Technology Guide

4

Telecommunications

T4.1 Telecommunications Concepts

The term **telecommunications** generally refers to all types of long-distance communication that use common carriers, including telephone, television, and radio. **Data communications** is a subset of telecommunications and is achieved through the use of telecommunication technologies.

In modern organizations, communications technologies are integrated. Businesses are finding electronic communications essential for minimizing time and distance limitations. Telecommunications plays a special role when customers, suppliers, vendors, and regulators are part of a multinational organization in a world that is continuously awake and doing business somewhere 24 hours a day, 7 days a week ("24/7"). Figure T4.1 represents a model of an integrated computer and telecommunications system common in today's business environment.

TELECOMMUNICATIONS SYSTEM

A **telecommunications system** is a collection of compatible hardware and software arranged to communicate information from one location to another. These systems can transmit text, data, graphics, voice, documents, or video information.

A typical telecommunications system is shown in Figure T4.2. Such systems have two sides: the transmitter and the receiver.

The major components are:

1. **Hardware**—all types of computers and communications processors (such as a modems or small computers dedicated solely to communications).
2. **Communications media**—the physical media through which **electronic signals** are transferred; includes both wireline and wireless media.
3. **Communications networks**—the linkages among computers and communications devices.
4. **Communications processors**—devices that perform specialized data communication functions; includes front-end processors, controllers, multiplexors, and modems.
5. **Communications software**—software that controls the telecommunications system and the entire transmission process.
6. **Data communications providers**—regulated utilities or private firms that provide data communications services.
7. **Communications protocols**—the rules for transferring information across the system.
8. **Communications applications**—electronic data interchange (EDI), teleconferencing, videoconferencing, e-mail, facsimile, electronic funds transfer, and others.

To transmit and receive information, a telecommunications system must perform the following separate functions that are transparent to the user:

- Transmit information.
- Establish the interface between the sender and the receiver.

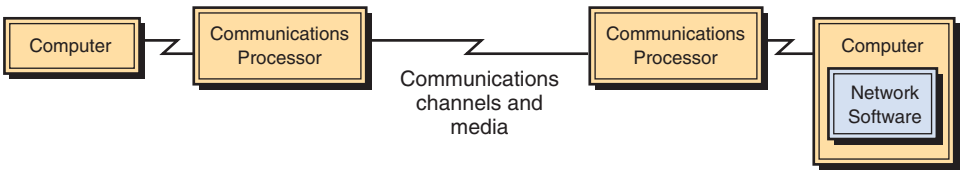

Figure T4.1 An integrated computer and telecommunications system.

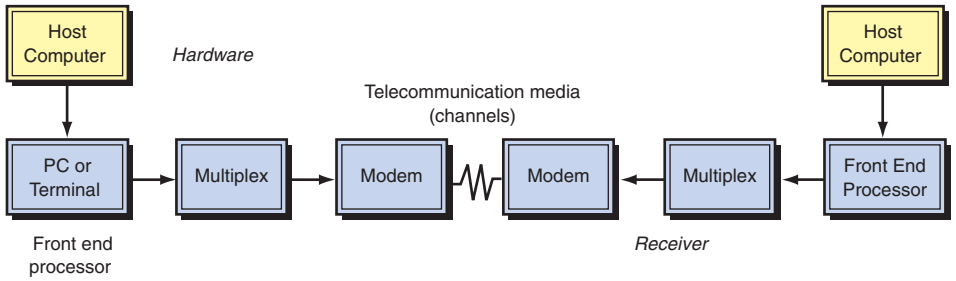

Figure T4.2 A telecommunications system.

- Route messages along the most efficient paths.
- Process the information to ensure that the right message gets to the right receiver.
- Check the message for errors and rearrange the format if necessary.
- Convert messages from one speed to that of another communications line or from one format to another.
- Control the flow of information by routing messages, polling receivers, and maintaining information about the network.
- Secure the information at all times.

ELECTRONIC SIGNALS

Telecommunications media can carry two basic types of signals, *analog and digital* (see Figure T4.3). **Analog signals** are continuous waves that "carry" information by altering the *amplitude and frequency* of the waves. For example, sound is analog and travels to our ears in the form of waves—the greater the height (amplitude) of the waves, the louder the sound; the more closely packed the waves (higher frequency), the higher the pitch. Radio, telephones, and recording equipment historically transmitted and received analog signals, but they are rapidly changing to digital signals.

Digital signals are discrete on-off pulses that convey information in terms of 1's and 0's, just like the central processing unit in computers. Digital signals have several advantages over analog signals. First, digital signals tend to be less affected by interference or "noise." Noise (e.g., "static") can seriously alter the information-carrying characteristics of analog signals, whereas it is generally easier, in spite of noise, to distinguish between an "on" and an "off." Consequently, digital signals can be repeatedly strengthened over long distances, minimizing the effect of any noise. Second, because computer-based systems process digitally, digital communications among computers require no conversion from digital to analog to digital.

COMMUNICATIONS PROCESSORS

Communications processors are hardware devices that support data transmission and reception across a telecommunications system. These devices include modems, multiplexers, front-end processors, and concentrators.

Modem. A modem is a communications device that converts a computer's digital signals to analog signals before they are transmitted over standard telephone lines. The public telephone system (called POTS for "Plain Old Telephone Service") was

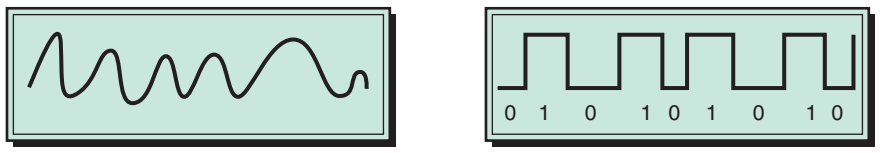

Figure T4.3 Analog vs. digital signals.

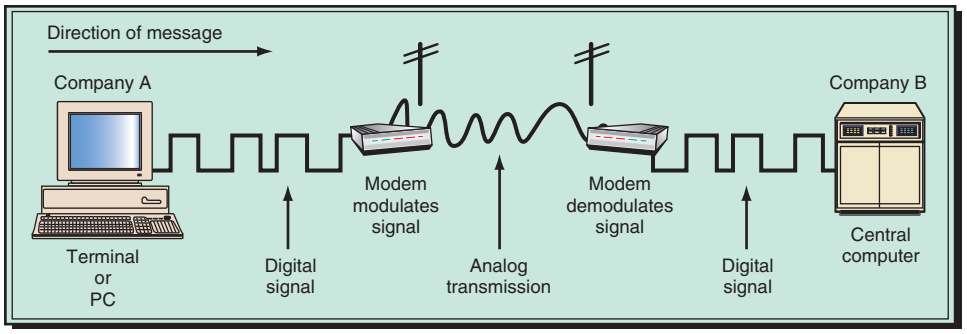

Figure T4.4 A modem converts digital to analog signals and vice versa. (*Source: Computing in the Information Age,* Stern and Stern, © 1993 John Wiley & Sons, Inc.)

designed as an analog network to carry voice signals or sounds in an analog wave format. In order for this type of circuit to carry digital information, that information must be converted into an analog wave pattern. The conversion from digital to analog is called **modulation,** and the reverse is **demodulation.** The device that performs these two processes is called a **modem,** a contraction of the terms *modulate/demodulate* (see Figure T4.4). Modems are always used in pairs.

Alternatives to Analog Modems. **Digital subscriber line (DSL)** service allows the installed base of twisted-pair wiring in the telecommunications system (see Section T4.2) to be used for high-volume data transmission. DSL uses digital transmission techniques over copper wires to connect the subscribers to network equipment located at the telephone company central office. *Asymmetric DSL* (ADSL) is a variety of DSL that enables a person connecting from home to upload data at speeds from 16 to 640 Kbps and download data at 1.5 to 8 Mbps. Clearly, this is many times faster than an analog modem.

A DSL circuit connects a DSL modem on each end of a twisted-pair telephone line, creating three information channels—a high-speed downstream channel; a medium-speed duplex channel, depending on the implementation of the DSL architecture; and a POTS (Plain Old Telephone Service) or an ISDN channel. The POTS/ISDN channel is split off from the digital modem by filters, thus guaranteeing uninterrupted POTS/ISDN, even if DSL fails.

Cable modems are offered by cable television companies in many areas as a high-speed way to access a telecommunications network. These modems operate on one channel of the TV coaxial cable. Cost and transmission speed are comparable to that of a DSL. A cable modem gives users high-speed Internet access through a cable TV network at more than 1 Mbps (1 million bits per second), or about 20 times faster than a traditional dial-up modem. When a cable modem unit is installed next to the computer, a splitter is placed on the side of the household. It separates the coaxial cable line serving the cable modem from the line that serves the TV sets. A separate coaxial cable line is then run from the splitter to the cable modem. Cable modems typically connect to computers through a standard 10Base-T Ethernet interface. Data are transmitted between the cable modem and computer at 10 Mbps. For details, see *cable-modem.net/tt/primer.html.*

T4.2 Communications Media (Channels)

For data to be communicated from one location to another, a physical pathway or medium must be used. These pathways are called **communications media (channels)** and can be either physical or wireless. The physical transmission use wire, cable, and

other tangible materials; wireless transmission media send communications signals through the air or space. The physical transmission media are generally referred to as **cable media** (e.g., twisted pair wire, coaxial cable, and fiber optic cable). **Wireless media** include cellular radio, microwave transmission, satellite transmission, radio and infrared media.

CABLE MEDIA

Cable media (also called *wireline media*) use physical wires or cables to transmit data and information. Twisted-pair wire and coaxial cable are made of copper, and fiber-optic cable is made of glass. However, with the exception of fiber-optic cables, cables present several problems, notably the expense of installation and change, as well as a fairly limited capacity.

Several cable media exist, and in many systems a mix of media (e.g., fibercoax) can be found. The major cable media are as follows (see Table 4.1).

Twisted-Pair Wire.

Twisted-pair wire is the most prevalent form of communications wiring, because it is used for almost all business telephone wiring. Twisted-pair wire consists of strands of insulated copper wire twisted in pairs to reduce the effect of electrical noise.

Twisted-pair wire is relatively inexpensive, widely available, easy to work with, and can be made relatively unobtrusive by running it inside walls, floors, and ceilings. However, twisted-pair wire has some important disadvantages. It emits electromagnetic

TABLE T4.1 Advantages and Disadvantages of Communications Channels

Channel	Advantages	Disadvantages
Twisted-pair	Inexpensive Widely available Easy to work with Unobtrusive	Slow (low bandwidth) Subject to interference Easily tapped (low security)
Coaxial cable	Higher bandwidth than twisted pair Less susceptible to electromagnetic interference	Relatively expensive and inflexible Easily tapped (low-to-medium security) Somewhat difficult to work with
Fiber-optic cable	Very high bandwidth Relatively inexpensive Difficult to tap (good security)	Difficult to work with (difficult to splice)
Microwave	High bandwidth Relatively inexpensive	Must have unobstructed line of sight Susceptible to environmental interference
Satellite	High bandwidth Large coverage area	Expensive Must have unobstructed line of sight Signals experience propagation delay Must use encryption for security
Radio	High bandwidth No wires needed Signals pass through walls Inexpensive and easy to install	Create electrical interference problems Susceptible to snooping unless encrypted
Cellular Radio	Low-to-medium bandwidth Signals pass through walls	Require construction of towers Susceptible to snooping unless encrypted
Infrared	Low-to-medium bandwidth	Must have unobstructed line of sight Used only for short distances

interference, is relatively slow for transmitting data, is subject to interference from other electrical sources, and can be easily "tapped" to gain unauthorized access to data.

Coaxial Cable. **Coaxial cable** consists of insulated copper wire surrounded by a solid or braided metallic shield and wrapped in a plastic cover. It is much less susceptible to electrical interference and can carry much more data than twisted-pair wire. For these reasons, it is commonly used to carry high-speed data traffic as well as television signals (i.e., in cable television). However, coaxial cable is 10 to 20 times more expensive, more difficult to work with, and relatively inflexible. Because of its inflexibility, it can increase the cost of installation or recabling when equipment must be moved.

Data transmission over coaxial cable is divided into two basic types:

- **Baseband.** Transmission is analog, and each wire carries only one signal at a time.
- **Broadband.** Transmission is digital, and each wire can carry multiple signals simultaneously.

Because broadband media can transmit multiple signals simultaneously, it is faster and better for high-volume use. Therefore, it is the most popular Internet-access method.

Broadband needs a **network interface card (NIC),** also called a LAN adapter, in order to run. An NIC is a card that is inserted into an expansion slot of computer or other device, enabling the device top connect to a network.

Fiber Optics. Fiber-optic cables (FOCs) are steadily replacing copper wire as a means of communications signal transmission. For example, Time Warner Telecom had 20,928 fiber route miles at the end of the first quarter of 2006, or capacity for its business customers to send 5,100 four-minute audio or video files at the same moment.

FOCs are used over long distances to connect local phone systems; and they provide the backbone for many network systems. Other FOC users are office buildings, industrial plants, cable TV services, university campuses, and electric utilities. Fiber is the ultimate medium for broadband (short for *broad bandwidth*). Bandwidth refers to the size of existing fiber-optic lines and their ability to carry all the data traffic companies want to send.

The fiber-optic system is similar to the copper wire system that it continues to replace. The key difference is that fiber optics use light pulses (light waves) to transmit information down fiber lines instead of using electronic pulses to transmit information down copper lines. The advantages of FOC over copper wire are:

1. **Speed:** FOC networks operate at higher speeds, in the gigabits (Gbit). Industry forecasts indicate the 8-Gbit-per-second (Gbit/sec) fiber-optic channels will be widespread by 2011.
2. **Bandwidth:** Larger carrying capacity. Using wavelength division multiplexing (WDM), the bandwidth carried by a single fiber is in the range of terabits per second. In comparison, the bandwidth for WiMax is in the one- megabit to two-megabit range.
3. **Distance:** Signals can be transmitted farther distances without needing to be strengthened (regenerated).
4. **Maintenance:** FOC costs much less to maintain.
5. **Resistance:** Greater resistance to electromagnetic noise such as radios, motors, or other nearby cables.

Telecommunication applications of fiber optics range from global networks to desktop computers. These involve the transmission of voice, data, or video over distances of less than a meter to hundreds of kilometers.

Telecommunications carriers use optical fiber to carry plain old telephone service (POTS) across their nationwide networks. Local exchange carriers (LECs) use fiber to carry this same service between central office switches at local levels, and sometimes to neighborhoods or individual home. Fiber to the home (FTTH) is being deployed in select areas of the United States.

Multinational firms use FOC for secure, reliable data transfer between buildings to the desktop computers and to transfer data around the world. Cable television companies also use fiber for delivery of digital video and data services. The high bandwidth provided by fiber makes it the perfect choice for transmitting broadband signals, such as high-definition television (HDTV) telecasts. Intelligent transportation systems, such as smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, also use fiber-optic-based telemetry systems. The biomedical industry uses fiber-optic systems in modern telemedicine devices for transmission of digital diagnostic images. Other industries that use FOC extensively are space, military, automotive, and the industrial sector.

Companies such as Time Warner Telecom, Level 3, and Qwest have thousands of miles of **dark fiber** in the ground, which is buried FOC that has not been used, which can be put to use by adding the switch technology.

WIRELESS MEDIA

Cable media (with the exception of fiber-optic cables) present several problems, notably the expense of installation and change, as well as a fairly limited capacity. The alternative is **wireless communication.** Common uses of wireless data transmission include pagers, cellular telephones, microwave transmissions, communications satellites, mobile data networks, personal communications services, and personal digital assistants (PDAs).

Microwave. **Microwave** systems are widely used for high-volume, long-distance, point-to-point communication. These systems were first used extensively to transmit very-high-frequency (up to 500 GHz) radio signals at the speed of light in a line-of-sight path between relay stations spaced approximately 30 miles apart (due to the earth's curvature). To minimize line-of-sight problems, microwave antennas were usually placed on top of buildings, towers, and mountain peaks. Long-distance telephone carriers adopted microwave systems because they generally provide about 10 times the data-carrying capacity of a wire without the significant efforts necessary to string or bury wire. Compared to 30 miles of wire, microwave communications can be set up much more quickly (within a day) and at much lower cost.

Satellite. A **satellite** is a space station that receives microwave signals from an earth-based station, amplifies the signals, and broadcasts the signals back over a wide area to any number of earth-based stations. Transmission *to* a satellite is an uplink, whereas transmission *from* a satellite to an earth-based station is a downlink.

A major advance in communications in recent years is the use of *communications satellites* for digital transmissions. Although the radio frequencies used by satellite data communication transponders are also line-of-sight, the enormous "footprint" of a satellite's coverage area from high altitudes overcomes the limitations of microwave data relay stations. For example, a network of just three evenly spaced communications

satellites in stationary "geosynchronous" orbit 22,241 miles above the equator is sufficient to provide global coverage.

The advantages of satellites include the following: The cost of transmission is the same regardless of the distance between the sending and receiving stations within the footprint of a satellite, and cost remains the same regardless of the number of stations receiving that transmission (simultaneous reception). Satellites have the ability to carry very large amounts of data. They can easily cross or span political borders, often with minimal government regulation. Transmission errors in a digital satellite signal occur almost completely at random; thus, statistical methods for error detection and correction can be applied efficiently and reliably. Finally, users can be highly mobile while sending and receiving signals.

The disadvantages of satellites include the following: Any one-way transmission over a satellite link has an inherent propagation delay (approximately one-quarter of a second), which makes the use of satellite links inefficient for some data communications needs (voice communication and "stepping-on" each other's speech).

Global Positioning Systems. A **global positioning system (GPS)** is a wireless system that uses satellites to enable users to determine their position anywhere on the earth. GPS is supported by 24 U.S. government satellites that are shared worldwide. Each satellite orbits the earth once in 12 hours, on a precise path at an altitude of 10,900 miles. At any point in time, the exact position of each satellite is known, because the satellite broadcasts its position and a time signal from its on-board atomic clock, accurate to 1-billionth of a second. Receivers also have accurate clocks that are synchronized with those of the satellites. Knowing the speed of signals (186,272 miles per second), it is possible to find the location of any receiving station (latitude and longitude) within an accuracy of 50 feet by triangulation, using the distance of three satellites for the computation. GPS software computes the latitude and longitude and converts it to an electronic map.

GPS equipment has been used extensively for navigation by commercial airlines and ships and for locating trucks. GPS is now also being added to many consumer-oriented electronic devices. The first dramatic use of GPS came during the Persian Gulf War, when troops relied on the technology to find their way in the Iraqi desert. GPS also played the key role in targeting for smart bombs. Since then, commercial use has become widespread, including navigation, mapping, and surveying, particularly in remote areas. For example, several car manufacturers (e.g., Toyota, Cadillac) provide built-in GPS navigation systems in their cars. GPSs are also available on cell phones, so you can know where the caller is located.

Radio. **Radio** electromagnetic data communications do not have to depend on microwave or satellite links, especially for short ranges such as within an office setting. Broadcast radio is a wireless transmission medium that distributes radio signals through the air over both long distances and short distances. Radio is being used increasingly to connect computers and peripheral equipment or computers and local area networks. The greatest advantage of radio for data communications is that no wires need be installed. Radio waves tend to propagate easily through normal office walls. The devices are fairly inexpensive and easy to install. Radio also allows for high data transmission speeds.

Infrared. **Infrared (IR) light** is light not visible to human eyes that can be modulated or pulsed for conveying information. IR requires a line-of-sight transmission. Many computers and devices have an IrDA (Infrared Data Association) port that enables the transfer of data using infrared light rays. IrDA is a standard defined by

the IrDA Consortium. It specifies a way to transfer data wirelessly via infrared radiation. The most common application of infrared light is with television or videocassette recorder remote control units. With computers, infrared transmitters and receivers (or "transceivers") are being used for short-distance connection between computers and peripheral equipment, or between computers and local area networks. Many mobile phones have a built-in infrared (IrDA) port that supports data transfer.

Cellular (Radio) Technology. Mobile telephones, which are being used increasingly for data communications, are based on **cellular (radio) technology,** which is a form of broadcast radio that is widely used for mobile communications. The basic concept behind this technology is relatively simple: The Federal Communication Commission (FCC) has defined geographic cellular service areas; each area is subdivided into hexagonal cells that fit together like a honeycomb to form the backbone of that area's cellular radio system. Located at the center of each cell is a radio transceiver and a computerized cell-site controller that handles all cell-site control functions. All the cell sites are connected to a mobile telephone switching office that provides the connections from the cellular system to a wired telephone network and transfers calls from one cell to another as a user travels out of the cell serving one area and into another.

Personal Communication Service. **Personal communication service (PCS)** uses lower-power, higher-frequency radio waves than does cellular technology. It is a set of technologies used for completely digital cellular devices, including handheld computers, cellular telephones, pagers, and fax machines. The cellular devices have wireless modems, allowing you Internet access and e-mail capabilities. The lower power means that PCS cells are smaller and must be more numerous and closer together. The higher frequency means that PCS devices are effective in many places where cellular telephones are not, such as in tunnels and inside office buildings. PCS telephones need less power, are smaller, and are less expensive than cellular telephones. They also operate at higher, less-crowded frequencies than cellular telephones, meaning that they will have the bandwidth necessary to provide video and multimedia communications.

Personal Digital Assistants. **Personal digital assistants (PDAs)** are small, handheld computers capable of entirely digital communications transmission (see discussion in Technology Guide 1). They have built-in wireless telecommunications capabilities. Applications include Internet access, e-mail, fax, electronic scheduler, calendar, and notepad software.

UPS's Delivery Information Acquisition Device (DIAD) is a handheld electronic data collector that UPS drivers use to record and store information, thus helping UPS to keep track of packages and gather delivery information within UPS's nationwide, mobile cellular network. It digitally captures customers' package information, thus enabling UPS to keep accurate delivery records. Drivers insert the DIAD into a DIAD vehicle adapter (DVA) in their delivery vehicles to transmit over UPS's nationwide cellular network for immediate customer use.

Wireless Application Protocol. **Wireless Application Protocol (WAP)** is a technology that enable wireless trasmissions. For example, one popular application that utilizes WAP is i-mode, a wireless portal that enables users to connect to the Internet. Developed by NTT DoCoMo, i-mode provides an always-on connection to the Internet and content sites from popular media outlets, all accessible via color-screen

handsets with polyphonic sound. It is charged at actual usage instead of on a prepaid basis. WAP is criticized for browsing with small screens, little compelling content, and bad connections at great cost through a browser. Despite these drawbacks, it offers users the ability to make wireless connections to the Internet, which has enormous commercial appeal.

Bluetooth. A relatively new technology for wireless connectivity is called **Bluetooth.** It is the term used to describe the protocol of a short-range (10meter), frequency-hopping radio link between devices. Bluetooth allows wireless communication between mobile phones, laptops, and other portable devices. Bluetooth technology is currently being built into mobile PCs, mobile telephones, and PDAs.

Bluetooth is the code name for a technology designed to provide an open specification for wireless communication of data and voice. It is based on a low-cost, short-range radio link built into a 9 × 9 mm microchip, providing protected ad hoc connections for stationary and mobile communication environments. It allows for the replacement of the many existing proprietary cables that connect one device to another with one universal short-range radio link.

T4.3 Network Systems: Protocols, Standards, Interfaces, and Topologies

Network architectures facilitate the operation, maintenance, and growth of the network by isolating the user and the application from the physical details of the network. Network architectures include protocols, standards, interfaces, and topologies.

COMMUNICATION AND NETWORK PROTOCOLS

Devices that are nodes in a network must access and share the network to transmit and receive data. These components work together by adhering to a common set of rules that enable them to communicate with each other. This set of rules and procedures governing transmission across a network is a **protocol.**

The principal functions of protocols in a network are line access and collision avoidance. Line access concerns how the sending device gains access to the network to send a message. Collision avoidance refers to managing message transmission so that two messages do not collide with each other on the network. Other functions of protocols are to identify each device in the communication path, to secure the attention of the other device, to verify correct receipt of the transmitted message, to verify that a message requires retransmission because it cannot be correctly interpreted, and to perform recovery when errors occur.

The **Transmission Control Protocol/Internet Protocol (TCP/IP)** is a protocol for sending information across sometimes-unreliable networks with the assurance that it will arrive in uncorrupted form. TCP/IP allows efficient and reasonably error-free transmission between different systems and is the standard protocol of the Internet and intranets.

Convergence is used to refer to the ability to transfer all types of information—voice, data, video—utilizing a single Internet protocol (IP) network infrastructure. In **voice-over IP (VoIP)** systems, analog voice signals are digitized and transmitted as a stream of packets over a digital IP data network. VoIP utilizes a gateway to compress and convert the caller's voice into digital IP packets. These packets are then sent along the IP network. A second gateway then puts the voice packets in the correct order, decompresses them, and converts the voice packets back into a sound signal that can be received by existing telephone equipment.

Internet telephony (IP) is the transport of telephone calls over the Internet, no matter whether traditional telephony devices, multimedia PCs, or dedicated terminals take part in the calls and no matter whether the calls are entirely or only partially transmitted over the Internet.

In 1999, the Internet Engineering Task Force (IETF) published RFC 2543, which defined the **session initiation protocol (SIP).** SIP is the IETF's take on the end-to-end model of IP telephony. It can be used to increase speed, scalability, and functionality for emergency calling and notification systems.

COMMUNICATIONS STANDARDS

Networks typically have hardware and software from a number of different vendors which must communicate with each other by "speaking the same language" and following the same protocols. Unfortunately, commercially available data communication devices speak a variety of languages and follow a number of different protocols, causing substantial problems with data communications networks.

Attempts at standardizing data communications have been somewhat successful, but standardization in the United States has lagged behind other countries where the communications industry is more closely regulated. Various organizations, including the Electronic Industries Association (EIA), the Consultative Committee for International Telegraph and Telephone (CCITT), and the International Standards Organization (ISO), have developed electronic interfacing standards that are widely used within the industry. The major types of standards are *networking standards, transmission standards,* and *software standards.*

Networking Standards. Typically, the protocols required to achieve communication on behalf of an application are actually multiple protocols existing at different levels or layers. Each layer defines a set of functions that are provided as services to upper layers, and each layer relies on services provided by lower layers. At each layer, one or more protocols define precisely how software programs on different systems interact to accomplish the functions for that layer.

This layering notion has been formalized in several architectures. The most widely known is the *Open Systems Interconnection (OSI) Reference Model* developed by the ISO. There is peer-to-peer communication between software at each layer, and each relies on underlying layers for services to accomplish communication. The OSI model has seven layers, each having its own well-defined function:

- **Layer 1: Physical layer.** Concerned with transmitting raw bits over a communications channel; provides a physical connection for the transmission of data among network entities and creates the means by which to activate and deactivate a physical connection.
- **Layer 2: Data link layer.** Provides a reliable means of transmitting data across a physical link; breaks up the input data into data frames sequentially and processes the acknowledgment frames sent back by the receiver.
- **Layer 3: Network layer.** Routes information from one network computer to another; computers may be physically located within the same network or within another network that is interconnected in some fashion; accepts messages from source host and sees to it they are directed toward the destination.
- **Layer 4: Transport layer.** Provides a network-independent transport service to the session layer; accepts data from session layer, splits it up into smaller units as required, passes these to the network layer, and ensures all pieces arrive correctly at the other end.

- **Layer 5: Session layer.** User's interface into network; where user must negotiate to establish connection with process on another machine; once connection is established the session layer can manage the dialogue in an orderly manner.
- **Layer 6: Presentation layer.** Here messages are translated from and to the format used in the network to and from a format used at the application layer.
- **Layer 7: Application layer.** Includes activities related to users, such as supporting file transfer, handling messages, and providing security.

The SNA Standard. The *Systems Network Architecture* (SNA) is a standard developed by IBM that is widely used in private networks. Similar to OSI, SNA uses a layered approach; however, the layers are somewhat different. Certain types of expected errors, like those occurring over phone lines, are handled automatically. Other errors, like software problems, are isolated, logged, and reported to the central technical staff for analysis.

NETWORK MANAGEMENT SOFTWARE

Network management software comes in different shapes, and it has many functions in operating a network. These functions reduce time spent on routine tasks, such as remote, electronic installation of new software on many devices across a network. They also provide faster response to network problems, greater control over the network, and remote diagnosing of problems in devices connected to the network. In short, network management software performs functions that decrease the human resources needed to manage the network.

Active Directory. Active Directory is a software product created by Microsoft that provides applications with a single user interface for accessing network directory services from multiple operating systems. An Active Directory service application interacts with the directory services of each operating system through the set of interfaces supported for each namespace. Because many of the administrative tasks and directory services are performing across namespaces, a similar set of interfaces is supported by each directory service implementation on the organization's network. Active Directory is a key component of Microsoft's Windows Server 2003 operating system, which simplifies management tasks, enhances data security, and extends interoperability with other networked operating systems. For details, see *microsoft.com/windowsserver2003/technologies/directory/activedirectory/default.mspx.*

INTERFACES

An **interface** is a physical connection between two communications devices. One important concept of interfacing concerns the types of data transfer—parallel or serial. **Parallel data transfer,** most often used for local communication, employs a communications interface with a series of dedicated wires, each serving one purpose. In parallel communication, both data and control signals are transmitted simultaneously.

A **serial data transfer,** most often used for long-distance communications, is bit by bit rather than many bits in parallel. Most data communications devices transmit in serial fashion. While much slower than parallel data transfer, serial transfer is simpler and requires much less on the part of the receiving system.

NETWORK TOPOLOGY

The **topology** of a network is the physical layout and connectivity of a network. Specific protocols, or rules of communications, are often used on specific topologies, but the two concepts are different. *Topology* refers to the ways the channels connect the nodes, whereas *protocol* refers to the rules by which data communications take

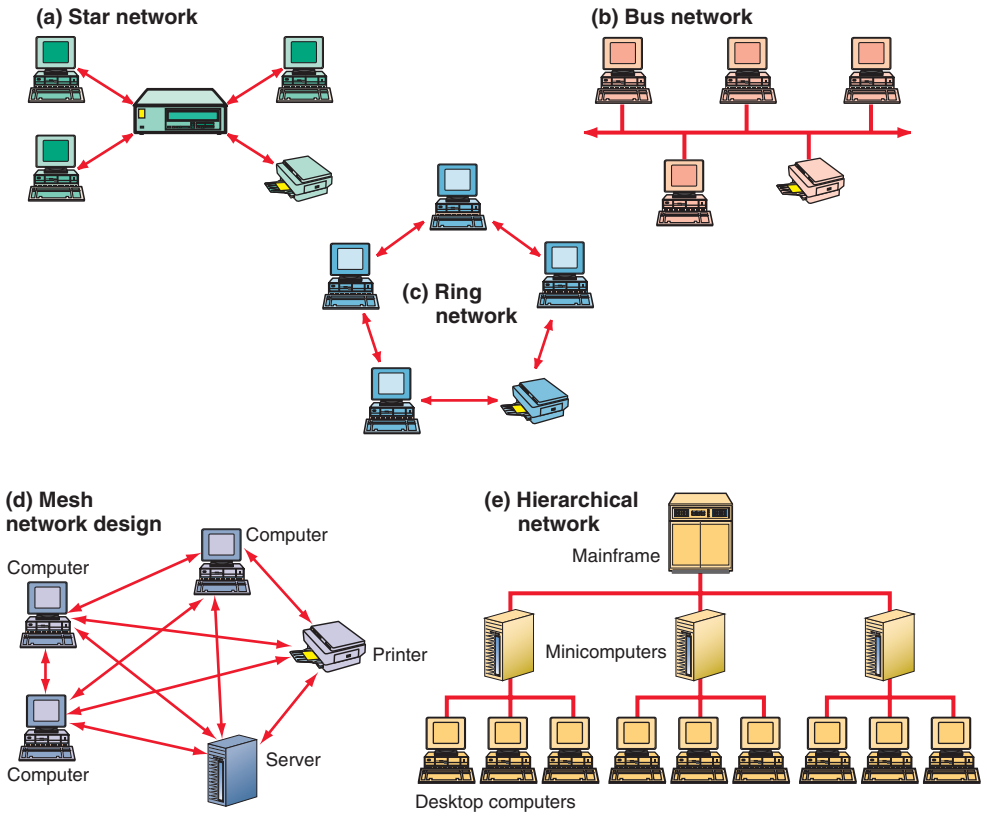

Figure T4.5 The main network topologies.

place over these channels. Neither concept should be confused with the *physical cabling* of the network.

There are several basic network topologies: star, bus, ring, mesh, and hierarchical. Figure T4.5 illustrates these different types. *Hierarchical* topologies typically connect desktops and minicomputers to a mainframe. Networks that combine more than one type (such as a ring segment connected to a star segment) are considered *hybrid* topologies. We discuss the various topologies in more detail below.

Star. A **star** network has a central node that connects to each of the other nodes by a single, point-to-point link. Any communication between one node and another in a star topology must pass through the central node.

Bus. In a **bus** topology, nodes are arranged along a single length of twisted-pair wire, coaxial cable, or fiber-optic cable that can be extended at the ends. Using a bus topology, it is easy and inexpensive to add a node to the network, and losing a node in the network will not cause the network to fail. The main disadvantages to the bus topology are that a defective bus causes the *entire network* to fail. Also, providing a bus with inadequate bandwidth will degrade the performance of the network.

Ring. In a **ring** topology, nodes are arranged along the transmission path so that a signal passes through each station one at a time before returning to its originating node. The nodes, then, form a closed circle. It is relatively easy and inexpensive to add a node to the network, and losing a node does not necessarily mean that the network will fail.

Mesh. A **mesh** network design is one in which each device is connected to every other device located on the network, like a spider web. The advantage to this design is the redundancy of the connected devices; if one link fails, it will not affect the rest of the network. The disadvantages of this design are the cost of all the required medium and limited scalability. If you add a device to a network that currently has four devices, then you must connect the new device to the four existing devices with individual cable drops.

Hierarchical. In a **hierarchical** topology, nodes are arranged like an inverted tree with the root (usually the mainframe computer) as the highest level and the leaves (usually the desktop computers) as the lowest level. It is very cheap, but may have possible traffic jams at the top level.

An advantage of the hierarchical topology is its ability to scale to very large networks. This scalability is because of the exponential reduction in size of the visible topology and amount of received topology state information at each switch in the network. These reductions improve the effectiveness of your network by reducing the control traffic, memory, and processing required by each switch in the network.

Hybrid. In a **hybrid** topology, nodes are arranged in more than one topology, which may include star, ring, and hierarchical (see Figure T4.6). A hybrid topology can integrate together various computer configurations that may have special reasons for their own choice of topology (as mentioned in the preceding sections). A hybrid network will allow companies to pick the advantages from several different topologies.

Each topology has strengths and weaknesses. When systems developers choose a topology, they should consider such performance issues as delay, speed, reliability, and the network's ability to continue through, or recover after, the failure of one or more of its nodes. A company should also consider such physical constraints as the maximum transmission speed of the circuit, the distances between nodes, the circuit's susceptibility to errors, and the overall system costs.

NETWORK ARCHITECTURE AND SIZE

Because people need to communicate over long as well as short distances, the geographic size of data communications networks is important. There are two general network sizes: local area networks and wide area networks. A "metropolitan" area network falls between the two in size. In addition, home networks are a type of LAN.

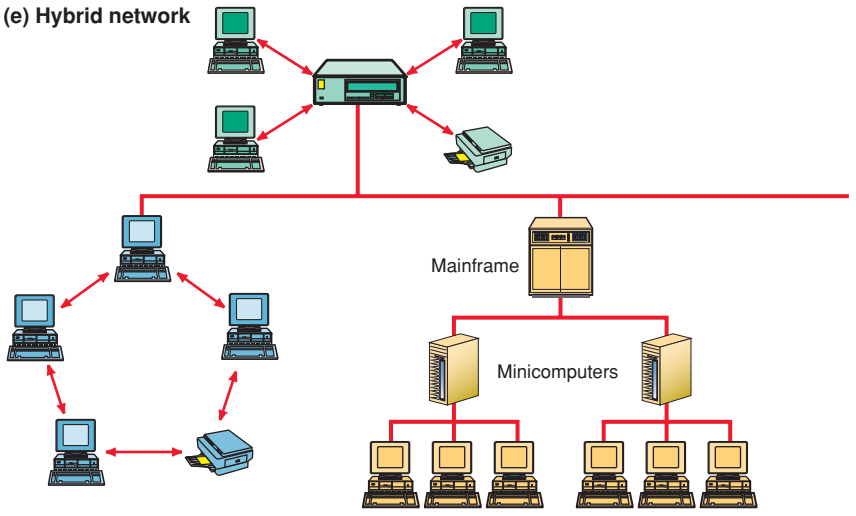

Figure T4.6 A hybrid network topology.

Local Area Networks. A **local area network (LAN)** connects two or more communicating devices within a short distance (e.g., 2000 feet), so that every user device on the network has the potential to communicate with any other device. LANs are usually intraorganizational, privately owned, internally administered, and not subject to regulation by the FCC. LANs do not cross public rights-of-way and do not require communications hardware and software that are necessary to link computer systems to existing communications networks. A LAN allows a large number of its intelligent devices to share corporate resources (such as storage devices, printers, programs, and data files), and it integrates a wide range of functions into a single system. Many LANs are physically connected as a star, with every device connected to a hub or switch.

Metropolitan Area Networks. A **metropolitan area network (MAN)** is a network that interconnects users with computer resources in a geographic area or region larger than that covered by a local area network (LAN) (even a large LAN), but smaller than the area covered by a wide area network (WAN). The term is applied to the interconnection of networks in a city into a single larger network (which may then also offer efficient connection to a wide area network). It is also used to mean the interconnection of several local area networks by bridging them with *backbone lines*, which are larger transmission lines that carry data gathered from smaller lines that interconnect with them. The latter usage is also sometimes referred to as a *campus network*. A typical use of MANs to provide shared access to a wide area network is shown in Figure T4.7.

Home Networks. **Home networks** are the computer-networking infrastructure installed at home. The components of a home network are very similar to those used in an office network, but the scale is much smaller. By connecting their home computers into a network, users can:

- Share a single printer or expensive equipment between computers.
- Share a single Internet connection among all the computers in your home.
- Access shared files such as photographs, MP3s, Excel spreadsheets, and Word documents on any computer in the house.
- Play games that allow multiple users at different computers.
- Send the output of a device like a DVD player or Webcam to the home's other computer(s).

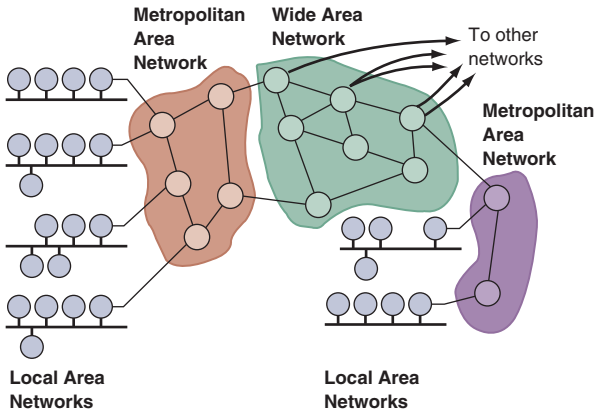

Figure T4.7 Use of MANs to provide regional networks, which share the cost of access to a WAN. *(Source: erg.abdn.ac.uk/users/gorry/eg3561/intro-pages/man.html.)*

Wide Area Networks. **Wide area networks (WANs)** are long-haul, broadband, generally public-access networks covering wide geographic areas that cross rights-of-way where communications media are provided by common carriers. WANs include *regional networks* such as telephone companies or *international networks* such as global communications service providers. They usually have very-large-capacity circuits with many communications processors to use these circuits efficiently. WANs may combine switched and dedicated lines, microwave, and satellite communications.

A leased line may handle data only, or it may be capable of handling both voice and data just as a standard telephone line does. When leased lines have been designed specifically for data transmission, they produce less noise and fewer transmission errors than regular telephone lines, and they are more secure from wiretapping and other security risks. Most importantly, the central processor is always accessible through the leased line, and the line usually transmits data at speeds (e.g., 1.544 Mbps) faster than a standard telephone line.

Some WANs are commercial, regulated networks, while others are privately owned, usually by large businesses that can afford the costs. Some WANs, however, are "public" in terms of their management, resources, and access. One such public WAN is the Internet, the foundation of the worldwide information superhighway.

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