15.1 Networking

Computer network A collection of computing devices connected so that they can communicate and share resources

Wireless A network connection made without physical wires

Node (host) Any addressable device attached to a network

Data transfer rate (bandwidth) The speed with which data is moved from one place to another on a network

Protocol A set of rules that defines how data is formatted and processed on a network

Client/server model A distributed approach in which a client makes requests of a server and the server responds

File server A computer dedicated to storing and managing files for network users

A **computer network** is a collection of computing devices that are connected in various ways to communicate and share resources. Email, instant messaging, and Web pages all rely on communication that occurs across an underlying computer network. We use networks to share both intangible resources, such as files, and tangible resources, such as printers.

Usually, the connections between computers in a network are made using physical wires or cables. However, some connections are **wireless**, using radio waves or infrared signals to convey data. Networks are not defined only by physical connections; they are defined by the ability to communicate.

Computer networks contain devices other than computers. Printers, for instance, can be connected directly to a network so that anyone on the network can print to them. Networks also contain a variety of devices for handling network traffic. We use the generic term **node** or **host** to refer to any device on a network.

A key issue related to computer networks is the **data transfer rate**, the speed with which data is moved from one place on a network to another. We are constantly increasing our demand on networks as we rely on them to transfer more data in general, as well as data that is inherently more complex (and therefore larger). Multimedia components such as audio and video are large contributors to this increased traffic. Sometimes the data transfer rate is referred to as the **bandwidth** of a network. (Recall that we discussed bandwidth in Chapter 3 in the discussion of data compression.)

Another key issue in computer networks is the **protocols** they use. As we've mentioned at other points in this book, a protocol is a set of rules describing how two things interact. In networking, we use well-defined protocols to describe how transferred data is formatted and processed.

Computer networks have opened up an entire frontier in the world of computing called the **client/server model**. No longer do you have to think of computers solely in terms of the capabilities of the machine sitting in front of you. Instead, software systems are often distributed across a network, in which a client sends a request to a server for information or action, and the server responds, as shown in Figure 15.1.

For example, a **file server** is a computer that stores and manages files for multiple users on a network. That way every user doesn't need to have

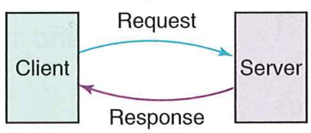

FIGURE 15.1 Client/server interaction

his or her own copy of the files. A web server is a computer dedicated to responding to requests (from the browser client) for Web pages. Client/server relationships have become more complex as we rely heavily on networks in our everyday lives. Therefore, the client/server model has become increasingly important in the world of computing.

The client/server model has also grown beyond the basic request/response approach. Increasingly, it is being used to support parallel processing, in which multiple computers are used to solve a problem by breaking it into pieces as discussed in Chapter 5. Using networks and the client/server model, parallel processing can be accomplished by the client requesting that multiple machines perform specific, separate parts of the same problem. The client then gathers their responses to form a complete solution to the problem.

Types of Networks

Computer networks can be classified in various ways. A local-area network (LAN) connects a relatively small number of machines in a relatively close geographical area. LANs are usually confined to a single room or building. They may sometimes span a few close buildings.

Various configurations, called topologies, have been used to administer LANs. A ring topology connects all nodes in a closed loop on which messages travel in one direction. The nodes of a ring network pass along messages until they reach their destination. A star topology centers on one node to which all others are connected and through which all messages are sent. A star network puts a huge burden on the central node; if it is not working, communication on the network is not possible. In a bus topology, all nodes are connected to a single communication line that carries messages in both directions. The nodes on the bus check any message sent on the bus, but ignore any that are not addressed to them. These topologies are pictured in Figure 15.2. A bus technology called Ethernet has become the industry standard for local-area networks.

A wide-area network (WAN) connects two or more local-area networks over a potentially large geographic distance. A WAN permits communication among smaller networks. Often one particular node on a LAN is set up to serve as a gateway to handle all communication going between that LAN and other networks. See Figure 15.3.

Communication between networks is called internetworking. The Internet, as we know it today, is essentially the ultimate wide-area network, spanning the entire globe. The Internet is a vast collection of smaller networks that have all agreed to communicate using the same protocols and to pass along messages so that they can reach their final destination.

Web server A computer dedicated to responding to requests for Web pages

Local-area network (LAN) A network connecting a small number of nodes in a close geographic area

Ring topology A LAN configuration in which all nodes are connected in a closed loop

Star topology A LAN configuration in which a central node controls all message traffic

Bus topology A LAN configuration in which all nodes share a common line

Ethernet The industry standard for local-area networks, based on a bus topology

Wide-area network (WAN) A network connecting two or more local-area networks

Gateway A node that handles communication between its LAN and other networks

Internet A wide-area network that spans the planet

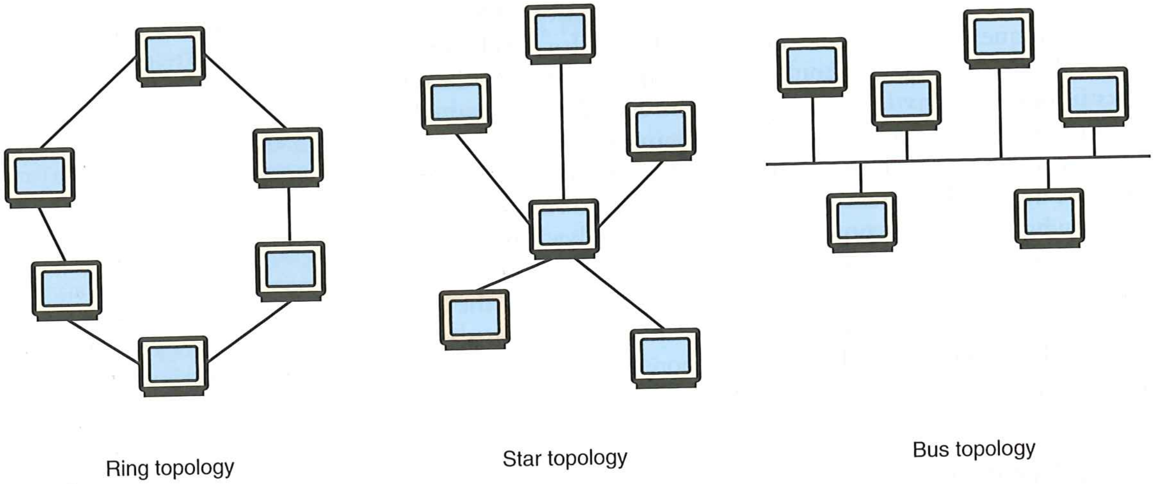

FIGURE 15.2 Network topologies

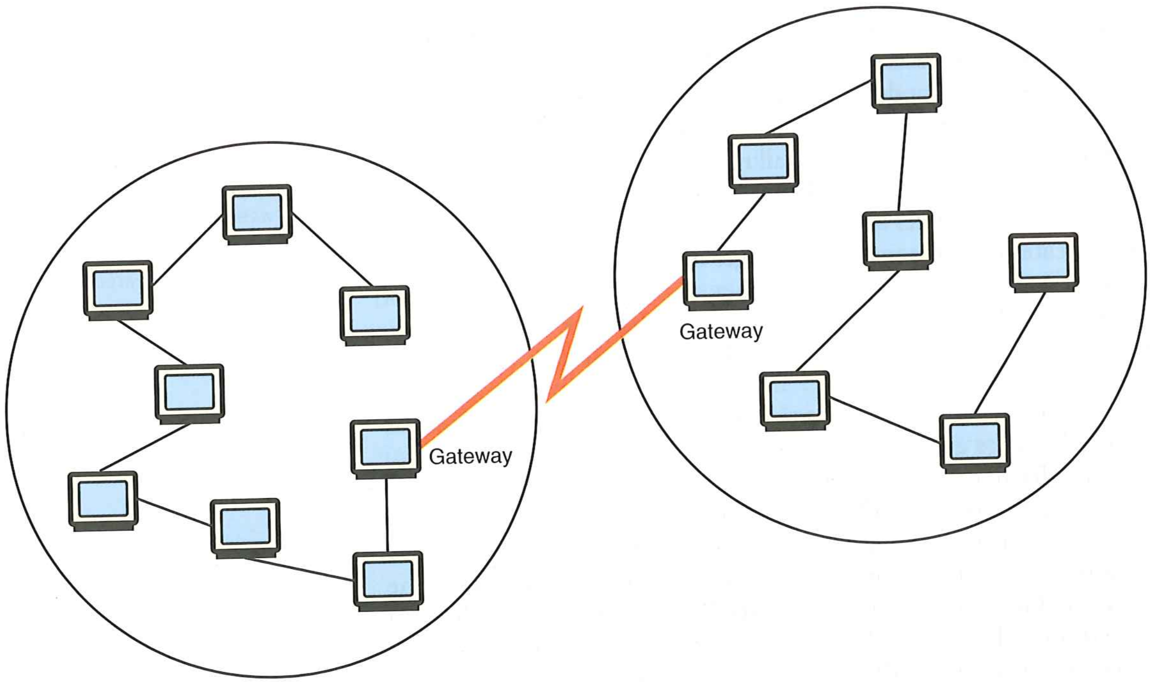

FIGURE 15.3 Local-area networks connected across a distance to create a wide-area network

The term metropolitan-area network (MAN) is sometimes used to refer to a large network that covers a campus or a city. Compared to a general wide-area network, a MAN is more narrowly focused on a particular organization or geographic area. A MAN that services a college or business campus typically interconnects the local-area networks used by various buildings and departments. Some cities have formed a MAN in their geographical area to service the general populace. Metropolitan-area networks are often implemented using wireless or optical fiber connections.

Metropolitan-area network (MAN) A network infrastructure developed for a large city

Internet backbone A set of high-speed networks carrying Internet traffic

Internet service provider (ISP) A company providing access to the Internet

Phone modem A device that converts computer data into an analog audio signal and back again

Internet Connections

So who owns the Internet? Well, no one. No single person or company owns the Internet or even controls it entirely. As a wide-area network, the Internet is made up of many smaller networks. These smaller networks are often owned and managed by a person or organization. The Internet, then, is defined by how connections can be made among these networks.

The Internet backbone refers to a set of high-capacity data routes that carry Internet traffic. These routes are provided by various companies such as AT&T, Verizon, and British Telecom, as well as by several government and academic sources. The backbone networks all operate using connections that have high data transfer rates, ranging from 1.5 megabits per second to more than 600 megabits per second (using special optical cables). Keep in mind, though, that Internet routes, including the backbone networks, employ a large amount of redundancy, so there is really no central network.

An Internet service provider (ISP) is a company that provides other companies or individuals with access to the Internet. ISPs connect directly to the Internet backbone, or they connect to a larger ISP with a connection to the backbone. America Online® and Prodigy® are examples of Internet service providers.

You can use any of several technologies to connect a home computer to the Internet. The three most popular techniques for home connections are a phone modem, a digital subscriber line, or a cable modem. Let's examine each in turn.

The telephone system had already connected homes throughout the world long before the desire for Internet connections came along. Therefore, it makes sense that the first technique for home-based network communication was a phone modem. The word *modem* stands for modulator/demodulator. A phone modem converts computer data into an analog audio signal for transfer over a telephone line, and then a modem at the destination converts it back into data again. One audio frequency is used to represent binary 0 and another to represent binary 1.

?

SETI at Home

SETI@Home (SETI at home) is a distributed computing experiment that uses Internet-connected computers in the Search for Extraterrestrial Intelligence (SETI). It is hosted by the Space Sciences Laboratory at the University of California, Berkeley. SETI@home uses spare computing capacity on users' computers to analyze data collected by the Arecibo radio telescope, which is searching for possible evidence of radio transmissions from extraterrestrial intelligence. The project has millions of participants worldwide, and it is acknowledged by the *Guinness Book of Records* as the largest computation in history. BOINC (Berkeley Open Infrastructure for Network Computing) is a middleware system for volunteer and grid computing originally developed to support SETI@home. BOINC lets users donate their idle computer time to projects such as SETI@home. It is now being used for other applications as well, such as mathematics, medicine, molecular biology, climatology, and astrophysics. BOINC has 565,000 active computers worldwide.

To use a phone modem, you must first establish a telephone connection between your home computer and a computer that is permanently connected to the Internet. That's where your Internet service provider comes in. You pay your ISP a monthly fee for the right to call one of several (preferably local) computers that it has set up for this purpose. Once that connection is made, you can transfer data via your phone lines to your ISP, which then sends it on its way through the Internet backbone. Incoming traffic is routed through your ISP to your home computer.

This approach was fairly simple to implement because it does not require any special effort on the part of the telephone company. Because the data is treated as if it were a voice conversation, no special translation is needed except at either end. But that convenience comes at a price. The data transfer rate available with this approach is limited to that of analog voice communication, usually 64 kilobits per second at most.

A phone line can provide a much higher transfer rate if the data is treated as digital rather than analog. A **digital subscriber line (DSL)** uses regular copper phone lines to transfer digital data to and from the phone company's central office. Because DSL and voice communication use different frequencies, it is even possible to use the same phone line for both purposes.

> **Digital subscriber line (DSL)** An Internet connection made using a digital signal on regular phone lines
>
> **Cable modem** A device that allows computer network communication using the cable TV hookup in a home
>
> **Broadband** Network technologies that generally provide data transfer speeds greater than 128K bps
>
> **Download** Receiving data on your home computer from the Internet

To set up a DSL connection, your phone company may become your Internet service provider, or it may sell the use of its lines to a third-party ISP. To offer DSL service, the phone company must set up special computers to handle the data traffic. Although not all phone companies support DSL yet, it is becoming an increasingly popular approach.

With DSL, there is no need to "dial in" to create the network connection, unlike with a phone modem. The DSL line maintains an active connection between your home and a computer at the ISP. However, to take advantage of DSL technology, your home must be within a certain distance from the central office; otherwise, the digital signal degrades too much while traveling between those two points.

A third option for home connections is a **cable modem**. In this approach, data is transferred on the same line that your cable TV signals come in on. Several leading cable TV companies in North America have pooled their resources to create Internet service providers for cable modem service.

Both DSL connections and cable modems fall into the category of **broadband** connections. Depending on the location and whether access is by satellite, phone wire, video cable, or fiber optics, it is possible to obtain broadband transfer speeds that range from 384 kilobits per second to 50 megabits per second or more. Increasingly more households are moving away from the use of phone modems to a broadband solution for their computing network needs. Debate between the DSL and cable modem communities continues to rage to see who can claim the dominant market share. Both generally provide data transfer speeds in the range of 1.5 to 3 megabits per second.

For both DSL and cable modems, the speed for **downloads** (getting data from the Internet to your home computer) may not be the same as the speed

Upload Sending data from your home computer to a destination on the Internet

Packet A unit of data sent across a network

Packet switching The approach to network communication in which packets are individually routed to their destination, then reassembled

Router A network device that directs a packet between networks toward its final destination

Repeater A network device that strengthens and propagates a signal along a long communication line

for uploads (sending data from your home computer to the Internet). Most traffic for home Internet users consists of downloads: receiving Web pages to view and retrieving data (such as programs and audio and video clips) stored somewhere else on the network. You perform an upload when you send an email message, submit a Web-based form, or request a new Web page. Because download traffic dominates upload traffic, many DSL and cable modem suppliers use technology that devotes more speed to downloads.

Packet Switching

To improve the efficiency of transferring data over a shared communication line, messages are divided into fixed-size, numbered packets. These packets are sent over the network individually to their destination, where they are collected and reassembled into the original message. This approach is referred to as packet switching.

The packets of a message may take different routes on their way to the final destination. Therefore, they may arrive in a different order than the way they were sent. The packets must be put into the proper order once again, and then combined to form the original message. Figure 15.4 illustrates this process.

A packet may make several intermediate hops between computers on various networks before it reaches its final destination. Network devices called routers direct the packets as they move between networks. Intermediate routers don't plan out the packet's entire course; each router merely knows the best next step to get it closer to its destination. Eventually a message reaches a router that knows where the destination machine is. If a path is blocked due to a down machine, or if a path currently has a lot of network traffic, a router might send a packet along an alternative route.

If a communication line spans a long distance, such as across an ocean, devices called repeaters are installed periodically along the line to strengthen and propagate the signal. Recall from Chapter 3 that a digital signal loses information only if it is allowed to degrade too much. A repeater keeps that from happening.

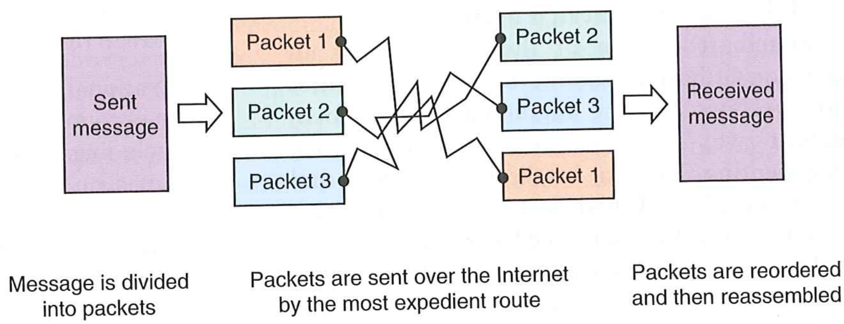

FIGURE 15.4 Messages sent by packet switching