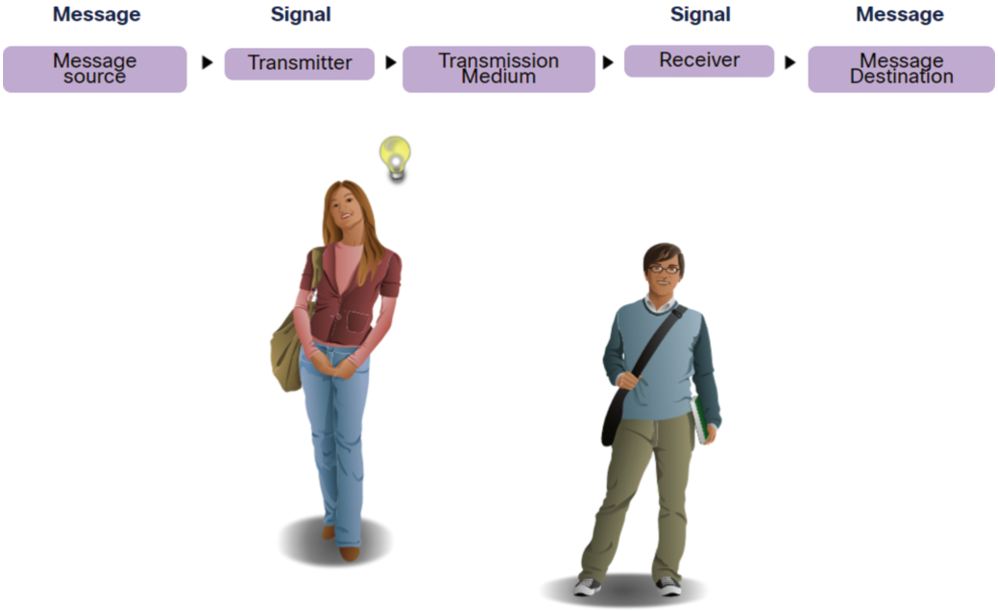


Figure 5-1 Protocols for Face-to-Face Communications

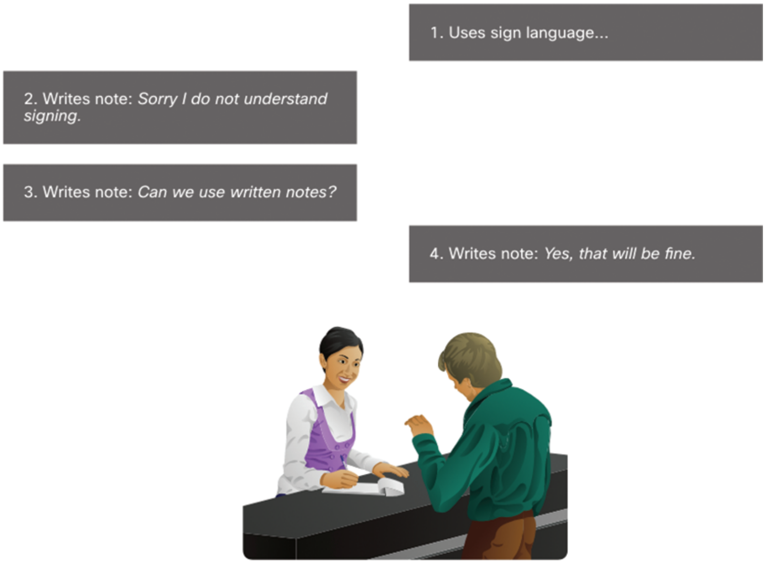
Communication Protocols (5.1.2)

Communication in your daily life takes many forms and occurs in many environments. You have different expectations depending on whether you are chatting via the Internet or participating in a job interview. Each situation has its corresponding expected behaviors and styles.

Before beginning to communicate with each other, you establish rules or agreements to govern the conversation. These agreements include the following:

- What method of communication should you use? (See Figure 5-2.)
- What language should you use? (See Figure 5-3.)
- Do you need to confirm that your messages are received? (See Figure 5-4.)

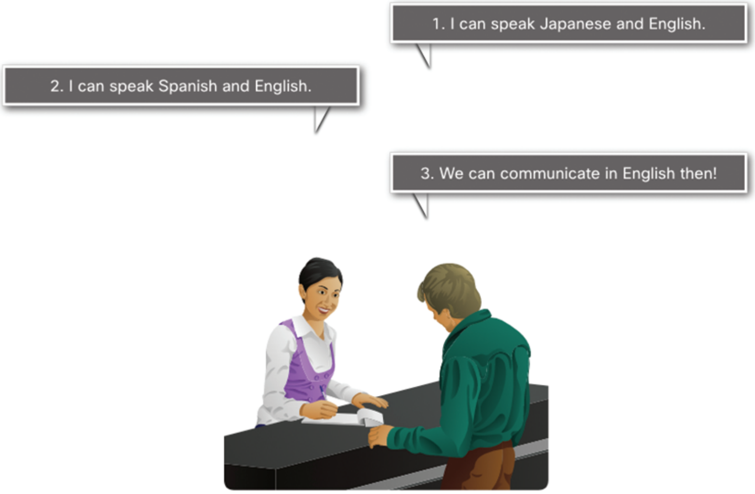
Figure 5-2 shows two people agreeing on a method of communication.


1. Uses sign language...
2. Writes note: *Sorry I do not understand signing.*
3. Writes note: *Can we use written notes?*
4. Writes note: *Yes, that will be fine.*

Before communication can begin, we may have to reach an agreement on the method used.

Figure 5-2 Method of Communication

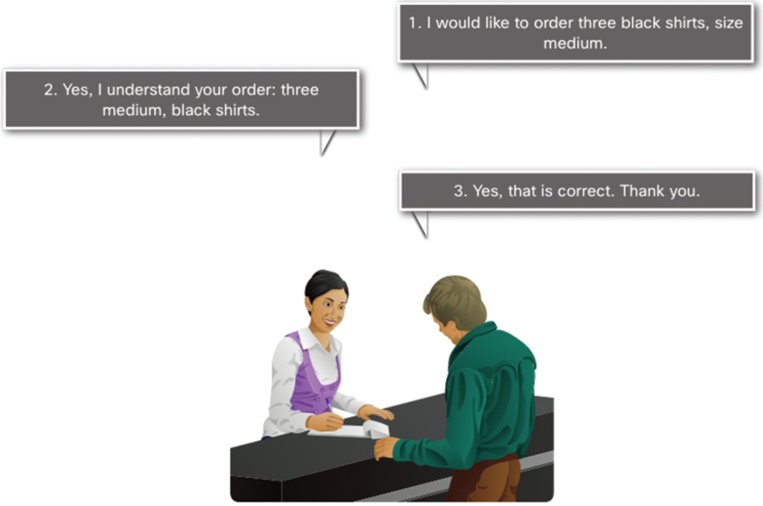
Figure 5-3 shows two people agreeing on a common language to use for communication.


1. I can speak Japanese and English.
2. I can speak Spanish and English.
3. We can communicate in English then!

Before communication can begin, we may have to reach an agreement on the language used.

Figure 5-3 Language Used for Communication

Figure 5-4 shows the communication between two people, including confirmation of the order.


1. I would like to order three black shirts, size medium.
2. Yes, I understand your order: three medium, black shirts.
3. Yes, that is correct. Thank you.

Communication is successful when the intended message has been received and confirmed.

Figure 5-4 Confirmation of Communication

These rules, or *protocols*, must be followed for the message to be successfully delivered and understood. Among the protocols that govern successful human communication are these:

- An identified sender and receiver
- Agreed-upon method of communicating (face-to-face, telephone, letter, photograph)
- Common language and grammar
- Speed and timing of delivery
- Confirmation or acknowledgment requirements

The techniques that are used in network communications share these fundamentals with human conversations.

Now think about the commonly accepted protocols for sending text messages to your friends.

Why Protocols Matter (5.1.3)

Just like humans, computers use rules, or protocols, to communicate. Protocols are required for computers to properly communicate across the network. In both a wired and wireless environment, a local network is defined as an area where all hosts must "speak the same language," which in computer terms means they must "share a common protocol."

If everyone in the same room spoke a different language, they would not be able to communicate. Likewise, if devices in a local network did not use the same protocols, they would not be able to communicate.

Networking protocols define many aspects of communication over the local network. As shown in Table 5-1, these protocols include message format, message size, timing, encoding, encapsulation, and message patterns.

Table 5-1 Protocol Characteristics

Protocol Characteristic	**Description**
Message format	When a message is sent, it must use a specific format or structure. Message formats depend on the type of message and the channel that is used to deliver the message.
Message size	The rules that govern the size of the pieces communicated across the network are very strict. They can also be different, depending on the channel used. When a long message is sent from one host to another over a network, breaking the message into smaller pieces might be necessary to ensure that the message can be delivered reliably.
Timing	Many network communication functions are dependent on timing. Timing determines the speed at which the bits are transmitted across the network. It also affects when an individual host can send data and the total amount of data that can be sent in any one transmission.
Encoding	Messages sent across the network are first converted into bits by the sending host. Each bit is encoded into a pattern of sounds, light waves, or electrical impulses depending on the network media over which the bits are transmitted. The destination host receives and decodes the signals to interpret the message.
Encapsulation	Each message transmitted on a network must include a header that contains addressing information that identifies the source and destination hosts; otherwise, it cannot be delivered. Encapsulation is the process of adding this information to the pieces of data that make up the message. In addition to addressing, other information in the header may ensure that the message is delivered to the correct application on the destination host.
Message pattern	Some messages require an acknowledgment before the next message can be sent. This type of request/response pattern is a common aspect of many networking protocols. However, other types of messages may be simply streamed across the network, without concern as to whether they reach their destination.

Lab—My Protocol Rules (5.1.4)

In this lab, you will complete the following objectives:

- Relate computer network protocols to the rules that you use every day for various forms of communication.
- Define the rules that govern how you send and interpret text messages.
- Explain what would happen if the sender and receiver did not agree on the details of the protocol.

Communication Standards (5.2)

Communication standards are required in all aspects of human communications such as when addressing an envelope. There is a standard regarding the placement of the sender's address, destination address, and even where you put the stamp. Network communication also requires standards to ensure that all the devices in the network use the same rules to send and receive information.

Video

Video—Devices in a Bubble (5.2.1)

Refer to the online course to view this video.

The Internet and Standards (5.2.2)

With the increasing number of new devices and technologies coming online, how is it possible to manage all the changes and still reliably deliver services such as email? The answer is Internet standards.

A standard is a set of rules that determine how something must be done. Networking and Internet standards ensure that all devices connecting to the network implement the same set of rules or protocols in the same manner. Using standards, different types of devices are able to send information to each other over the Internet. For example, the way in which an email is formatted, forwarded, and received by all devices is done according to a standard. If one person sends an email via a personal computer, another person can use a mobile phone to receive and read the email as long as the mobile phone uses the same standards as the personal computer.

Network Standards Organizations (5.2.3)

An Internet standard is the end result of a comprehensive cycle of discussion, problem solving, and testing. These different standards are developed, published, and maintained by a variety of organizations, as shown in Figure 5-5. When a new standard is proposed, each stage of the development and approval process is recorded in a numbered *Request for Comments (RFC)* document so that the evolution of the standard is tracked. RFCs for Internet standards are published and managed by the *Internet Engineering Task Force (IETF)*.

Other standards organizations that support the Internet are shown in Figure 5-5.

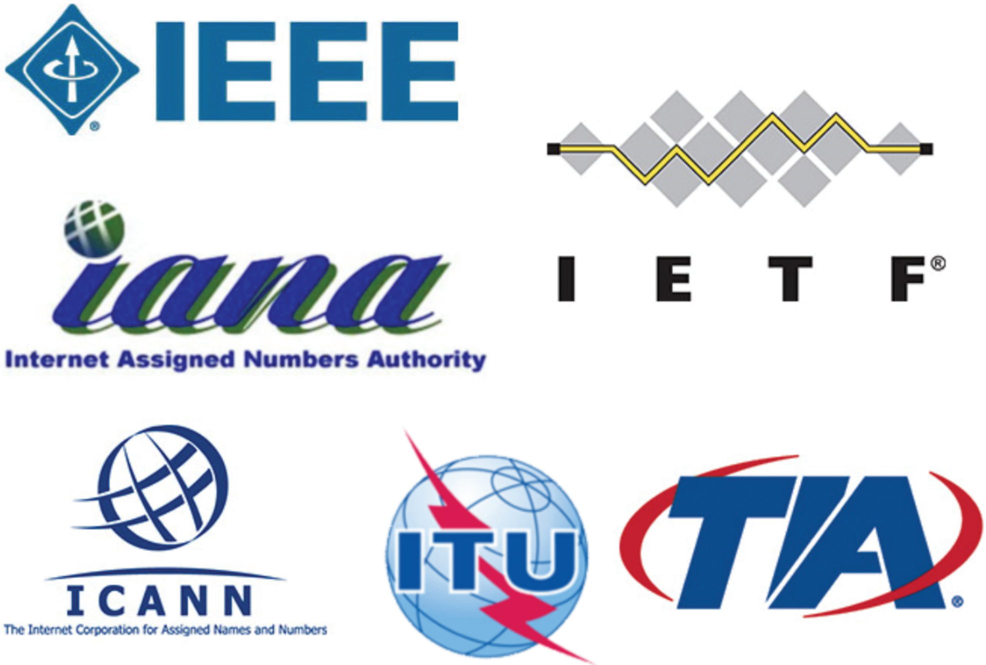

IEEE
IETF
iana
Internet Assigned Numbers Authority
ICANN
The Internet Corporation for Assigned Names and Numbers
ITU
TIA

Figure 5-5 Internet Standards Organizations

Network Communication Models (5.3)

Network communication models help you understand the various components and protocols used in network communications. These models help you see the function of each protocol and their relationship to other protocols.

Video

Video—Network Protocols (5.3.1)

Refer to the online course to view this video.

Video

Video—The Protocol Stack (5.3.2)

Refer to the online course to view this video.

The Protocol Stack (5.3.3)

Successful communication between hosts requires interaction between many protocols. These protocols are implemented in software and hardware that are installed on each host and networking device.

The interaction between the different protocols on a device can be illustrated as a protocol stack, as shown in Figure 5-6. A stack illustrates the protocols as a layered hierarchy, with each higher-level protocol depending on the services of the protocols shown in the lower levels.

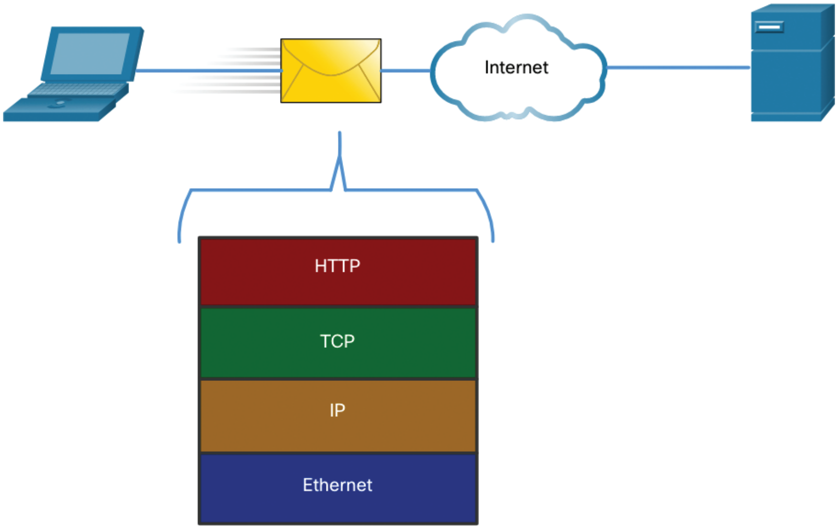


Figure 5-6 A Protocol Stack for Internet Communications

The separation of functions enables each layer in the stack to operate independently of others. For example, you can use your laptop computer connected to a cable modem at home to access your favorite website, or you can view the same website on your laptop using a wireless connection at the library. The function of the web browser is not affected by the change in the physical location or the method of connectivity.

The protocols in Figure 5-6 are described as follows:

- **Hypertext Transfer Protocol (HTTP)**—This protocol governs the way a web server and a web client interact. HTTP defines the content and formatting of the requests and responses that are exchanged between the client and server. Both the client and the web server software implement HTTP as part of the application. HTTP relies on other protocols to govern how the messages are transported between the client and server.
- **Transmission Control Protocol (TCP)**—This protocol manages the individual conversations. TCP is responsible for guaranteeing the reliable delivery of the information and managing flow control between the end devices.
- **Internet Protocol (IP)**—This protocol is responsible for delivering messages from the sender to the receiver. IP is used by routers to forward the messages across multiple networks.
- **Ethernet**—This protocol is responsible for the delivery of messages from one NIC to another NIC on the same Ethernet local-area network (LAN).

The TCP/IP Model (5.3.4)

Layered models help you visualize how the various protocols work together to enable network communications. A layered model depicts the operation of the protocols occurring within each layer, as well as the interaction with the layers above and below it. The layered model has many benefits:

- Assists in protocol design, because protocols that operate at a specific layer have defined information that they act upon and a defined interface to the layers above and below
- Fosters competition because products from different vendors can work together
- Enables technology changes to occur at one level without affecting the other levels
- Provides a common language to describe networking functions and capabilities

The first layered model for internetwork communications was created in the early 1970s and is referred to as the Internet model. It defines four categories of functions that must occur in order for communications to be successful. The suite of TCP/IP protocols that are used for Internet communications follows the structure of this model, as shown in Table 5-2. Because of this, the Internet model is commonly referred to as the TCP/IP model.

Table 5-2 The Layers of the TCP/IP Model

TCP/IP Model Layer	Description
Application	Represents data to the user, plus encoding and dialogue control
Transport	Supports communication between various devices across diverse networks
Internet	Determines the best path through the network
Network Access	Controls the hardware devices and media that make up the network

The OSI Reference Model (5.3.5)

Two basic types of models are used to describe the functions that must occur in order for network communications to be successful: protocol models and reference models.

- **Protocol model**—This model closely matches the structure of a particular *protocol suite*. A protocol suite includes the set of related protocols that typically provide all the functionality required for people to communicate with the data network. The TCP/IP model is a protocol model because it describes the functions that occur at each layer of protocols within the TCP/IP suite.
- *Reference model*—This type of model describes the functions that must be completed at a particular layer but does not specify exactly how a function should be accomplished. A reference model is not intended to provide a sufficient level of detail to define precisely how each protocol should work at each layer. The primary purpose of a reference model is to aid in clearer understanding of the functions and processes necessary for network communications.

The most widely known internetwork reference model was created by the Open Systems Interconnection (OSI) project at the *International Organization for Standardization (ISO)*. It is used for data network design, operation specifications, and troubleshooting. This model is commonly referred to as the OSI model. The OSI layers are described in Table 5-3.

Table 5-3 The Layers of the OSI Model

OSI Model Layer	Description
7–Application	The application layer contains protocols used for process-to-process communications.
6–Presentation	The presentation layer provides for common representation of the data transferred between application layer services.

OSI Model Layer	Description
5–Session	The session layer provides services to the presentation layer to organize its dialogue and to manage data exchange.
4–Transport	The transport layer defines services to segment, transfer, and reassemble the data for individual communications between the end devices.
3–Network	The network layer provides services to exchange the individual pieces of data over the network between identified end devices.
2–Data Link	The data link layer protocols describe methods for exchanging data frames between devices over a common media.
1–Physical	The physical layer protocols describe the mechanical, electrical, functional, and procedural means to activate, maintain, and de-activate physical connections for bit transmission to and from a network device.

Upper and Lower Layers of the OSI Model (5.3.6)

You can visualize how data moves across a network by using the seven layers of the OSI model, as shown in Table 5-3. The OSI model breaks down network communication into multiple processes, as shown in Table 5-4. Each process is a small part of the larger task.

For example, in a vehicle manufacturing plant, the entire vehicle is not assembled by one person. Rather, the vehicle moves from station to station where specialized teams add specific components. The complex task of assembling a vehicle is made easier by breaking it into manageable and logical tasks. This process also makes troubleshooting easier. When a problem occurs in the manufacturing process, it is possible to isolate the problem to the specific task where the defect was introduced and then fix that problem.

In a similar manner, the OSI model helps you troubleshoot by focusing on a specific layer to identify and resolve network problems. Networking teams often refer to different functions occurring on a network by the number of the OSI model layer that specifies that functionality. For example, the process of encoding the data bits for transmission across the media occurs at Layer 1, the physical layer. The formatting of data so it can be interpreted by the network connection in your laptop or phone is described at Layer 2, the data link layer.

Table 5-4 Common Components of the Layers of the OSI Model

Group	Layer Number	Layer Name	Common Network Components Associated with This Layer
Upper Layers	7	Application	■ Network-aware applications ■ Email ■ Web browsers and servers ■ File transfer ■ Name resolution
	6	Presentation	
	5	Session	
Lower Layers	4	Transport	■ Video and voice streaming mechanisms ■ Firewall filtering lists
	3	Network	■ IP addressing ■ Routing
	2	Data Link	■ Network interface cards and drivers ■ Network switching ■ WAN connectivity
	1	Physical	■ Physical medium (copper twisted-pair, fiber-optic cables, wireless transmitters)

OSI Model and TCP/IP Model Comparison (5.3.7)

Because TCP/IP is the protocol suite in use for Internet communications, why do you need to learn the OSI model as well? The TCP/IP model is a method of visualizing the interactions of the various protocols that make up the TCP/IP protocol suite. It does not describe general functions that are necessary for all networking communications. It describes the networking functions specific to those protocols in use in the TCP/IP protocol suite. For example, at the network access layer, the TCP/IP protocol suite does not specify which protocols to use when transmitting over a physical medium, nor the method of encoding the signals for transmission. OSI Layers 1 and 2 discuss the necessary procedures to access the media and the physical means to send data over a network.

The protocols that make up the TCP/IP protocol suite can be described in terms of the OSI reference model. The functions that occur at the Internet layer in the TCP/IP model are contained in the network layer of the OSI model, as shown in Figure 5-7. The transport layer functionality is the same between both models. However, the network access layer and the application layer of the TCP/IP model are further divided in the OSI model to describe discrete functions that must occur at these layers.

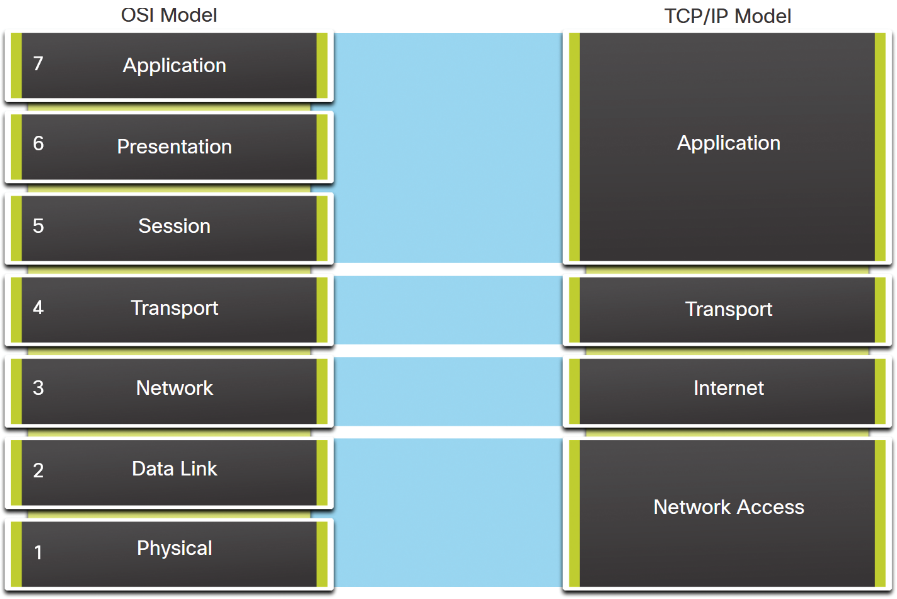


Figure 5-7 The OSI and TCP/IP Models

The key similarities are in the transport and network layers; however, the two models differ in how they relate to the layers above and below each layer:

- OSI Layer 3, the network layer, maps directly to the TCP/IP Internet layer. This layer is used to describe protocols that address and route messages through an internetwork.
- OSI Layer 4, the transport layer, maps directly to the TCP/IP transport layer. This layer describes general services and functions that provide ordered and reliable delivery of data between source and destination hosts.
- The TCP/IP application layer includes several protocols that provide specific functionality to a variety of end-user applications. The OSI model Layers 5, 6, and 7 are used as references for application software developers and vendors to produce applications that operate on networks.
- Both the TCP/IP and OSI models are commonly used when referring to protocols at various layers. Because the OSI model separates the data link layer from the physical layer, it is commonly used when referring to these lower layers.

Ethernet (5.4)

When you are connecting to a network using a wired interface, you are using the Ethernet protocol. Even most wireless networks ultimately connect to a wired Ethernet network. Ethernet is an important data link layer protocol used in LANs and most wide-area networks (WANs).

The Rise of Ethernet (5.4.1)

In the early days of networking, each vendor used its own proprietary methods of interconnecting network devices and networking protocols. If you bought equipment from different vendors, there was no guarantee that the equipment would work together. Equipment from one vendor might not communicate with equipment from another.

As networks became more widespread, standards were developed that defined rules by which network equipment from different vendors operated. Standards are beneficial to networking in many ways:

- Facilitate design
- Simplify product development
- Promote competition
- Provide consistent interconnections
- Facilitate training
- Provide more vendor choices for customers

There is no official local-area networking standard protocol, but over time, one technology, Ethernet, has become more common than the others. ***Ethernet*** protocols define how data is formatted and how it is transmitted over the wired network. The Ethernet standards specify protocols that operate at Layer 1 and Layer 2 of the OSI model. Ethernet has become the de facto standard, which means that it is the technology used by almost all wired local-area networks, as shown in Figure 5-8.

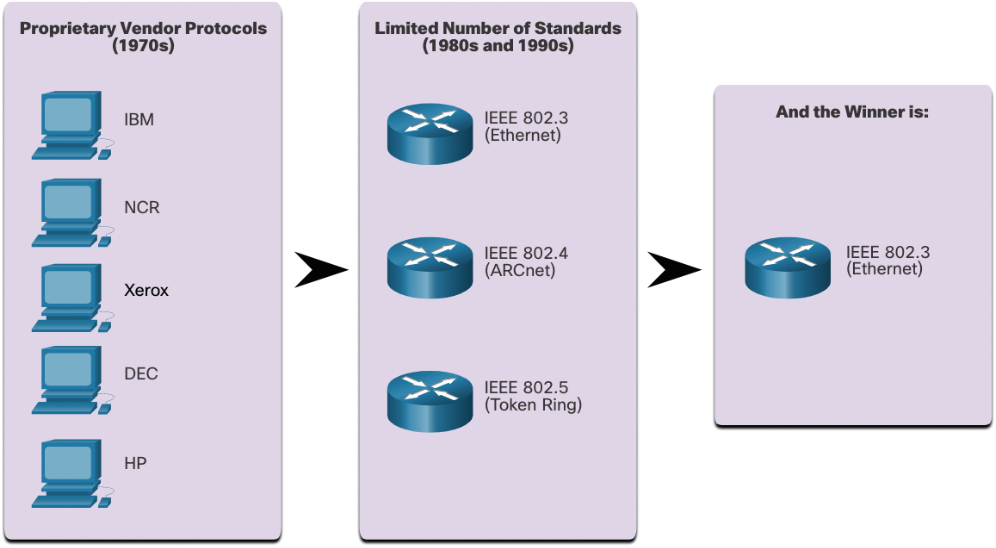


Figure 5-8 The Evolution from Proprietary LAN Protocols to Ethernet

Ethernet Evolution (5.4.2)

The ***Institute of Electrical and Electronic Engineers***, or ***IEEE*** (pronounced "eye-triple-e"), maintains the networking standards, including Ethernet and wireless standards. IEEE committees are responsible for approving and maintaining the standards for connections, media requirements, and communication protocols. Each technology standard is assigned a number that refers to the committee that is responsible for approving and maintaining the standard. The committee responsible for Ethernet standards is 802.3.

Since the creation of Ethernet in 1973, standards have evolved for specifying faster and more flexible versions of the technology. This ability for Ethernet to improve over time is one of the main reasons that it has become so popular. Each version of Ethernet has an associated standard. For example, 802.3 100BASE-T represents the 100 megabit Ethernet using twisted-pair cable standards. The standard notation translates as follows:

- *100* is the speed in Mbps.
- *BASE* stands for baseband transmission.
- *T* stands for the type of cable—in this case, twisted-pair.

Early versions of Ethernet were relatively slow at 10 Mbps. The latest versions of Ethernet operate at 10 gigabits per second and more. Imagine how much faster these new versions are than the original Ethernet networks.

Video

Video—Ethernet Addressing (5.4.3)

Refer to the online course to view this video.

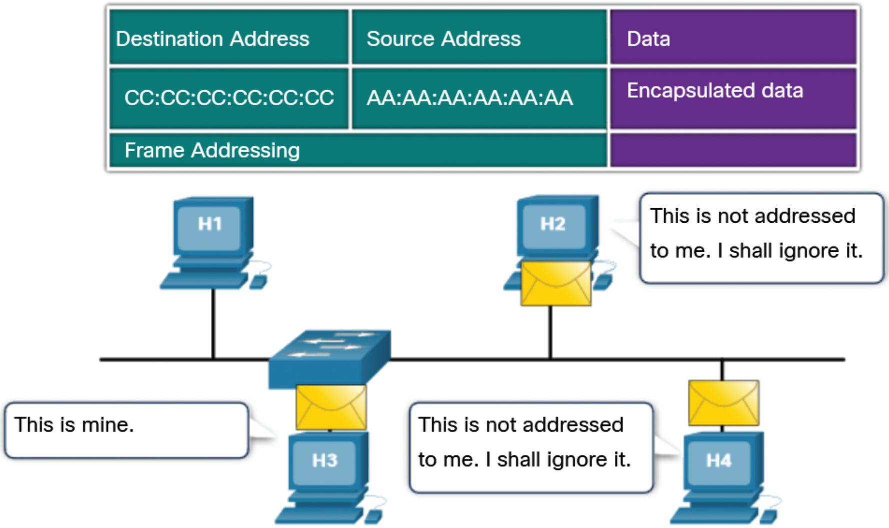
The Ethernet MAC Address (5.4.4)

All communication requires a way to identify the source and destination. The source and destination in human communication are represented by names.

When your name is called, you listen to the message and respond. Other people in the room may hear the message, but they ignore it because it is not addressed to them.

On Ethernet networks, a similar method exists for identifying source and destination hosts. Each host connected to an Ethernet network is assigned a physical address that serves to identify the host on the network.

Every Ethernet network interface has a physical address assigned to it when it is manufactured. This address is known as the Media Access Control (MAC) address. The MAC address identifies each source and destination host on the network, as shown in Figure 5-9.



Destination Address	Source Address	Data
CC:CC:CC:CC:CC:CC	AA:AA:AA:AA:AA:AA	Encapsulated data
Frame Addressing		

H1
H2
This is not addressed to me. I shall ignore it.
This is mine.
H3
This is not addressed to me. I shall ignore it.
H4

Figure 5-9 MAC Addresses Identify Unique Hosts on a LAN

Lab—Determine the MAC Address of a Host (5.4.5)

In this lab, you will complete the following objectives:

- Determine the MAC address of a Windows computer on an Ethernet network using the **ipconfig /all** command.
- Analyze a MAC address to determine the manufacturer.

Summary (5.5)

The following is a summary of each topic in the chapter:

- **The Rules**—All communication methods have three elements in common. The first is the message source, or sender. Message sources are people or electronic devices that need to communicate a message to other individuals or devices. The second is the destination, or receiver, of the message. The destination receives the message and interprets it. The third is the transmission medium, or channel. It provides the pathway over which the message can travel from source to destination.

  Among the protocols that govern successful human communication are an identified sender and receiver, an agreed-upon method of communicating, common language and grammar, speed and timing of delivery, and confirmation or acknowledgment requirements. Networking protocols define the message format, message size, timing, encoding, and message patterns over the local network.

- **Communication Standards**—Networking and Internet standards ensure that all devices connecting to the network implement the same set of rules or protocols in the same manner. Using standards, different types of devices are able to send information to each other over the Internet. These standards are developed, published, and maintained by a variety of organizations. When a new standard is proposed, each stage of the development and approval process is recorded in a numbered RFC document so that the evolution of the standard is tracked. RFCs for Internet standards are published and managed by the IETF.

- **Network Communication Models**—A stack illustrates the protocols as a layered hierarchy, with each higher-level protocol depending on the services of the protocols shown in the lower levels. The separation of functions enables each layer in the stack to operate independently of others.

  The layered model has many benefits:

  - Assists in protocol design, because protocols that operate at a specific layer have defined information that they act upon and a defined interface to the layers above and below
  - Fosters competition because products from different vendors can work together
  - Enables technology changes to occur at one level without affecting the other levels
  - Provides a common language to describe networking functions and capabilities

  The suite of TCP/IP protocols used for Internet communications follows the structure of the stack model. The two basic types of models to describe the functions that must occur for network communications to be successful are protocol models and reference models. The most widely known internetwork reference model is the OSI model. The OSI model breaks down network communications into multiple processes. Each process is a small part of the larger task.

The protocols that make up the TCP/IP protocol suite can be described in terms of the OSI reference model. The functions that occur at the Internet layer in the TCP/IP model are contained in the network layer of the OSI model. The transport layer functionality is the same between both models. However, the network access layer and the application layer of the TCP/IP model are further divided in the OSI model to describe discrete functions that must occur at these layers.

- **Ethernet**—There is no official LAN standard protocol, but over time, Ethernet has become more common than the others. Ethernet protocols define how data is formatted and how it is transmitted over the wired network. The Ethernet standards specify protocols that operate at Layer 1 and Layer 2 of the OSI model. Ethernet standards have evolved for specifying faster and more flexible versions of the technology. Each version of Ethernet has an associated standard. Each host connected to an Ethernet network is assigned a physical address that serves to identify the host on the network. Every Ethernet network interface has a physical address assigned to it when it is manufactured. This address is known as the MAC address. The MAC address identifies each source and destination host on the network.

Practice

The following labs provide practice with the topics introduced in this chapter.

Labs

Lab—My Protocol Rules (5.1.4)

Lab—Determine the MAC Address of a Host (5.4.5)

Check Your Understanding Questions

Complete all the review questions listed here to test your understanding of the topics and concepts in this chapter. Appendix A, “Answers to the ‘Check Your Understanding’ Questions,” lists the answers.

1. Which organization publishes and manages the Request for Comments (RFC) documents?

   a. TIA/EIA
   b. IETF
   c. ISO
   d. IEEE

2. What identifier is used at the data link layer to uniquely identify an Ethernet device?

   a. MAC address
   b. Sequence number
   c. IP address
   d. UDP port number
   e. TCP port number

3. Which layers of the OSI model are comparable in function to the application layer of the TCP/IP model? (Choose three.)

   a. Data link
   b. Transport
   c. Network
   d. Presentation
   e. Application
   f. Session
   g. Physical

4. Which term refers to a common set of rules that are developed to define rules by which network equipment from different vendors can interoperate?

   a. Domain
   b. Standard
   c. Model
   d. Protocol

5. Which standards organization publishes current Ethernet standards?

   a. ANSI
   b. CCITT
   c. IEEE
   d. EIA/TIA

6. Which statement describes a MAC address?
   a. It contains two portions: the network portion and a host portion.
   b. It is 128 bits in length.
   c. It identifies the source and destination addresses of hosts on the Internet.
   d. It is a physical address assigned to an Ethernet NIC by the manufacturer.

7. Which elements do all communication methods have in common? (Choose three.)
   a. Message priority
   b. Message source
   c. Transmission medium
   d. Message type
   e. Message data
   f. Message destination

8. Which layers of the OSI model specify protocols that are associated with Ethernet standards? (Choose two.)
   a. Physical layer
   b. Transport layer
   c. Session layer
   d. Data link layer
   e. Network layer

9. Which layer of the OSI model defines services to segment and reassemble data for individual communications between end devices?
   a. Network
   b. Presentation
   c. Transport
   d. Session
   e. Application

10. Which statement defines a data communications protocol?
    a. An alliance of network device manufacturers
    b. A set of product standards for types of network devices
    c. An exchange agreement of network devices among vendors
    d. A set of rules that govern the communication process

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