CHAPTER 2

# Communicating over the Network

## Objectives

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

- What is the structure of a network, including devices and media necessary for communications?
- What function do protocols perform in network communications?
- What are the advantages of using a layered model to describe network functionality?
- What is the role of each layer in the OSI network model and the TCP/IP network model?
- What is the importance of addressing and naming schemes in network communications?

## Key Terms

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

*channel page 40*

*segmentation page 41*

*multiplexing page 41*

*switch page 42*

*end device page 42*

*host page 42*

*client page 43*

*host address page 43*

*physical address page 43*

*intermediary device page 43*

*encoding page 45*

*local-area network (LAN) page 46*

*Internet service provider (ISP) page 47*

*protocols page 49*

*protocol suite page 50*

*Institute of Electrical and Electronics Engineers (IEEE) page 51*

*Internet Engineering Task Force (IETF) page 51*

*layered models page 52*

*TCP/IP page 53*

*encapsulation page 56*

*decapsulation page 56*

*protocol data unit (PDU) page 56*

*segment page 56*

*frame page 56*

*Open Systems Interconnection (OSI) page 58*

*International Organization for Standardization (ISO) page 58*

*port page 63*

More and more, networks connect us. People communicate online from everywhere. Efficient, dependable technology enables networks to be available whenever and wherever we need them. As the human network continues to expand, the platform that connects and supports it must also grow.

Rather than developing unique and separate systems for the delivery of each new service, the network industry as a whole has developed the means to both analyze the existing platform and enhance it incrementally. This ensures that existing communications are maintained while new services are introduced that are both cost effective and technologically sound.

This book focuses on these aspects of the information network:

- Devices that make up the network
- Media that connect the devices
- Messages that are carried across the network
- Rules and processes that govern network communications
- Tools and commands for constructing and maintaining networks

Central to the study of networks is the use of generally accepted models that describe network functions. These models provide a framework for understanding current networks and for facilitating the development of new technologies to support future communications needs.

Within this book, you learn about these models and the tools designed to analyze and simulate network functionality. Two of the tools that will enable you to build and interact with simulated networks are Packet Tracer 4.1 software and Wireshark network protocol analyzer.

In this chapter, you explore the fundamentals of communication and learn how they apply to communication in and between data networks. You also learn about two important models that describe the process of network communication and the devices used to achieve communication between network hosts.

## The Platform for Communications

Networks are becoming the foundation to human communication over distance. In the last decade or so, personal letters have become e-mails, typed and handwritten documents have become word processing files, photographs have become digital, and phone calls are moving from analog to digital. This transformation to a digital platform is possible because computer networks have grown in size, reliability, and diversity, enabling people to take advantage of the benefits of digital communication. The following sections focus on the platform for this digital communication that is built upon fundamental communication concepts. These concepts are applied to devices and media that enable the sending of data messages between end users.

## The Elements of Communication

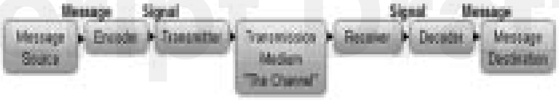
People exchange ideas using many different communication methods. All of these methods have three elements in common:

- **Message source, or sender:** Message sources are people, or electronic devices, that need to send a message to other individuals or devices.
- **Destination, or receiver of the message:** The destination receives the message and interprets it.
- ***Channel*:** A channel consists of the media that provides the pathway over which the message can travel from source to destination.

This model of sending a message through a channel to the receiver is also the basis of network communication between computers. The computers encode the message into binary signals and transport them across a cable or through wireless media to the receiver, which knows what rules to follow to understand the original message.

The basic model of communication between people and between computers is illustrated in Figure 2-1.

**Figure 2-1** Elements of Network Communication



In this book, the term *network* refers to data networks carrying messages containing text, voice, video, and other types of data.

## Communicating the Messages

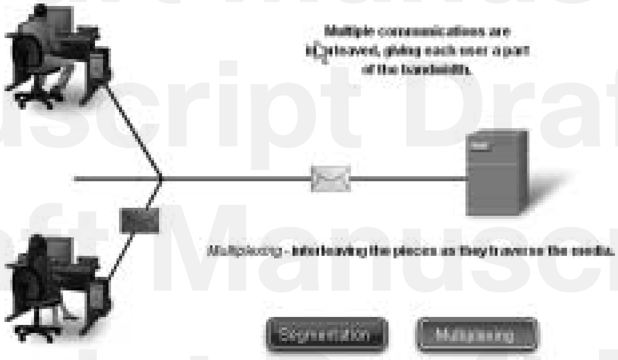
Computer networks carry messages large and small. Devices often exchange updates that are small and require very little bandwidth, yet are very important. Other messages, for example, high-quality photos, can be very large and consume a lot of network resources. Sending a large photograph in one continuous stream of data might mean that a device misses an important update or other communication that will need to be resent, using even more bandwidth.

The answer to this problem is a process called ***segmentation***, in which all messages are broken into smaller pieces that can be easily transported together across a medium. Segmenting messages has two primary benefits:

- Multiplexing
- Increased efficiency of network communications

***Multiplexing*** occurs when the segments of two or more messages can shuffle into each other and share the medium. Figure 2-2 depicts how messages can be broken into smaller pieces and multiplexed onto a single medium.

**Figure 2-2** Multiplexing Messages on a Network


Multiple communications are interleaved, giving each user a part of the bandwidth.
Multiplexing - interleaving the pieces as they traverse the media.
Segmentation
Multiplexing

A second benefit of segmentation is that networks can more efficiently send the message through different routes if necessary. This can happen because the Internet is always adjusting routes for efficiency. For example, consider what happens if someone in Las Vegas e-mails a picture of her new kitten to a friend in Boston. First, the picture of the kitten is segmented into small pieces and each piece is given, among other things, a destination address and a code telling where the piece belongs in the big picture. When the message is under way, the pieces might not travel along the same route. Traffic conditions on the Internet are constantly changing, and a large file with many segments can take a couple different routes. Depending on traffic conditions, the data containing the kitten's ears might go through Chicago on the way to Boston, the paws might go through Denver, and the whiskers and tail might travel through Atlanta. It doesn't matter which way the pieces travel as long as they all get to Boston and the destination computer can reassemble them into one photograph.

The downside to using segmentation and multiplexing to transmit messages across a network is the level of complexity that is added to the process. Imagine if you had to send a 100-page letter, but each envelope would only hold one page. The process of addressing, labeling, sending, receiving, and opening the entire hundred envelopes would be time consuming for both the sender and the recipient.

In network communications, each segment of the message must go through a similar process to ensure that it gets to the correct destination and can be reassembled into the content of the original message.

Various types of devices throughout the network participate in ensuring that the pieces of the message arrive reliably at their destination.

## Components of the Network

The path that a message takes from source to destination can be as simple as a single cable connecting one computer to another or as complex as a network that literally spans the globe. This network infrastructure is the platform that supports our human network. It provides the stable and reliable channel over which our communications can occur.

Devices and media are the physical elements or hardware of the network. Hardware is often the visible components of the network platform such as a laptop, a PC, a ***switch***, or the cabling used to connect the devices. Occasionally, some components might not be so visible. In the case of wireless media, messages are transmitted through the air using invisible radio frequency or infrared waves.

Services and processes are the communication programs, called software, that run on the networked devices. A network service provides information in response to a request. Services include many of the common network applications people use every day, like e-mail hosting services and web hosting services. Processes provide the functionality that directs and moves the messages through the network. Processes are less obvious to us but are critical to the operation of networks.

## End Devices and Their Role on the Network

An ***end device*** refers to a piece of equipment that is either the source or the destination of a message on a network. Network users usually only see and touch an end device, which is most often a computer. Another generic term for an end device that sends or receives messages is a ***host***. A host can be one of several pieces of equipment performing a wide variety of functions. Examples of hosts and end devices are:

- Computers, including workstations, laptops, and servers connected to a network
- Network printers
- Voice over Internet Protocol (VoIP) phones
- Cameras on a network, including webcams and security cameras
- Handheld devices such as PDAs and handheld scanners
- Remote monitoring stations for weather observation

An end user is a person or group using an end device. Not all end devices are operated by people all of the time, though. For example, file servers are end devices that are set up by people but perform their tasks on their own. Servers are hosts that are set up to store and share information with other hosts called ***clients***. Clients request information and services, like e-mail and web pages, from servers, and servers reply with the requested information if they recognize the client.

When hosts communicate with each other, they use addresses to find each other. The ***host address*** is a unique ***physical address*** used by hosts inside a local-area network (LAN), and when a host sends a message to another host, it uses the physical address of the destination device.

## Intermediary Devices and Their Role on the Network

End devices are the hosts that initiate communications and are the ones that people are most familiar with. But getting a message from the source to the destination can be a complex task involving several ***intermediary devices*** along the way. Intermediary devices connect the individual hosts to the network and can connect multiple individual networks to form an internetwork.

Intermediary devices are not all the same. Some work inside the LAN performing switching functions, and others help route messages between networks. Table 2-1 lists some intermediary devices and their functions.

**Table 2-1** Intermediary Devices

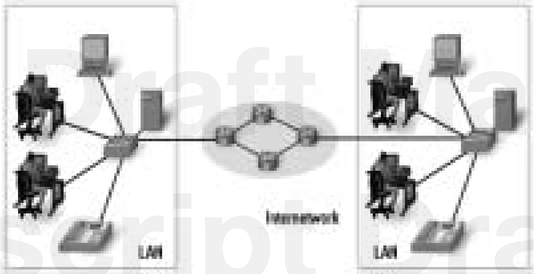
| Device Type | Description |
|---|---|
| Network access devices | Connect end users to their network. Examples are hubs, switches, and wireless access points. |
| Internetwork devices | Connect one network to one or more other networks. Routers are the main example. |
| Communication servers | Route services such as IPTV and wireless broadband. |
| Modems | Connect users to servers and networks through telephone or cable. |
| Security devices | Secure the network with devices such as firewalls that analyze traffic exiting and entering networks. |

The management of data as it flows through the network is also a role of the intermediary devices. These devices use the destination host address, in conjunction with information about the network interconnections, to determine the path that messages should take through the network. Processes running on the intermediary network devices perform these functions:

- Regenerate and retransmit data signals
- Maintain information about what pathways exist through the network and internetwork
- Notify other devices of errors and communication failures
- Direct data along alternate pathways when there is a link failure
- Classify and direct messages according to quality of service (QoS) priorities
- Permit or deny the flow of data, based on security settings

Figure 2-3 depicts two LANs with end devices connected by intermediary switches in the LANs and routers between the LANs.

**Figure 2-3** LANs Connected by Routers



## Network Media

Communication across a network is carried on a medium. The medium provides the channel over which the message travels from source to destination. The three main types of media in use in a network are:

- Copper
- Fiber-optic cable
- Wireless

Each of these media has vastly different physical properties and use different methods to encode messages. ***Encoding*** messages refers to the way data is converted to patterns of electrical, light, or electromagnetic energy and carried on the medium. Each medium is briefly described in Table 2-2.

**Table 2-2** Networking Media

| Media | Example | Encoding |
|---|---|---|
| Copper | Twisted-pair cable usually used as LAN media | Electrical pulses |
| Fiber-optic | Glass or plastic fibers in a vinyl coating usually used for long runs in a LAN and as a trunk | Light pulses |
| Wireless | Connects local users through the air | Electromagnetic waves |

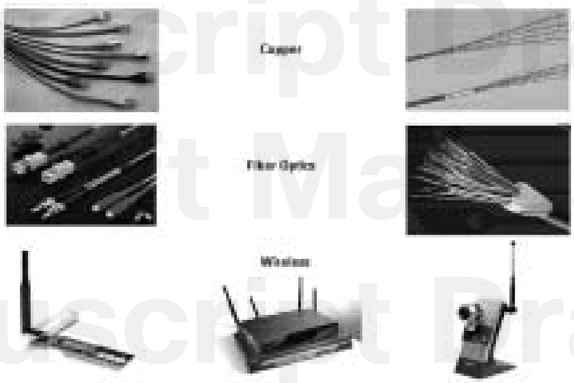
The differences in the media make each one ideal for different roles in networking situations. When choosing network media, administrators must consider the following:

- The distance the media can carry the signal
- The environment in which the media works

- The bandwidth requirements for users
- The cost of installation
- The cost of connectors and compatible equipment

Fiber, copper, and wireless media are shown in Figure 2-4.

**Figure 2-4** Network Media



## LANs, WANs, and Internetworks

Networks come in many sizes and serve a wide variety of functions. Some of the basic differences can be

- The size of the area covered
- The number of users connected
- The number and types of services available

Three distinct groups of networks accommodate different groups and extend geographic boundaries: local-area networks (LANs), wide-area networks (WANs), and internetworks.

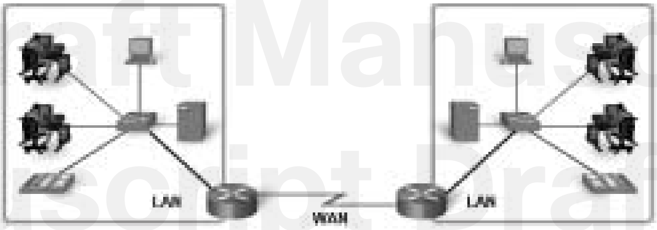
### Local-Area Networks

A ***local-area network (LAN)*** is a group of end devices and users under the control of a common administration. The term *local* first meant that the computers were grouped geographically close together and had the same purpose in an organization. This is still true in many situations, but as technologies evolve, the definition of local has evolved as well. A LAN can consist of one group of users on one floor, but the term can also be used to describe all users on a multibuilding campus.

## Wide-Area Networks

A wide-area network (WAN) is a network that is used to connect LANs that are located geographically far apart. If a company has offices in different cities, it will contract with a telecommunications service provider (TSP) to provide data lines between LANs in each city. The leased lines will vary in service and bandwidth, depending on the terms of the contract. The TSP is responsible for the intermediary devices on the WAN that transports messages, while LANs at both ends are controlled by the company. The sole purpose of WANs is to connect LANs, and there are usually no end users on WANs. Figure 2-5 depicts two LANs connected by a WAN.

**Figure 2-5** Network with a WAN Connection



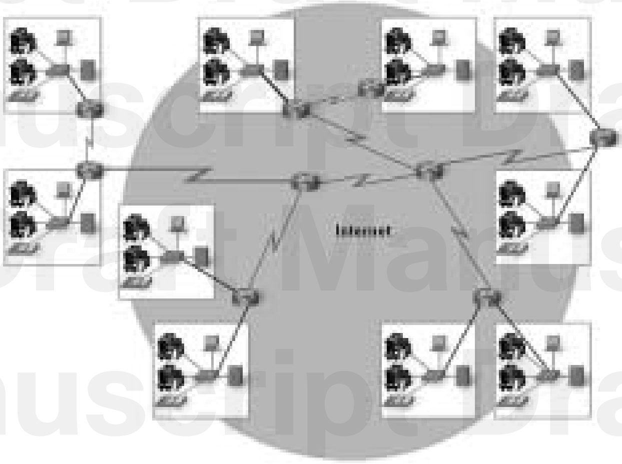
## The Internet: A Network of Networks

In years past, LANs changed the way people work, but they were limited to the resources within each network. Now workers who are not restricted to their own LAN can access other LANs on an internetwork. An internetwork is a collection of two or more LANs connected by WANs. Internetworks are referred to interchangeably as *data networks* or simply *networks*. The most popular internetwork is the Internet, which is open to public use.

With LANs able to communicate with other LANs using WANs, many organizations developed intranets. A term often confused with the Internet, an *intranet* is a private web of networks closed to the public but open for employees to browse. For example, many companies use intranets to share company information and training across the globe to far-away employees. Documents are shared and projects are managed securely over great distances on an intranet.

***Internet service providers (ISP)***, who are often also TSPs, connect their customers to the Internet. The customer can be a home user, a company, or government institution. All Internet users access the web through ISPs. The ISPs cooperate with TSPs and other ISPs to make sure that all users have access to the web. This involves implementing rules and standards that enable any user to communicate with any other user regardless of location and equipment type. Figure 2-6 demonstrates how many WANs connect to form the Internet. Note the difference in symbols representing LAN connections to routers and the WAN connections between routers.

**Figure 2-6** Internetworks Made Up of LANs and WANs

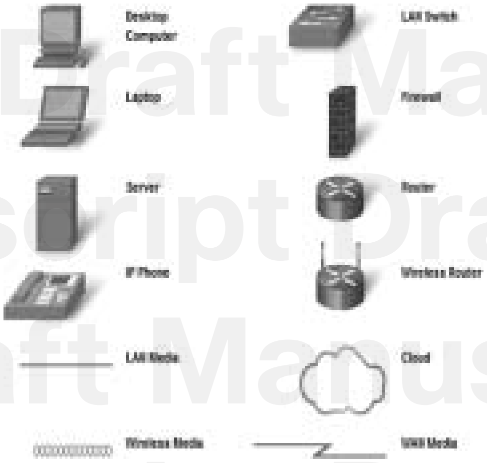


## Network Representations

Chapter 1, "Living in a Network-Centric World," introduced many common data network symbols pictured in Figure 2-7. When discussing how devices and media connect to each other, remember these important terms:

- **Network interface card (NIC):** A NIC, or LAN adapter, provides the physical connection to the network at the PC or other host device. The media connecting the PC to the networking device plugs directly into the NIC. Each NIC has a unique physical address that identifies it on the LAN.
- **Physical port:** A physical port is a connector or outlet on a networking device where the media is connected to a host or other networking device. You can assume that all network host devices used in this book have a physical port that allows a connection to the network.
- **Interface:** The term *interface* refers to how the device can allow two different networks to communicate. Routers connect to different networks, and the specialized NICs on routers are simply called interfaces. The interface on a router device has a unique physical address and appears as a host on the local network.

**Figure 2-7** Network Device and Media Symbols



Packet Tracer □ Activity

**Network Representations (2.2.4.2)**

In this activity, you will gain experience with data network symbols by creating a simple logical topology. Use file e1-2242.pka on the CD-ROM that accompanies this book to perform this activity using Packet Tracer.

# Protocols

All communication, whether face-to-face or over a network, is governed by predetermined rules called ***protocols***. These protocols are specific to the characteristics of the conversation. Network communication follows protocols similar to those used in human communication.

## Rules That Govern Communications

Protocols are rules used by anyone who communicates with another. During a conversation, people usually don't think about protocols until someone breaks one, but many levels of behavior are important for successful communication. For example, the clothing and informal language that is appropriate when you're with your close friends is not appropriate in a formal setting with a court official. Being improperly dressed for the communication situation could derail the message before any words are spoken. Also, people who interrupt conversations, speak too loudly, or walk away from conversations without the proper closing words like “thank you” or “good-bye” are considered rude, and the rude behavior can distract from the importance of the message. In addition, if a person tries to communicate in a language that the receiver does not understand, attempts at verbal communication will likely fail.

The protocols in human communication are separate rules about appearance, speaking, listening, and understanding. All of these rules, also called protocols of conversation, represent different layers of communication. They work together to help people successfully communicate.

You can use these examples to understand three different layers of a simple conversation. Consider two people communicating face to face. The bottom layer, the physical layer, has two people, each with a voice that can utter words aloud. The second layer, the rules layer, has an agreement to speak in a common language. The top layer, the content layer, has the words actually spoken, that is, the content of the communication.

Were you to witness this conversation, you would not see the layers. It is important to understand that the use of layers is a model and, as such, layers provide a way to conveniently break a complex task into parts and describe how they work.

The need for protocols also applies to network devices. Computers have no way of learning protocols, so network engineers have written rules for communication that must be strictly followed for successful host-to-host communication. These rules apply to different layers of sophistication such as physical connections, how hosts listen, how to interrupt, how to say good-bye, what language to use, and many others. These rules, or protocols, that work together to ensure successful communication are grouped into what is known as a ***protocol suite***.

## Network Protocols

For devices to communicate on a network, they must follow different protocols that perform the many tasks to be completed. The protocols define the following:

- The format of the message, such as how much data to put into each segment
- The way intermediary devices share information about the path to the destination
- The method to handle update messages between intermediary devices
- The process to initiate and terminate communications between hosts

The authors of the protocols might be writing them for a specific company that will own the protocol. The protocol is treated like a copyright and can be licensed to other companies to use. Protocols controlled by a company and not for public use are considered proprietary. Other protocols are written for public use at no charge, and are considered open source protocols.

## Protocol Suites and Industry Standards

In the early days of networking, each manufacturer had proprietary network equipment and protocols to support it. This worked well as long as the company that purchased the equipment did not need to share data outside its own network. As companies started to do business with other companies who were using different network systems, the need for a cross-platform standard for network communication became apparent.

People from the telecommunications industry gathered to standardize the way network communication works by writing common protocols. These standards are practices that are endorsed by representatives from industry groups and are followed to ensure interoperability between vendors. For example, Microsoft, Apple, and Linux operating systems each have a way to implement the TCP/IP protocol stack. This allows the users of different operating systems to have common access to network communication. The organizations that standardize networking protocols are the ***Institute of Electrical and Electronics Engineers (IEEE)*** and the ***Internet Engineering Task Force (IETF)***.

## Interaction of Protocols

An example of the use of a protocol suite in network communications is the interaction between a web server and a web browser. This interaction uses a number of protocols and standards in the process of exchanging information between them. The different protocols work together to ensure that the messages are received and understood by both parties. Examples of these protocols are:

- **Hypertext Transfer Protocol (HTTP):** HTTP is a common protocol that governs the way that a web server and a web client interact. HTTP defines the content and formatting of the requests and responses exchanged between the client and server. Both the client and the web server software implement HTTP as part of the application. The HTTP protocol relies on other protocols to govern how the messages are transported between client and server.
- **Transport protocol:** Transmission Control Protocol (TCP) is the transport protocol that manages the individual conversations between web servers and web clients. TCP divides the HTTP messages into smaller pieces, called segments, to be sent to the destination client. It is also responsible for controlling the size and rate at which messages are exchanged between the server and the client.

- **Internetwork protocol:** The most common internetwork protocol is Internet Protocol (IP). IP is responsible for taking the formatted segments from TCP, encapsulating them into packets, assigning the appropriate addresses, and selecting the best path to the destination host.
- **Network access protocols:** Network access protocols describe two primary functions: data-link management and the physical transmission of data on the media. Data-link management protocols take the packets from IP and format them to be transmitted over the media. The standards and protocols for the physical media govern how the signals are sent over the media and how they are interpreted by the receiving clients. Transceivers on the network interface cards implement the appropriate standards for the media that is being used.

### Technology-Independent Protocols

Protocols that guide the network communication process are not dependent on any specific technology to carry out the task. Protocols describe what must be done to communicate, not how the task is to be completed. For example, in a classroom, the protocol for asking a question might be to raise a hand for attention. The protocol instructs students to raise hands, but does not specify how high to raise it, nor specify whether the right hand or left hand is better or whether waving the hand is helpful. Each student can raise his or her hand in a slightly different way, but if the hand is raised, the teacher will likely give attention to the student.

So network communication protocols state what tasks must be completed, not how to complete them. This is what enables different types of devices, such as telephones and computers, to use the same network infrastructure to communicate. Each device has its own technology, but it is able to interact with different devices at the network level. In the previous example of Apple, Microsoft, and Linux, the operating systems must find a way to present data to others using TCP/IP, but each operating system will have its own way to do it.

## Using Layered Models

The IT industry uses ***layered models*** to describe the complex process of network communication. Protocols for specific functions in the process are grouped by purpose into well-defined layers.

## The Benefits of a Layered Model

By breaking the network communication process into manageable layers, the industry can benefit in the following ways:

- Defines common terms that describe the network functions to those working in the industry and allows greater understanding and cooperation.
- Segments the process to allow technologies performing one function to evolve independently of technologies performing other functions. For example, advancing technologies of wireless media is not dependent on advances in routers.
- Fosters competition because products from different vendors can work together.
- Provides a common language to describe networking functions and capabilities.
- 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.

As an IT student, you will benefit from the layered approach as you build your understanding of the network communication process.

## Protocol and Reference Models

Networking professionals use two networking models to communicate within the industry: protocol models and reference models. Both were created in the 1970s when network communication was in its infancy.

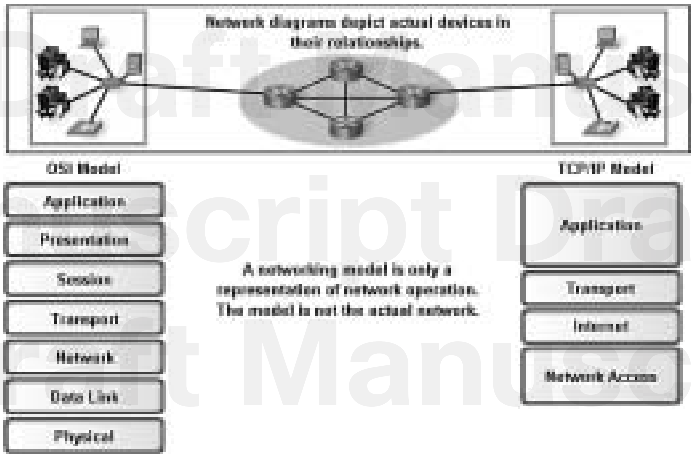
A protocol model provides a model that closely matches the structure of a particular protocol suite. The hierarchical set of related protocols in a suite typically represents all the functionality required to interface the human network with the data network. The ***TCP/IP*** model is a protocol model because it describes the functions that occur at each layer of protocols within the TCP/IP suite.

A reference model provides a common reference for maintaining consistency within all types of network protocols and services. A reference model is not intended to be an implementation specification or to provide a sufficient level of detail to define precisely the services of the network architecture. The primary purpose of a reference model is to aid in clearer understanding of the functions and process involved. The Open Systems Interconnection (OSI) model is the most widely known internetwork reference model.

The OSI model describes the entire communication process in detail, and the TCP/IP model describes the communication process in terms of the TCP/IP protocol suite and the way it functions. It is important to know details of the OSI model to understand the entire network communication process and to know the TCP/IP model to understand how the process is implemented in current networks.

The OSI model is used to reference the process of communication, not to regulate it. Many protocols in use today apply to more than one layer of the OSI model. This is why some of the layers of the OSI model are combined in the TCP/IP model. Some manufacturers use variations on these models to demonstrate the functions of their products within the industry. Figure 2-8 shows both OSI and TCP/IP models.

**Figure 2-8** OSI and TCP/IP Models


Network diagrams depict actual devices in their relationships.
OSI Model
Application
Presentation
Session
Transport
Network
Data Link
Physical
A networking model is only a representation of network operation. The model is not the actual network.
TCP/IP Model
Application
Transport
Internet
Network Access

## TCP/IP Model

The TCP/IP model defines the four communication functions that protocols perform. TCP/IP is an open standard, which means that one company does not control it. The rules and implementations of the TCP/IP model were cooperatively developed by members of the industry using Request for Comments (RFC) documents. RFC documents are publicly accessible documents that define specifications and policies of the protocols and of the Internet in general. Solicitation and maintenance of RFCs are the responsibility of the IETF. Table 2-3 briefly describes the functions of each layer of the TCP/IP model.

**Table 2-3** Layers of the TCP/IP Model

| Layer | Description |
|---|---|
| Application | Represents application data to the user. For example, the HTTP presents data to the user in a web browser application like Internet Explorer. |
| Transport | Supports communication between devices and performs error correction. |
| Internet | Finds the best path through the network. |
| Network access | Controls hardware devices and media. |

## Communication Process

The TCP/IP model describes the functionality of the protocols that make up the TCP/IP protocol suite. These protocols, which are implemented on both the sending and receiving hosts, interact to provide end-to-end delivery of applications over a network.

A complete communication process includes these steps:

1. Creation of data at the application layer of the originating source end device.
2. Segmentation and encapsulation of data as it passes down the protocol stack in the source end device.
3. Generation of the data onto the media at the network access layer of the stack.
4. Transportation of the data through the internetwork, which consists of media and any intermediary devices.
5. Reception of the data at the network access layer of the destination end device.
6. Decapsulation and reassembly of the data as it passes up the stack in the destination device. You learn more about the encapsulation and decapsulation processes in the next section.
7. Passing this data to the destination application at the application layer of the destination end device.

## Protocol Data Units and Encapsulation

For application data to travel uncorrupted from one host to another, header, or control data, which contains control and addressing information, is added to the data as it moves down the layers. The process of adding control information as it passes through the layered model is called ***encapsulation***. ***Decapsulation*** is the process of removing the extra information and sending only the original application data up to the destination application layer.

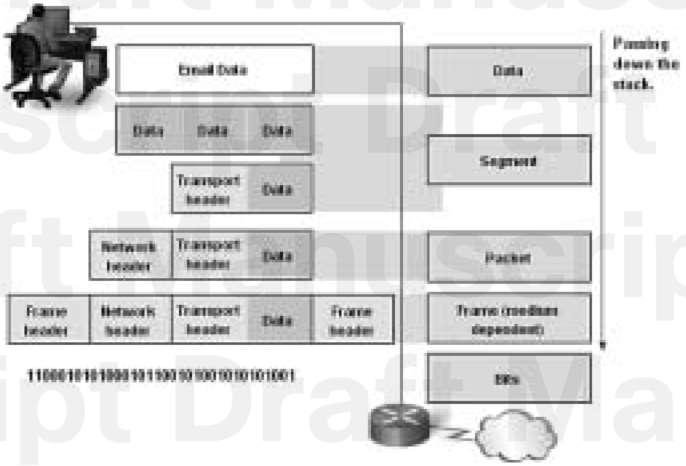
Each layer adds control information at each step. The generic term for data at each level is ***protocol data unit (PDU)***, but a PDU is different at each layer. For example, a PDU at the internetwork layer is different than the PDU at the transport layer, because internetwork layer data has been added to the transport layer data. The different names for PDUs at each layer are listed in Table 2-4.

**Table 2-4** Protocol Data Unit Naming Conventions

| PDU Name | Layer |
|---|---|
| Data | Application layer PDU |
| ***Segment*** | Transport layer PDU |
| Packet | Internetwork layer PDU |
| ***Frame*** | Network access layer PDU |
| Bits | PDU used for the physical transmission of binary data over media |

Figure 2-9 depicts the encapsulation process and shows how PDUs are modified.

**Figure 2-9** Encapsulation



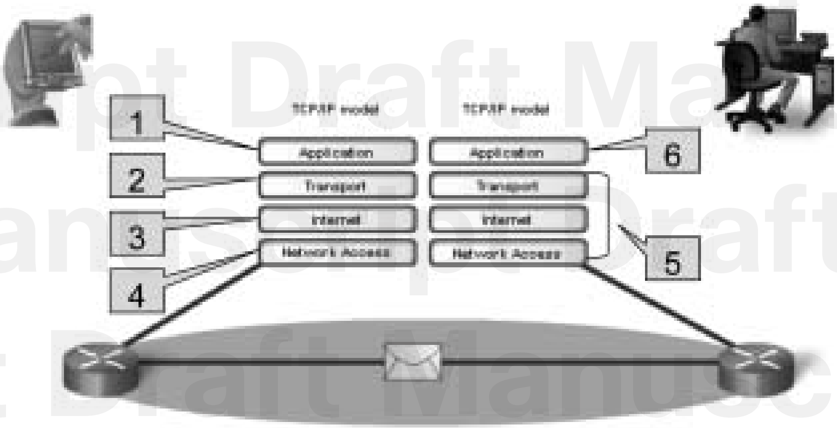
## Sending and Receiving Process

The common task of sending an e-mail has many steps in the process. Using the proper terms for PDUs and the TCP/IP model, the process of sending the e-mail is as follows:

1. An end user, using an e-mail application, creates data. The application layer codes the data as e-mail and sends the data to the transport layer.
2. The message is segmented, or broken into pieces, for transport. The transport layer adds control information in a header so that it can be assigned to the correct process and all segments put into proper order at the destination. The segment is sent down to the internetwork layer.
3. The internetwork layer adds IP addressing information in an IP header. The segment is now an addressed packet that can be handled by routers en route to the destination. The internetwork layer sends the packet down to the network access layer.
4. The network access layer creates an Ethernet frame with local network physical address information in the header. This will enable the packet to get to the local router and out to the web. The frame also contains a trailer with error-checking information. After the frame is created, it is encoded into bits and sent onto the media to the destination.
5. At the destination host, the process is reversed. The frame is decapsulated to a packet, then to a segment, and then the transport layer puts all segments into the proper order.
6. When all data has arrived and is ready, it is sent to the application layer, and then the original application data goes to the daughter's e-mail application. The message is successful.

Figure 2-10 depicts these steps as an encapsulated message travels down the TCP/IP model on the source and is en route to the destination for decapsulation.

**Figure 2-10** Steps in the Communication Process



## OSI Model

The ***Open Systems Interconnection (OSI)*** model, known as the OSI model, provides an abstract description of the network communication process. Developed by the ***International Organization for Standardization (ISO)*** to provide a road map for nonproprietary protocol development, the OSI model did not evolve as readily as the TCP/IP model. Many of the OSI protocols are no longer in use, but knowledge of the model as a reference is a basic expectation for networking professionals. Many professionals refer to the layers by number rather than name, so it is important to know both.

The OSI model is just a reference model, so manufacturers have been free to create protocols and products that combine functions of one or more layers. New protocols might not exactly match the functions described at each layer, but might fit into parts of two different layers.

As designed, the communication process begins at the application layer of the source, and data is passed down to each lower layer to be encapsulated with supporting data until it reaches the physical layer and is put out on the media. When the data arrives at the destination, the data is passed back up through layers and decapsulated by each layer. Each layer provides data services to the layer directly above by preparing information coming down the model or going up.

Table 2-5 briefly describes each layer of the OSI model. Each layer will be explored in its own chapter later in this book.

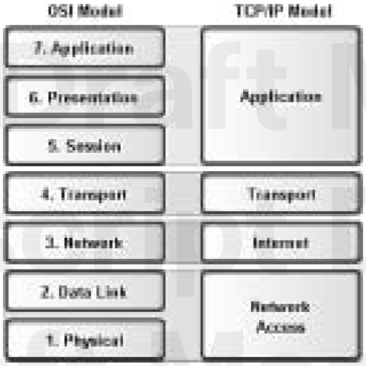
**Table 2-5** OSI Model

| No. | Layer Name | Description |
|---|---|---|
| 7 | Application | Performs services for the applications used by the end users. |
| 6 | Presentation | Provides data format information to the application. For example, the presentation layer tells the application layer whether there is encryption or whether it is a .jpg picture. |
| 5 | Session | Manages sessions between users. For example, the session layer will synchronize multiple web sessions and voice and video data in web conferences. |
| 4 | Transport | Defines data segments and numbers them at the source, transfers the data, and reassembles the data at the destination. |
| 3 | Network | Creates and addresses packets for end-to-end delivery through intermediary devices in other networks. |
| 2 | Data Link | Creates and addresses frames for host-to-host delivery on the local LANs and between WAN devices. |
| 1 | Physical | Transmits binary data over media between devices. Physical layer protocols define media specifications. |

## Comparing the OSI Model with the TCP/IP Model

The TCP/IP model evolved faster than the OSI model and is now more practical in describing network communication functions. The OSI model describes in detail functions that occur at the upper layers on the hosts, while networking is largely a function of the lower layers. Figure 2-11 shows the two models side by side for comparison.

**Figure 2-11** Comparing the OSI and TCP/IP Models



When juxtaposed, you can see that the functions of the application, presentation, and session layers of the OSI model are combined into one application layer in the TCP/IP model.

The bulk of networking functions reside at the transport and the network layers, so they remain individual layers. TCP operates at the transport layer, and IP operates at the Internet layer.

The data link and physical layers of the OSI model combine to make the network access layer of the TCP/IP model.

Packet Tracer
☐ Activity

**Use of the TCP/IP Protocols and the OSI Model in Packet Tracer (2.4.8.2)**

In this activity, you will see how Packet Tracer uses the OSI model as a reference to display the encapsulation details of a variety of the TCP/IP protocols. Use file e1-2482.pka on the CD-ROM that accompanies this book to perform this activity using Packet Tracer.

## Network Addressing

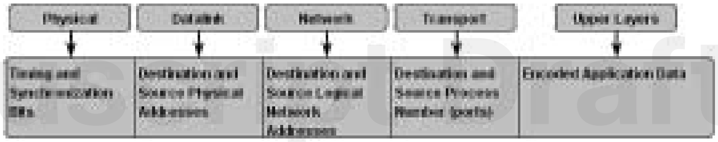
Successful communication requires that a sender and a receiver know how to get messages to each other. Postal systems use geography to deliver mail to physical addresses, but getting messages between computers is a more complicated matter. With the Internet, computers can communicate regardless of physical location.

Instead of using a geographical addressing scheme for computers, engineers devised a logical addressing scheme using numeric network addresses. The following sections introduce the addressing process. Chapter 6, “Addressing the Network: IPv4,” explores network addressing in greater detail.

## Addressing in the Network

There are millions of computers in use on the web and billions of messages traversing networks at any given time, so proper addressing is essential to make sure that the sent message arrives intact at the proper destination. Addressing of data happens in three different layers of the OSI model. The PDU at each layer adds address information for use by the peer layer at the destination. Figure 2-12 depicts the different addressing information added by each layer.

**Figure 2-12** Addressing Added at Each Layer


Physical
Data Link
Network
Transport
Upper Layers
Timing and Synchronization Bits
Destination and Source Physical Addresses
Destination and Source Logical Network Addresses
Destination and Source Process Number (ports)
Encoded Application Data

## Getting Data to the End Device

During the process of encapsulation, address identifiers are added to the data as it travels down the protocol stack on the source host. There are two layers of addressing added to ensure that data is delivered to the destination.

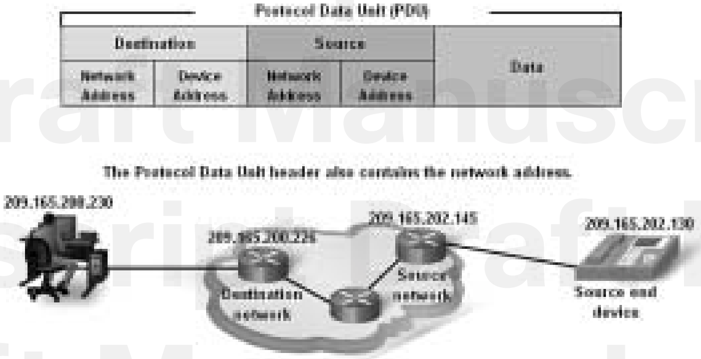
The first identifier, the host physical address, is contained in the header of the Layer 2 PDU, called a frame. Layer 2 is concerned with the delivery of messages on a single local network. The Layer 2 address is unique on the local network and represents the address of the end device on the physical media. The physical address comes from codes placed on the NIC by the manufacturer. In a LAN using Ethernet, this address is called the Media Access Control (MAC) address. The terms *physical address* and *MAC address* are often used interchangeably. When two end devices communicate on the local Ethernet network, the frames that are exchanged between them contain the destination and source MAC addresses. After a frame is successfully received by the destination host, the Layer 2 address information is removed as the data is decapsulated and moved up the protocol stack to Layer 3.

## Getting Data Through the Internetwork

Layer 3 protocols are primarily designed to move data from one local network to another local network within an internetwork. Whereas Layer 2 addresses are only used to communicate between devices on a single local network, Layer 3 addresses must include identifiers that enable intermediary network devices to locate hosts on different networks. In the TCP/IP protocol suite, every IP host address contains information about the network where the host is located.

At the boundary of each local network, an intermediary network device, usually a router, decapsulates the frame to read the destination host address contained in the header of the packet, the Layer 3 PDU. Routers use the network identifier portion of this address to determine which path to use to reach the destination host. When the path is determined, the router encapsulates the packet in a new frame and sends it on its way toward the destination end device. When the frame reaches its final destination, the frame and packet headers are removed and the data moved up to Layer 4. The journey from source to destination is depicted in Figure 2-13.

**Figure 2-13** IP Addressing



## Getting Data to the Right Application

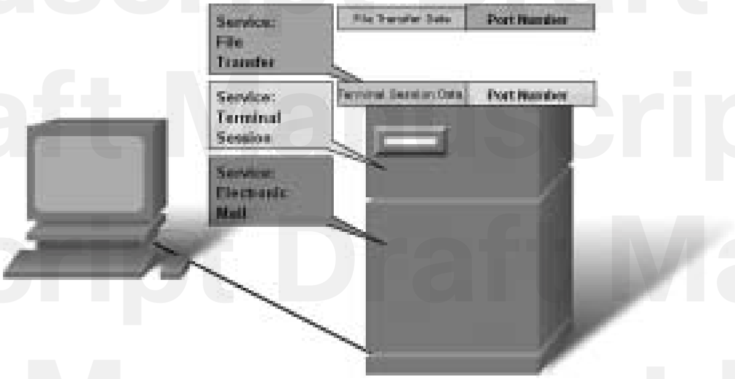
At Layer 4, information contained in the PDU header does not identify a destination host or a destination network. What it does identify is the specific process or service running on the destination host device that will act on the data being delivered. Hosts, whether they are clients or servers on the Internet, can run multiple network applications simultaneously. People using PCs often have an e-mail client running at the same time as a web browser, an instant messaging program, some streaming media, and perhaps even a game. All these separately running programs are examples of individual processes.

Viewing a web page invokes at least one network process. Clicking a hyperlink causes a web browser to communicate with a web server. At the same time, in the background, an e-mail client can be sending and receiving e-mail, and a colleague or friend can be sending an instant message.

Think about a computer that has only one network interface on it. All the data streams created by the applications that are running on the PC enter and leave through that one interface, yet instant messages do not pop up in the middle of a word processor document or e-mail showing up in a game.

This is because the transport layer adds ***port*** numbers to its segment header information to ensure that the destination host knows which application process is to receive the packet. The end host assigns a port number to each type of traffic going in and out. A user can send and receive many types of traffic over a single network interface, and using port numbers for each segment keeps traffic for web pages separate from e-mail traffic and so on. The segment contains both source and destination ports in case the receiver needs to contact the sender. Figure 2-14 shows different data types for two different services on an end device.

**Figure 2-14** Port Addressing



## Summary

Communication in data networks requires a source device and a destination device with a medium connecting the two. For messages to travel to other networks, intermediary devices such as routers are necessary.

The devices that handle messages and the media that carry them comply with communication rules called protocols. Many protocols can work together in a stack to complete the process of network communication.

Layered models describe the various steps that must occur for successful communication. The OSI and TCP/IP models are the most common models used in networking and can serve as a guide to the different protocols and devices used at each layer. Models are useful for students and companies in analyzing and troubleshooting networks as well as for future development of protocols.

Application data is sent down the protocol stacks and is encapsulated at each layer with addressing and control information. The data is segmented into pieces, addressed, and then encoded on the media. The process is reversed at the destination.

## Labs

The labs available in the companion *Network Fundamentals, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-203-6) provide hands-on practice with the following topics introduced in this chapter:

### Lab 2-1: Using NeoTrace to View Internetworks (2.2.5.1)

In this activity, you will observe the flow of information across the Internet. This activity should be performed on a computer that has Internet access and access to a command line. You will use the Windows embedded **tracert** utility and then the more enhanced NeoTrace program. This lab also assumes the installation of NeoTrace.

### Lab 2-2: Topology Orientation and Building a Small Network (2.6.1.1)

This lab begins by having you construct two small networks. It then shows how they are connected to the larger hands-on lab network used throughout the course. This network is a simplified model of a section of the Internet and will be used to develop your practical networking skills.

**Lab 2-3: Using Wireshark to View Protocol Data Units**

In this lab, you will begin learning the Wireshark tool by capturing ("sniffing") traffic off the model network.

Packet Tracer
□ Companion

Many of the hands-on labs include Packet Tracer companion activities, where you can use Packet Tracer to complete a simulation of the lab. Look for this icon in *Network Fundamentals, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-203-6) for hands-on labs that have Packet Tracer companion activities.

## Check Your Understanding

Complete all the review questions listed here to test your understanding of the topics and concepts in this chapter. The section "Check Your Understanding and Challenge Questions Answer Key" at the end of this chapter lists the answers.

1. Which OSI layer is associated with IP addressing?

   A. 1
   B. 2
   C. 3
   D. 4

2. The elements of communication include a message source, a message destination, and a ________________, or medium, to transport the message.

3. Which type of addressing is found at the OSI Layer 2? (Choose two.)

   A. Logical
   B. Physical
   C. MAC
   D. IP
   E. Port

4. When a server responds to a web request, what occurs next in the encapsulation process after the web page data is formatted and separated into TCP segments?

   A. The client decapsulates the segment and opens the web page.
   B. The client adds the appropriate physical address to the segments so that the server can forward the data.
   C. The server converts the data to bits for transport across the medium.
   D. The server adds the source and destination IP address to each segment header to deliver the packets to the destination.
   E. The server adds the source and destination physical addresses to the packet header.

This is a prepublication draft of the manuscript. The final book will publish in November and will be available for purchase at http://www.ciscopress.com/title/9781587132087.

5. Which term describes a specific set of rules that determines the formatting of messages and the process of encapsulation used to forward data?

   A. Segmentation
   B. Protocol
   C. Multiplexing
   D. QoS
   E. Reassembly

6. A limited-use protocol owned by a company is considered to be ____________________.

7. Which one of the following is associated with Layer 4 of the OSI model?

   A. IP
   B. TCP
   C. FTP
   D. TFTP

8. The device that connects a device to the media is called a/an _________________________.

9. Which of the following terms defines dividing data streams into smaller pieces suitable for transmission?

   A. Protocol
   B. Multiplexing
   C. Segmentation
   D. Encapsulation

10. A device that moves data between networks is a _______________.

11. Which of the following is the process for interweaving multiple data streams onto one shared communication channel or network medium?

   A. Multicasting
   B. Multiplexing
   C. Encapsulation
   D. Multidirecting

12. Which of the following is associated with the network layer?

A. IP address
B. Frames
C. MAC address
D. Physical addressing

13. Which of the following is the correct “top down” order of the OSI model?

A. Application, Presentation, Session, Network, Transport, Data Link, Physical
B. Application, Presentation, Session, Transport, Network, Data Link, Physical
C. Application, Session, Presentation, Transport, Network, Data Link, Physical
D. Application, Presentation, Session, Network, Data Link, Transport, Physical

14. Which layer of the OSI model is concerned with end-to-end message delivery over the network?

A. Network
B. Transport
C. Data Link
D. Application

## Challenge Questions and Activities

These questions require a deeper application of the concepts covered in this chapter. You can find the answers at the end of this appendix.

1. Which layers of the OSI model are combined into other layers of the TCP/IP model? (Choose all that apply.)

A. Network
B. Presentation
C. Internet
D. Data Link
E. Application
F. Physical
G. Session
H. Network access
I. Transport

2. Which of the following are true about LANs and WANs? (Choose two.)

   A. LANs connect groups of networks using ISPs.

   B. LANs consist of hosts communicating with logical addresses.

   C. WANs connect groups of networks using TSPs.

   D. WANs connect LANs.

   E. Hosts on a LAN use physical addressing to communicate.

Packet Tracer
□ **Challenge**

Look for this icon in *Network Fundamentals, CCNA Exploration Labs and Study Guide* (ISBN 1-58713-203-6) for instructions on how to perform the Packet Tracer Skills Integration Challenge for this chapter.

## To Learn More

The following questions encourage you to reflect on the topics discussed in this chapter. Your instructor might ask you to research the questions and discuss your findings in class.

1. How are the classifications LAN, WAN, and Internet still useful, and how might they be problematic in classifying networks?

2. What are strengths and weaknesses of the OSI and TCP/IP models? Why are both models still used?

3. Metaphors and analogies can be powerful aids to learning but must be used with care. Consider issues of devices, protocols, and addressing in the following systems:

   Standard postal service
   Express parcel delivery service
   Traditional (analog) telephone system
   Internet telephony
   Containerized shipping services
   Terrestrial and satellite radio systems
   Broadcast and cable television

4. Discuss what you see as common factors among these systems. Apply any similarities to other networks.

5. How could you apply these common concepts to developing new communications systems and networks?

# Check Your Understanding and Challenge Questions Answer Key

## Check Your Understanding

1. C. IP addressing is a concern of the OSI network layer (Layer 3). Physical addressing happens at OSI Layer 2.
2. channel
3. B, C. A MAC (Media Access Control) address is the physical address burned on to the OSI Layer 2 network interface card. Logical addressing happens at OSI Layer 3.
4. D. Encapsulating into TCP segments occurs at OSI Layer 4, so the next encapsulation is at OSI Layer 3, which includes adding source and destination IP addresses to the segment headers and converting them into packets. Then the physical addressing is added and the data is converted to bits.
5. B. A protocol describes a specific set of rules for communication, including message formatting and encapsulation.
6. proprietary
7. B. TCP has control features pertaining to OSI Layer 4, FTP is an application (Layer 7), and IP and TFTP are network layer protocols (Layer 3).
8. NIC, or network interface card
9. C. Segmentation, which occurs at OSI Layer 4, is the correct answer.
10. router
11. B. Multiplexing is the correct term.
12. A. IP addressing is an OSI Layer 3 function. All others are OSI Layer 2 functions.
13. B. The correct order is Application, Presentation, Session, Transport, Network, Data Link, Physical.
14. B. End-to-end message delivery is the concern of OSI Layer 4, the transport layer.

## Challenge Questions and Activities

1. B, D, F, G. The OSI presentation and session layers are combined into the application layer of the TCP/IP model. The OSI data link and physical layers are combined into the network access layer of TCP/IP. The transport and network layers have parallel layers in TCP/IP.

2. C, E. LANs are connected by WANs. WANs connect networks through telephone service providers (TSP). Logical addressing is used between networks, and physical addressing, or MAC addresses, are used inside LANs.