# 1
# Basic Concepts

This chapter defines basic telecommunications terms. Terms such as analog, digital and bandwidth are used in the context of services that touch the everyday work experiences of professionals. Understanding fundamenatal terminology creates a basis for learning about advanced telecommunications services. A grasp of such fundamental concepts as digital, analog, bandwidth, compression, protocols, codes and bits, provides a basis for comprehending technologies such as high speed digital services, convergence and wireless networks. These technologies, in addition to the Internet, are changing the way Americans do business, spawning new telecommunications services and creating a smaller, linked, worldwide community.

Protocols are an important ingredient in enabling computers to communicate with each other. Protocols may be likened to etiquette between computers. Just as etiquette spells out who shakes hands first, how people greet each other and rules for how guests should leave parties, protocols spell out the order in which computers take turns transmitting and how long computers should wait before they terminate a transmission. Protocols handle functions such as error correction, error detection and file transmissions in a common manner so that computers can “talk” to each other. A computer sends data to another computer using a protocol such as IPX, Novell NetWare’s protocol designed for communications between local area networks (LANs).

Computers, printers and devices from different vendors also need to be able to send information such as electronic mail and attachments across networks. This is the role of architectures and protocol suites. Architectures tie computers and peripherals together into a coherent whole. Layers within architectures have protocols that define functions such as routing, error checking and addressing. The architecture or protocol suite is the umbrella under which the protocols and devices communicate with each other.

Computers located in firms' offices are physically connected together by local area networks (LANs), which are located within a building or in a campus environment. LANs connect computers, printers, scanners and shared devices such as modems, video conferencing units and facsimile units. LANs are connected to other LANs over metropolitan area networks (MANs), and wide area networks (WANs). The growing number of devices and peripherals on LANs is adding congestion to data networks. Workers encounter network congestion when there are delays in transmission and receipt of, for example, e-mail and database look-ups. This chapter reviews why there is congestion on local area networks and ways companies can eliminate this congestion.

One solution to traffic jams on wide area networks is the use of multiplexing. Multiplexing enables multiple devices to share one telephone line. For example, T-1 provides 24 communications paths on one high-speed link. Newer multiplexing schemes add even more capacity. T-3 provides 672 communications paths on one telecommunications link. These multiplexing schemes provide private and non-profit organizations with ways to carry increasing amounts of data, video and imaging traffic between sites. T-3 is an important way for large call centers, such as airlines, to handle large volumes of incoming calls.

Another way to add capacity for applications such as graphics, x-ray images and Internet-based video is the use of compression. Compression squeezes large amounts of data into smaller sizes, something like putting data into a corset. As a matter of fact, the availability of affordable video conferencing systems is made possible by advances in compression. Compression makes the video images "fit" onto slower speed telephone lines than those required without compression. Before advances in compression were developed, the high-speed telecommunications lines needed for video conferencing were prohibitively expensive.

Compression has made a major impact on the nature of the Internet, particularly its use in streaming media. The Internet is no longer a place for only text and graphics. Compression in combination with more powerful computers and faster modems is making it possible to hear reasonable quality audio over the Internet. The quality of video over the Internet will continue to improve as higher speed digital telephone lines become more prevalent.

## ANALOG AND DIGITAL . . . . . . . . . . . . . . . . . . . . . .

The public telephone network was originally designed for voice telephone calls. The telegraph, invented in 1840, was used for short text messages. When the telephone was invented in 1876, it was used to transmit speech. Spoken words are transmitted as analog sound waves. People speak in an analog format, waves. Telephone calls were transmitted in an analog form until the late 1960s. While much of the public telephone network is now digital, there are still many analog services in use, and portions of the telephone network are analog. The majority of telephones that plug into home telephone jacks are analog instruments. Most TV signals and telephone lines from homes to the nearest telephone company equipment are analog, as are cable TV drops, the cabling portions from subscribers to their nearest telephone pole.

As more people use their computers to communicate, and as calling volume increases, the analog format, designed for lower volumes of voice traffic, is proving inefficient. Digital signals are faster, have more capacity and contain fewer errors than analog waves.

High-speed telecommunications signals sent on ISDN service, within computers, via fiber optic lines and between most telephone company offices, are digital. With the exception of most current TV and portions of cable TV wiring, analog services are used for slow-speed transmissions. Analog services are mainly plain old telephone service (POTS) lines used by residential and small business customers.

## *Analog Signals*

### *Frequency on Analog Services*

Analog signals move down telephone lines as electromagnetic waves. The way analog signals travel is expressed in frequency. Frequency refers to the number of times per second that a wave oscillates or swings back and forth in a complete cycle from its starting point to its end point. A complete cycle, as illustrated in Figure 1.1, occurs when a wave starts at a zero point of voltage, goes to the highest positive part of the wave, down to the negative voltage portion and then back to zero. The higher the speed or frequency, the more complete cycles of a wave are completed in a period of time. This speed or frequency is stated in hertz (Hz). For example, a wave that oscillates or swings back and forth ten times per second has a speed of ten hertz or cycles per second.

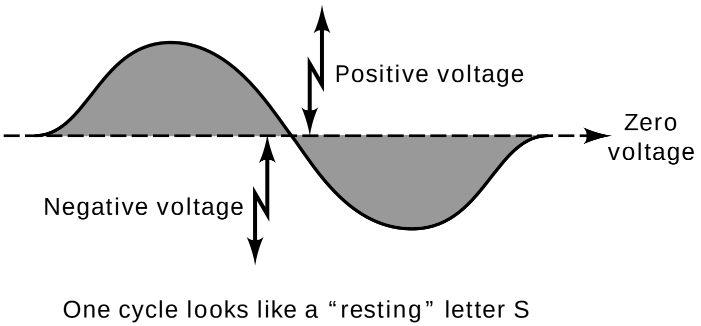


***Figure 1.1***

*One cycle of an analog wave, one hertz.*

Analog services, such as voice, radio and TV signals, oscillate within a specified range of frequencies. For example, voice is carried in the 300 to 3300 Hz range. The bandwidth, or range of frequencies that a service occupies, is determined by subtracting the lower range from the higher range. Thus, the range that voice travels at within the public network is 3000 hertz (3300 minus 300), also expressed as Hz or cycles per second.

The frequencies that analog services use are expressed in abbreviated forms. For example, thousands of cycles per second are expressed as kilohertz (KHz), and millions of cycles per second are expressed as megahertz (MHz). Analog transmissions take place in enclosed media such as coaxial cable, cable TV and on copper wires used for home telephone services. They are also transmitted via “open” media such as microwave, home wireless telephones and cellular phones. Particular services are carried at predefined frequencies. Examples of analog frequencies are:

- kilohertz or kHz = thousands of cycles per second

  Voice is carried in the frequency range of .3 kHz to 3.3 kHz, or 3000 Hz.
- megahertz or MHz = millions of cycles per second

  Analog cable TV signals are carried in the frequency range of 54 MHz to 750 MHz.
- gigahertz or GHz = billions of cycles per second

  Most analog microwave towers operate at between 2 and 12 GHz.

The 3000-cycle bandwidth allocated to each conversation in the public network is slow for digital computers when they communicate on analog lines via modems. Modems, which enable digital computers and facsimile machines to communicate over analog telephone lines, have methods of overcoming some of the speed limitations in the public, analog portion of the network. (See Chapter 7 for information about modems.)

## *Impairments on Analog Services*

Sending an analog telephone signal is analogous to sending water through a pipe. Rushing water loses force as it travels through a pipe. The further it travels in the pipe, the more force it loses and the weaker it becomes. Similarly, an analog signal weakens as it travels over distances whether it is sent over copper, coaxial cable or through the air as a radio or microwave signal. The signal meets resistance in the media (copper, coaxial cable, air) over which it is sent, which causes the signal to fade or weaken. In voice conversation, the voice may sound softer. In addition to becoming weaker, the analog signal picks up electrical interference, or “noise” on the line. Power lines, lights and electric machinery all inject noise in the form of electrical energy into the analog signal. In voice conversations, noise on analog lines is heard as static.

To overcome resistance and boost the signal, an analog wave is periodically strengthened with a device called an amplifier. Amplifying a weakened analog signal is not without problems. In analog services, the amplifier that strengthens the signal cannot tell the difference between the electrical energy present in the form of noise and the actual transmitted voice or data. Thus, the noise as well as the signal is amplified. In a voice telephone call, people hear static in the background when this happens. However, they can generally still understand what is being said. When noise on data transmissions is amplified, the noise may cause errors in the transmission. For example, on transmitted financial data, the received sales figures might be $300,000 whereas the sent information was $3 million.

## Digital Signals

Digital signals have the following advantages over analog:

- higher speeds
- clearer voice quality
- fewer errors
- less complex peripheral equipment required.

### Clearer Voice, Fewer Errors

Instead of waves, digital signals are transmitted in the form of binary bits. The word binary simply means being composed of two parts. In telecommunications, the term binary refers to the fact that there are only two values for transmitted voice and data bits, on and off. On bits are depicted as ones, the presence of voltage, and off bits are depicted as zeroes, no voltage. The fact that digital transmissions are only on or off is one reason why digital services are more accurate and clearer for voice. Digital signals can be recreated more reliably. It is more complex to recreate a wave that can have multiple forms than a bit that is either on or off.

Both analog and digital signals are subject to impairments. They both decrease in volume over distance, fade and are susceptible to interference, such as static. However, digital signals can be “repaired” better than analog signals. Figure 1.2 illustrates that when a digital signal loses strength and fades over distance, equipment on the line to regenerate the signal knows that each bit is either a one or zero and recreates it. Noise, or static, is discarded. The noise is not, as in an analog signal in Figure 1.2, regenerated. People who first used digital wireless telephones rather than analog cellular service commented on the improvement in voice clarity over analog cellular service.

In addition to clarity, digital signals have fewer errors. In analog transmission, where noise is amplified, receiving equipment may interpret the amplified signal as an

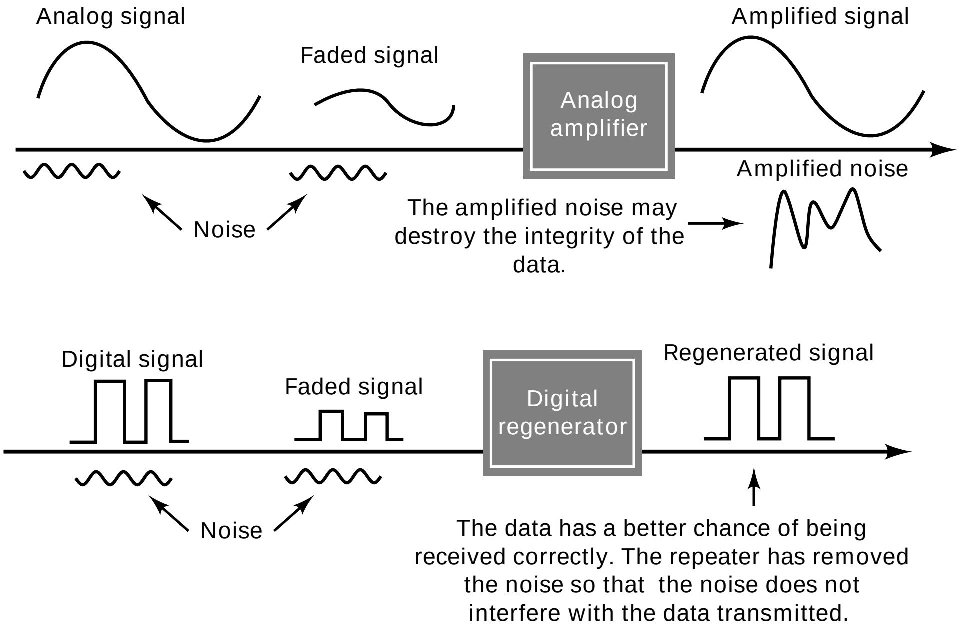


***Figure 1.2***

*Noise amplified on analog lines; eliminated on digital service.*

information bit. People using modems to transmit data often receive garbled data. In digital transmissions, where noise is discarded, garbling occurs less frequently; thus there are fewer errors in the transmission.

## *Digital Television—An Example of Digital Transmission to Enhance Clarity*

The FCC approved analog television standards in 1941 for black-and-white television. (Widespread television introduction was delayed by World War II.) Color TV standards set by the National Television Standards Committee (NTSC) were approved in 1954. As people with analog broadcast television know, “snow” and “ghosts” are frequently present along with the television images. TVs located far from broadcast antennas have the most problems with clarity. This is a function of analog signals fading or weakening. “Snow” seen on TV screens is interference on the television channel when the noise or interference becomes stronger than the signal. The further from the broadcast antenna, the greater the amount of noise relative to the picture being transmitted.

A factor in improved picture quality with digital television is the elimination of noise. With digital television, error correction code is sent along with the TV signal.

This additional 10% of error correction code provides digital TV with the same clarity 50 miles from an antenna as 5 miles from an antenna. The error correction code checks the signal and eliminates errors. The error correction code "corrects" the signal from within the TV receiver. Thus, the clarity of the digital signal is uniform throughout the range of the antenna.

Moreover, digital signals degrade or weaken less over distance than analog signals. A digital signal must travel further before it starts to weaken or fade. However, once a TV is out of range of a digital tower, the signal is lost altogether. The transition in terms of quality from analog to digital television is analogous to the change in quality from analog audiotapes to digital compact discs (CDs). Digital TV provides studio-quality audio and image on home screens.

Broadcasters in the top ten markets in the United States began airing high definition television (HDTV) signals in November of 1998. Top 30 areas have until November of 1999 to air digital broadcasts. (According to CableLabs®, the research and development consortium of the Cable TV industry of North and South America, digital cable television signals will be compatible with HDTV by the start of the year 2000.) The deadline for all broadcasters is May 2003. Networks are required to broadcast analog as well as digital transmissions. By 2006, networks must return analog spectrum to the federal government if 85% of the consumers in each broadcasting area have access to digital broadcasting. At the end of this simulcasting term, analog frequency channels will be sold by the FCC at public auctions.

### DIGITAL TELEVISION—TVS ACT LIKE PCS

*High-definition digital television allows broadcasters to transmit secondary, non-programming information, as well as television signals. A 20 megabit per second data channel has been set aside to bring information services such as weather forecasts, home automation, audio for audio's sake and stock quotes into homes. This ancillary channel can be used in conjunction with interactive, remote control devices. For instance, a user can be given the choice of downloading technical specifications, pricing and warranty notices in conjunction with a car commercial.*

*Just as personal computers manipulate bits in the form of word processing, spreadsheet and financial programs, digital televisions receive and manipulate a stream of bits. In essence, whether used by cable television or commercial broadcast television, digital television sends digital bits into peoples' homes. The bits will be audio, video or text images. The TV receiver, or in the case of cable TV, a set top device, acts as a computer and manipulates the signals to be viewed on the home screen. In telecommunications, a bit is a bit whether the source is the Internet, corporations or entertainment services.*

### Higher Speeds and Reliability

In addition to improved clarity, digital transmissions are faster than analog transmissions. This is because digital signals are less complex to transmit. They are either on or off bits, whereas analog signals take the form of complex waves. Whereas the highest speed projected for analog modems is 56,000 bits per second when receiving data and 33,600 bits when sending data, new routers, which are digital, now run at terabit-per-second speeds. A terabit is equal to a thousand gigabits.

Finally, digital service is more reliable than analog. Less equipment is required to boost the signal. Analog signals weaken and fade at shorter distances than digital signals. At every point that a signal fades, amplifiers or regenerators are required. Each amplifier is a place for a possible failure. For example, water can leak into a telephone company's manhole or the amplifier itself might fail. Organizations that use digital lines such as T-1 often experience only one or two brief failures in an entire year. High reliability results in lower maintenance costs for the telephone companies that support digital circuits.

### Digital Services in the Bell System

*Digital technology was first implemented in the public network in 1962. It was implemented, not in routing calls (central office switches), but rather in the transmission of calls within the long distance portion of the AT&T network. Coaxial cable between the central offices first carried digital calls. Because the digital technology was faster and was capable of carrying higher volumes of calls than analog technology, digital service was implemented as a way to save money by decreasing the amount of cabling required to carry high volumes of traffic. Fewer copper or coaxial lines were needed to carry equal volumes of digital rather than analog traffic.*

*Northern Telecom introduced the first digital telephone system switch for routing calls in 1975. However, to cut its financial risk, it first introduced the switch as a customer premise switch rather than a central office switch. At that time, telephone systems installed on customer premises were highly profitable and it was felt that there was less financial risk in introducing a smaller digital telephone system for end-users, rather than a larger, more expensive telephone company central office switch.*

*Significant dates for digital services are:*

*1962: T-1 on two pairs of telephone cable carried 24 voice or data calls in digital format.*

*1975: The first digital telephone system (PBX), the Northern Telecom SL-1.*

*1976: AT&T's #4 ESS toll office switched calls between central offices.*

*1977: Northern Telecom's central office switch, DMS 10, was installed in Canada. It was not installed in the U.S. until 1981.*

*1982: AT&T's #5 ESS central office switched calls from central offices to local homes and businesses.*

### Digital Telephone Company Equipment—Saving Money on Maintenance and Space

Prior to the 1960s, both the transmission of calls and equipment to route calls were analog. Beginning in the 1960s, calls were first carried in digital format on cabling between central offices with analog switches. It was cumbersome to connect digital call traffic to analog for processing by analog central office switches. Devices called channel banks were needed to convert digital signals to analog to be handled within the analog central offices and to convert analog central office signals to digital to be carried on digital coaxial cable running between central office toll switches. Converting to digital central offices eliminated the requirement for this analog-to-digital and digital-to-analog conversion equipment. This saved telephone companies money on:

- **maintenance** on channel banks for the analog-to-digital conversion, and vice versa.
- **space** required in the central offices for channel banks.

## BAUDS, BITS, BYTES AND CODES—GETTING DOWN TO BASICS . . . . . . . . . . . . . . . . . . . . . .

### Overview

Computers communicate using digital signals called bits. Bits are binary. They take two forms, on and off. Computers can "read" each others' communications when these bits are arranged in a standard, predefined series of on and off bits. All English-language IBM and Mac computers use variations of the same type of codes. The main code, ASCII, is used when personal computers communicate over telephone lines. IBM minis and mainframes use a different code, EBCDIC.

People use the terms bits, baud rate and bytes interchangeably. Their meaning, however, differs significantly. The signaling speed on analog lines is the baud rate. The baud rate is measured differently than bits per second. Bits per second are the actual number of bits sent in a given time from point A to point B. It is the amount of information or data transmitted on the electrical waves in analog telephone lines.

## *Baud Rate vs. Bits per Second—Signal vs. Amount of Information Sent*

A baud is one analog electrical signal or wave. One cycle of an analog wave equals one baud. A complete cycle starts at zero voltage, goes to the highest voltage and down to the lowest negative voltage and back to zero voltage. A 1200-baud line means that the analog wave completes 1200 cycles in one second. A 2400-baud line completes 2400 wave cycles in one second. The term *baud rate* refers only to analog electrical signals. It does not indicate the amount of information sent on these waves.

The public switched network runs at 2400 baud. If the public network could carry only 2400 bits in one second, data communications users would be severely hampered in retrieving and sending information over analog lines. To achieve greater capacity, modem manufacturers design modems capable of adding more than one bit to each analog wave or baud. Thus, a 9600 bit per second modem enables each analog wave to carry four bits of data per wave ($9600 \div 2400 = 4$). It is correct to state that the 9600 bps modem runs at 2400 baud. A 28,800 bit per second modem puts twelve bits of data onto each electrical signal or wave. It still uses a 2400-baud line.

Baud rate refers to analog, not digital transmission services. Digital services do not use waves to carry information. Information is carried as on or off electrical signals in the case of copper wires, and on or off light pulses on fiber optic lines. On digital services, 56,000 bit per second lines can carry 56,000 bits in one second. The speed is 56 Kbps, or 56 kilobits per second.

## *Codes—Adding Meaning to Bits*

To enable computers to converse in a common "language," digital bits are arranged in codes such as ASCII for personal computers and EBCDIC for IBM mainframes and mini-computers. Codes allow computers to translate binary off and on bits into information. For example, distant computers can read simple e-mail messages because they are both in ASCII. ASCII (American Standard Code for Information Interchange), is a seven-bit code used by PCs. ASCII code is limited to 128 characters. Extensions to ASCII support eight-bit codes. Most PCs now use extended ASCII. These characters

***Table 1.1*** *Examples of ASCII Code*

| Character | ASCII Representation |
|---|---|
| ! | 0100001 |
| A | 1000001 |
| m | 1101101 |

include all of the upper- and lower-case letters of the alphabet, numbers and punctuation such as !, " and : (see Table 1.1).

Because there are only 128 or 256 with ASCII extended characters, formatting such as bolding, underlining, tabs and columns are not included in ASCII code. Specialized word processing and spreadsheet programs add their own code to ASCII to include formatting and specialized features. Thus, Microsoft® Word® documents, for example, need to be "translated" if they are to be "read" by a WordPerfect® program. Each program uses a different arrangement of bits, for example, to format columns, tabs and footers. They each add proprietary formatting code to standard ASCII code. Sending documents between computers in ASCII allows them to be read by all PCs. However, specialized formatting such as tabs, tables, columns and bolding are not included in the transmission.

## *Sending Attachments with E-mail*

*E-mail is the most widely used application on the Internet. However, e-mail has format limitations. It only sends ASCII code. The limitation with ASCII is that it has just 128 characters. These characters do not include bold characters, images, tables or spreadsheet formats. This is a problem for people who want to conduct business or exchange complex documents.*

*For example, for my teaching at Northeastern, students send me their finals and I send consulting proposals and completed reports to clients and prospective clients. These files are usually in Microsoft® Word® or Microsoft® Excel® formats. Salespeople may send or receive presentations composed in the Microsoft PowerPoint® format. It is possible to exchange video, audio and JIF or JPEG image files.*

*To overcome ASCII limitations, mail protocols allow users to send attachments over communications lines. The mail protocol, MIME (multipurpose mail extensions), adds special bits to the beginning of the attachment which contains the word processing, spreadsheet or image* *file. These special bits tell the receiving computer when the attachment begins and ends and the type of encoding used—for example, word processing program, spreadsheet, image, etc. The receiving computer then opens that particular program (spreadsheet, PowerPoint, JPEG or video) and decodes the attachment so that the recipient can read the document.*

### Bytes = Characters

Each character of computer-generated code is called a byte. A bit is only an on or off signal. The entire character is a byte. A one-page document might have 250 words with an average of five letters per word. This equates to $5 \times 250$, or 1250 bytes or characters. It would, however, contain 8,750 bits if each character were made up of seven bits. To summarize, a byte is a character made up of seven or eight bits. A bit is an on or off signal. Table 1.3 contains definitions of various network terms.

## BANDWIDTH—MEASURING CAPACITY . . . . . . . . . . . . .

In telecommunications, bandwidth refers to capacity. Bandwidth is expressed differently in analog and digital transmissions. The carrying capacity of analog media, such as coaxial cable, is referred to in hertz. Hertz is a way of measuring the capacity or frequency of analog services. For example, someone might say coaxial cable has a bandwidth of 400 MHz; 400 MHz means four hundred million cycles per second. The capacity of the cable can be stated as a frequency of 400 MHz. The bandwidth of an analog service is the difference between the highest and lowest frequency within which the medium carries traffic. Cabling that carries data between 200 MHz and 300 MHz has a bandwidth, or frequency, of 100 MHz. The greater the difference between the highest and lowest frequency, the greater the capacity or bandwidth.

On digital services such as ISDN, T-1, and ATM, speed is stated in bits per second. Simply put, it is the number of bits that can be transmitted in one second. T-1 has a bandwidth of 1.54 million bits per second. Bandwidth in terms of bits per second or hertz can be stated in many ways. Some of these include:

- Individual ISDN channels have a bandwidth of 64 thousand bits per second, 64 kilobits per second or 64 Kbps.
- T-1 circuits have a bandwidth of 1.54 million bits per second, 1.54 megabits per second or 1.54 Mbps.

- One version of ATM has the capacity for 622 million bits per second, 622 megabits per second, or 622 Mbps.
- Another version of ATM has the capacity for 13.22 billion bits per second, 13.22 Gigabits per second or 13.22 Gbps.
- One thousand Gigabits is called one terabit; 10 terabits per second = 10,000,000,000,000 bits per second.

## Narrowband vs. Wideband—Slow and Fast

In addition to bits per second and hertz, speed is sometimes referred to as narrowband and wideband. Just as more water fits into a wide pipe and moves faster, wideband lines carry more information than narrowband lines, and the term wideband refers to higher speed services than narrow band. Again, digital speeds are expressed in bits per second and analog speeds are expressed in hertz.

The definition of wideband and narrowband technologies differs within the industry, as can be seen in Table 1.2.

***Table 1.2*** *Wideband and Narrowband Telecommunication Services*

| Narrowband | Wideband |
|---|---|
| ***T-1 at 1.54 Mbps*** 24 voice or data conversations on fiber optics, infrared, microwave or two pairs of wire. | ***Broadcast TV services—uses 6 MHz per channel*** Newer digital high-definition TV (HDTV) offers enhanced clarity over analog TV. |
| ***Analog telephone lines at 3000 Hz*** Plain old telephone service (POTS). Modems enable analog lines to carry data from digital computers. | ***Cable TV (CATV) and Community antenna television at 700 MHz*** Broadcasts local and satellite TV. Also available for data communications and access to the Internet. |
| ***BRI ISDN at 144 Kbps*** Two paths for voice or data, each at 64 Kbps. One path for signals at 16 Kbps. | ***ATM—up to 13.22 GBPS, gigabits*** A very high-speed service capable of sending voice, video and data. |
| | ***SONET—Up to 13.22 Gbps, Gigabits*** An optical multiplexing interface for high-speed transmission. Used mainly in carrier and telco networks. |
| | ***T-3 at 44.7 Mbps, megabits (equivalent to 28 T-1 circuits)*** A way of transmitting 672 conversations over fiber optics or digital microwave. |

Television and cable are carried at wideband speeds. Lines connecting telephone offices together use wideband services. Voice calls, video and data transported within carriers' networks are generally carried at wideband speeds. However, most traffic from central offices to individual homes and businesses are carried at the slower, narrowband speeds.

## Protocols and Architectures

### Protocols—A Common Language

Protocols allow like devices to communicate with each other. They provide a common language and set of rules. Devices communicate over the Internet using a suite of protocols called TCP/IP. For example, the IP, or Internet protocol portion of TCP/IP, allows portions of messages called datagrams to take different routes through the Internet. The datagrams are assembled into one message at the receiving end of the route. Other protocols, such as Ethernet enable communications among personal computers within an organization's building. The Internet uses HTTP (HyperText Transport Protocol) for end-users' computers to access documents and Web pages on the Internet. Apple's Mac computers can be connected to each other over the Apple Talk protocol.

Examples of protocol functions are:

- Who transmits first?
- In a network with many devices, how is it decided whose turn it is to send data?
- What is the structure of the addresses of devices such as computers?
- How is it determined if an error has occurred?
- How are errors fixed?
- If no one transmits, how long is the wait before disconnecting?
- If there is an error, does the entire transmission have to be resent or just the portion with the error?
- How is data packaged to be sent, one bit at a time or one block of bits at a time? How many bits are in each block? Should data be put into envelopes called packets?

Protocol structures have implications on speed and efficiency. The following protocols illustrate this point:

- SLIP (Serial Line Interface Protocol): Enables computers to use IP to access their Internet Service.

- PPP (Point-to-Point Protocol) has largely supplanted SLIP. It can be used in non-TCP/IP environments and has improved security functionality over SLIP. It is used to access the Internet and to tie dispersed networks together.

## Architectures—Communications Framework for Multiple Networks

Architectures tie dissimilar protocols together. Standards bodies and dominant companies, like IBM develop architectures. By the mid-l970s, IBM had sold its customers a variety of printers, terminals and mainframe and mini-computers. These devices communicated with each other by a variety of incompatible protocols. An architecture was developed by IBM to enable its devices to talk together. This architecture is called SNA, and it is specific to IBM.

During the same time period, an architecture was developed by the International Standards Organization, or ISO. This architecture, Open System Interconnection (OSI), was developed to allow devices from multiple vendors to communicate with each other. It is an open architecture.

While OSI has not been widely implemented, it has had a profound influence on telecommunications. It laid the foundation for the concept of open communications among multiple manufacturers' devices. The basic concept of OSI is that of layering: Groups of functions are broken up into seven layers, which can be changed and developed without having to change any other layer. Both LANs and the Internet are based on concepts developed by the OSI for a layered architecture.

*Layer 1* is the most basic layer, the physical layer. It defines the electrical interface (plugs) and type of media, for example, copper, wireless and fiber optics. Layer 1 also defines the electronics (e.g., modulation) for getting the signal on and off the network. In modems that work on analog lines, modulation changes the computer's digital signal to analog and at the receiving end, the analog signal to digital.

*Layer 2* is the data link layer. LANs, networks within corporations, correspond to Layer 2 of the OSI model. They provide rules for error control and gaining access to the local area networks within organizations. Layer 2 devices are analogous to the postal system's routing mail all the way to an end-user's residence.

*Layer 3* is called the network layer. It has more complex rules for addresses and routing and more error control than Layer 2. Communications between networks generally adhere to protocols corresponding to Layer 3 of the OSI. Layer 3 protocols are responsible for routing traffic between networks or sites. Layer 3 is analogous to a local post office routing an out-of-town letter by zip code. It only looks at the zip code not the street address. Layer 3 is also known as the routing layer. It is used to route IP (Internet protocol) traffic.

*Layer 4* is the transport layer. Layer 4 devices let networks differentiate between different types of applications. Layer 4 devices route by content. For example, video or voice transmissions over data networks might receive a higher priority or quality of service than e-mail. Layer 4 devices are also responsible for security in routers connected to the Internet or to virtual private networks, VPNs. (For VPNs see Chapter 9.) Filters in routers allow or deny access to networks based on the sender's IP address.

*Layer 5* is the session layer. Layer 5 manages the actual dialog of sessions. For example, can both ends send at the same time? Can transmissions be half-duplex, one-way-at-a-time sending? It can also define a session such that only one side is able to send.

*Layer 6* is the presentation layer. Layer 6 controls the format or how the information looks on the user screen.

*Layer 7* is the application layers. Layer 7 includes the application itself plus specialized services such as file transfers or print services.

The Internet suite of protocols, TCP/IP, corresponds to the functions in Layers 3 and 4 of the OSI model. These functions are addressing, error control and access to the network. The TCP/IP suite of protocols provides a uniform way for diverse devices to speak to each other from all over the world. It was developed in the 1970s by the U.S. Department of Defense and was provided at no charge to end-users in its basic format. Having a readily available, standard protocol is a key ingredient in the spread of the Internet.

# COMPRESSION AND MULTIPLEXING . . . . . . . . . . . . . . .

## Compression—Manipulating Data for More Capacity

Compression is comparable to a trash compactor. Just as a trash compactor makes trash smaller so that more can be packed into a garbage barrel, compression makes data smaller so that more information can be packed into telephone lines. It is a technique to get more capacity on telephone lines.

### Modems—Using Compression to Get Higher Throughput

With compression, data to be transmitted is made smaller by removing white spaces and redundant images, and by abbreviating the most frequently appearing letters. For example, with facsimile, compression removes white spaces from pictures and only transmits the images. Modems use compression to achieve higher rates of transmitted information, or throughput. Throughput is the actual amount of useful data sent on a transmission. When modems equipped with compression transmit text, repeated words are abbreviated into smaller codes. For example, the letters E, T, O and I appear frequently in text. Compression will send shortened versions of these letters with 3 bits rather than the entire eight bits for the letters E, T, O and I. Thus, a page of text might be sent using 1600 bits rather than 2200 bits.

Modems use compression to send greater amounts of computer data in less time over analog lines. For example, if a word processing file is ten pages long, compression that eliminates white spaces, redundant characters and abbreviates characters might compress the document to seven pages. Seven pages of data take less time to transmit than ten pages. This is an example of compression increasing throughput, or the amount of information sent through a line in a given amount of time. Telecommuters who access and send data to corporate locations often use modems equipped with compression to transmit files more quickly. Matching compression is needed at both the telecommuter's home and the corporate site (see Figure 1.3).

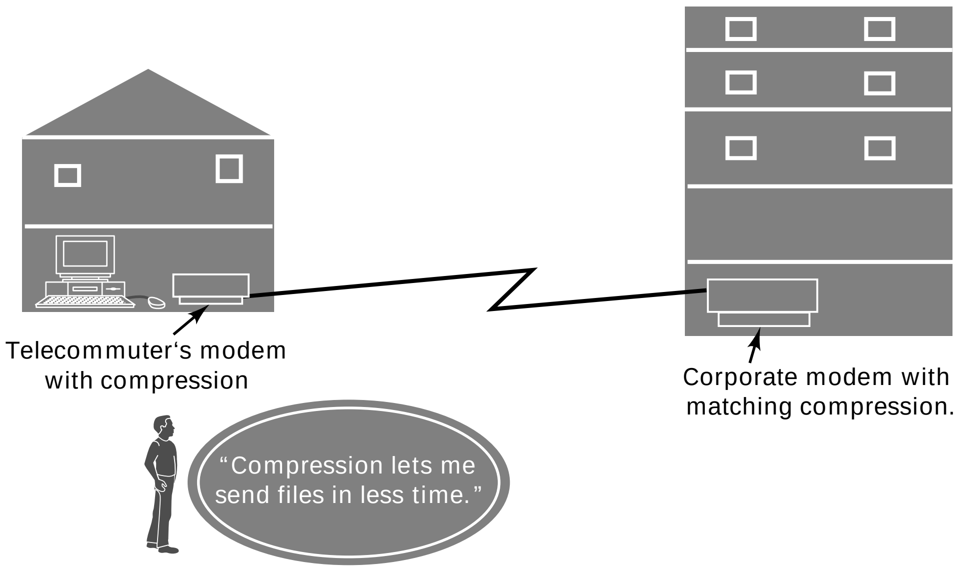


***Figure 1.3***
*Compression in modems.*

### Video—Compression Made Video Conferencing Commercially Viable

In video, compression works by transmitting only the changed image, not the same image over and over. For example, in a videoconference meeting with a person who listens, nothing is transmitted after the initial image of the person listening until that person moves or speaks. Fixed objects such as walls, desks and background are not repeatedly transmitted. Another way video compression works is by not transmitting an entire image. For example, the device performing the compression, the coder, knows that discarding minor changes in the image won't distort the viewed image noticeably.

Improvements in the mid-1980s in video compression spawned the commercial viability of room-type video conference systems. It made it economical to use video by requiring less bandwidth, which translates into cheaper telephone lines. The older compression systems required a full T-1 for video. This inhibited the sales of room-type video systems until the late 1980s. New compression techniques in the 1980s from companies such as PictureTel required only 56 Kbps to 128 Kbps for acceptable picture quality.

Thus, video conferencing became affordable to a wide range of organizations. For example, instead of using a T-1 at hundreds of dollars per hour, organizations could use a service from someone such as MCI Worldcom for as low as $14 per hour and still have acceptable video capability. New compression algorithms meant that slower speed digital lines were an acceptable choice for video meetings. A new industry boomed.

### Compression Standards = Interoperability

There are many types of compression methods. Companies such as AT&T, Motorola, PictureTel and Compression Labs have all designed unique compression schemes using mathematical algorithms. A device called a codec (short for coder-decoder) encodes text, audio, video or image using a compression algorithm. For compression to work, both the sending and receiving ends must use the same compression method. The sending end looks at the data, voice or image. It then codes it using a compression algorithm. The receiving end of the transmission decodes the transmission. For devices from multiple manufacturers to interoperate, compression standards have been agreed upon for modems, digital television, video teleconferencing and other devices. See Appendix for compression standards.

## Streaming Media

### Speeding Up Internet Connections

Streaming media, also called streaming video and streaming audio, is software used to speed up transmission of video and audio over the Internet. When graphics and text are sent to an Internet user's browser, the text can be viewed as soon as it is on the PC. The graphics are filled in as they are received.

Pornography is the biggest application to date for streaming video. It was the first to use cameras to record live action. However, many experts think streaming media will turn the Internet into another medium for communications. Mainstream corporations use streaming media to disseminate speeches and corporate events. Universities are using the technology to make their offerings more widely available. In particular, continuing education students at many universities take courses to keep up with developments in their field without traveling to distant campuses.

Web sites are starting to offer their customers the ability to generate their own audio and video clips. For example, GeoCities announced on March 1, 1999 that they would deploy RealNetworks server software on GeoCities site. End-users will be able to use the RealNetworks tools to produce their own audio and video clips. However, they will be charged for data-storage if they use more than the minimal amount offered at no charge.

### Streaming vs. Downloading and MPEG Standards

When text or graphics are downloaded, the entire file must be downloaded before it can be viewed. With streaming technology, as soon as a URL is clicked, it starts to be viewable by the end user. Streaming is an important feature of browsers. When Web pages with both text and graphical ads are downloaded, the text reaches the end user's computer faster than the graphics. For example, someone reading the online edition of the Wall Street Journal can start reading articles while the ads are being received.

MPEG standards are used for streaming audio and video. The ITU (International Telecommunications Union) formed the Moving Picture Experts Group in 1991 to develop compression standards for playback of video clips and digital TV. MPEG3 came to be used for streaming audio. MPEG and proprietary streaming media compression schemes are asymmetrical. It takes more processing power to code than to decode an image. Streaming compression algorithms assume that the end-user will have less prossessing power to decode than developers and broadcasters that encode the video and audio.

The two most prevalent streaming media software products are those developed by RealNetworks Inc. and Microsoft Corporation. RealNetworks has a larger share of the market than Microsoft. RealNetworks' products are RealSystem® and

RealPlayer®. Microsoft's product is NetShow services. Streaming media is an important force in the Internet's move toward becoming a mass media vehicle. Rob Glaser, Chief Executive of RealNetworks, said in response to AtHome Corporation's announcement that it will deliver television quality video clips to its cable modem customers: "[This is] another crucial step forward in enabling the Internet as the next mass medium for both consumers and content providers." (*The Wall Street Journal*, "AtHome to Use RealNetwork in Video Clips," Jan. 15, 1999, p. B-6)

Both Microsoft and RealNetworks give away their streaming media software for free in the hope that they will become de facto standards and that developers will purchase server-based products from them.

## *Processing Power: A Factor in Streaming Media's Improvement*

The increasing power of personal computers as well as improvements in compression is increasing the use of streaming audio and video over the Internet. As a matter of fact, Intel Corporation, in September of 1998, licensed the technology to RealNetworks to develop their streaming media software. Intel hoped to encourage people to buy more powerful computers. Streaming video and audio requires powerful chips, such as Pentium®, to decode streams fast enough to run the streaming software.

Intel Corporation and Microsoft Corporation, in April of 1998, announced that Intel's software program Intercast® will be included in Microsoft's operating system Windows 98®. Intercast® enables broadcasters to include data in the form of statistics along with TV programming. Examples of these data streams include sports statistics and electronic shopping announcements. Windows 98® also includes support for TV tuner cards within the PC. PCs also need antennas to receive digital broadcasts. To date, few PC manufacturers have made these tuners. Matsushita Electric Industrial Company's Panasonic unit and Philips Electronics NV both announced that they would have tuner cards for digital TVs available in 1999.

### *PCs Act Like TVs*

*SoftCom Inc and Broadcast.com Inc. are two companies that use streaming media in the core of their business. SoftCom works with universities and broadcasters to make their videos accessible to people with personal computers connected to the Internet. SoftCom creates the software for organizations to publish their videos and create interactive applications. For example, a nursing school offers its continuing education courses on the Internet so those students can take courses from their home without driving to a campus.*

*Once the streaming video application is completed, it is located on a SoftCom server at an Internet Service Provider. The server is a computer put inside a three by six-foot cage at the ISP's premise. Nursing students' calls, when viewing these courses, are directed to the ISP host's site. Three ISPs that specialize in hosting include Exodus Communications, Frontier Communications and Globix Corporation.*

*Broadcast.com, part of Yahoo! Inc., offers live radio and TV broadcasts via the Internet. The Broadcast.com Web site includes 370 radio stations and 30 TV stations. College and professional sports broadcasts are a TV specialty. In addition, they broadcast live business events. These events include shareholder meetings, speeches and earnings calls to stock analysts. To hear or see these businesses broadcasts, users click on a Broadcast.Com URL in the Internet. This address takes the caller to the Broadcast.com server located in Dallas Texas. The Dallas site is connected to the Internet by a T-3, 44.5 million bit per second telephone line.*

### *Digital Television—Sending Studio-Quality Pictures with Compression*

Compression squeezes video and analog signals into small enough units so that studio-quality television can be sent on standard digital television channels. The analog standard for television is set at 525 scan lines, or 525 lines of image. HDTV (high-definition television) enables a TV screen to display 1080 horizontal scanned lines and 1029 vertical scanned lines. A higher number of scan lines results in a clearer, studio-quality TV picture. Additional "lines" of image result in a denser, higher resolution of detailed images on the screen. This is done through computer manipulation of the video and audio portions of the television signal. Computerized compression takes out the redundancy and images in the picture that don't change. This reduces the signal that needs to be transmitted from 1.5 Gigabits to 19.3 megabits. However, the person seeing the TV image perceives the image to be almost as clear as the originating program. Because of powerful compression and decompression tools, very little is lost to the viewer. The quality on digital television is such that people watching television in their homes perceive the quality to be like that of movies at theaters.

## *Multiplexing—Let's Share*

Multiplexing combines traffic from multiple telephones or data devices into one stream so that many devices can share a telecommunications path. Like compression, multiplexing makes more efficient use of telephone lines. However, unlike compression, multiplexing does not alter the actual data sent. Multiplexing equipment is located in long distance companies, local telephone companies and at end-user premises. It is associated with both analog and digital services. Examples of multiplexing over digital facilities include T-1, fractional T-1, T-3, ISDN and ATM technologies.

The oldest multiplexing techniques were devised by AT&T for use with analog voice services. The goal was to make more efficient use of the most expensive portion of the public telephone network, the outside wires used to connect homes and telephone offices to each other. This analog technique was referred to as *frequency division multiplexing.* Frequency division multiplying divides the available range of frequencies among multiple users. It allowed multiple voice and later data calls to share paths between central offices. Thus, AT&T did not need to construct a cable connection for each conversation. Rather, multiple conversations could share the same wire between telephone company central offices.

Digital multiplexing schemes also enable multiple pieces of voice and data to share one path. Digital multiplexing schemes operate at higher speeds and carry more traffic than analog multiplexing. For example, T-3 carries 672 conversations over one line at a speed of 45 megabits per second (see Figure 1.4). With both digital and analog multiplexing, a matching multiplexer is required at both the sending and receiving ends of the communications channel.

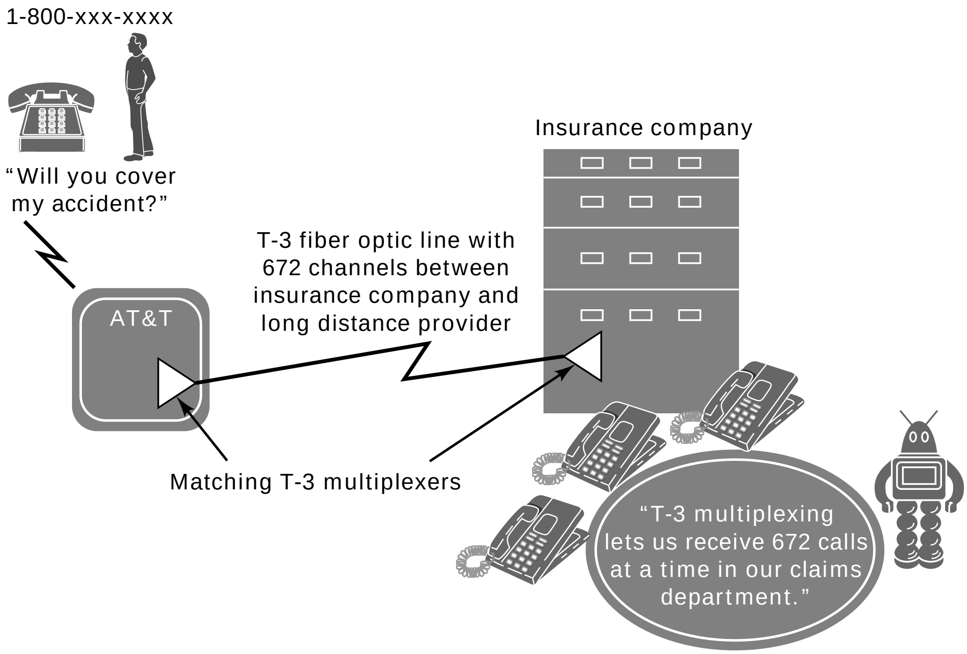


***Figure 1.4***
*Multiplexers for sharing a telephone line.*

While T-3 is used for very large customers and for telephone company and Internet service provider networks, T-1 is the most common form of multiplexing for end-user organizations. T-1 is lower in both cost and capacity than T-3. T-1 allows 24 voice and/or data conversations to share one path. T-1 applications include linking organization sites together for voice calls, e-mail, database access and links between end-users and telephone companies for discounted rates on telephone calls. Like T-3 services, matching multiplexers are required at both ends of a T-1 link.

## LANS, MANS, AND WANS . . . . . . . . . . . . . . . . . . . . . .

The difference between LANs, MANs and WANs is the distance over which devices can communicate with others. As the name implies, a local area network is local in nature. It is owned by one organization and is located in a limited geographic area, usually a single building. In larger organizations, LANs can be linked together within a complex of buildings on a campus. Devices such as computers linked together within a city or metropolitan area are part of a metropolitan area network. Similarly, devices that are linked together between cities are part of a wide area network.

**Table 1.3** *LANs, MANs and WANs—What's the Difference?*

| Term | Definition |
|---|---|
| LAN (Local Area Network) | A group of data devices, such as computers, printers and scanners, that can communicate with each other within a limited geographic area such as a floor, department or building. |
| MAN (Metropolitan Area Network) | A group of data devices, such as LANs, that can communicate with each other within a city or a large campus area covering many city blocks. |
| WAN (Wide Area Network) | A group of data devices, such as LANs, that can communicate with each other from multiple cities. |
| Hub | The intelligent wiring center to which all devices, printers, scanners, PCs, etc., are connected within a segment of a LAN. Hubs enable LANs to be connected to twisted pair cabling instead of coaxial cable. Only one device at a time can transmit via a hub. Hubs provide a point for troubleshooting and relocating devices. Speed is usually 10 Mbps. |
| Switching Hub | Switching hubs allow multiple simultaneous transmissions on a LAN segment. Total speeds range from 10 Mbps to 100 Mbps (megabits per second). |

**Table 1.3** *continued*

| *Term* | *Definition* |
|---|---|
| Backbone | Wiring running from floor to floor in single buildings and from building to building within campuses. A backbone connects to hubs located in wiring closets on each floor. |
| Bridge | Bridges connect multiple LANs together. They have limited intelligence and generally only connect a few LANs together. Bridges were in limited use as of the early 1990s when the price of routers dropped. |
| Layer 2 Switches | Bridges with multiple ports are able to switch data quickly between local area network segments. Layer 2 switches provide a dedicated connection during an entire data transmission. |
| Router | Routers connect multiple LANs. They are more complex than bridges and can handle a greater number of protocols and LANs. Routers select the best available path over which to send data between LANs. |
| Routing switches | Routing switches are faster than traditional routers. They do not look up each packet's address in the CPU's memory. Routing is done in chips on each module or card. |
| Server | A centrally located computer with common departmental or organizational files, such as personnel records, sales data, price lists, student information and medial records. The server connects to a hub or layer 2 switch. Access may be restricted. |

## *LANs—Local Area Networks*

Examples of devices within LANs that communicate are: shared printers, PCs, alarm devices, factory automation and quality control systems, shared databases, factory and retail scanners and security monitors (see Figure 1.5). A discrete LAN is typically located on the same floor or within the same department of an organization.

The growth of LANs grew out of the proliferation of PCs. Once people had PCs on their desktops, the next step was to connect these PCs together. LANs first appeared in 1980. The initial impetus for tying PCs together was for the purpose of sharing costly peripherals, such as high-speed printers. LANs are now the building blocks for connecting multiple locations together for the purpose of sending e-mail and sharing databases with remote locations and telecommuters. These e-mail and corporate information files are located in specialized computers called file servers. Access to file servers can be limited by password to only certain users.

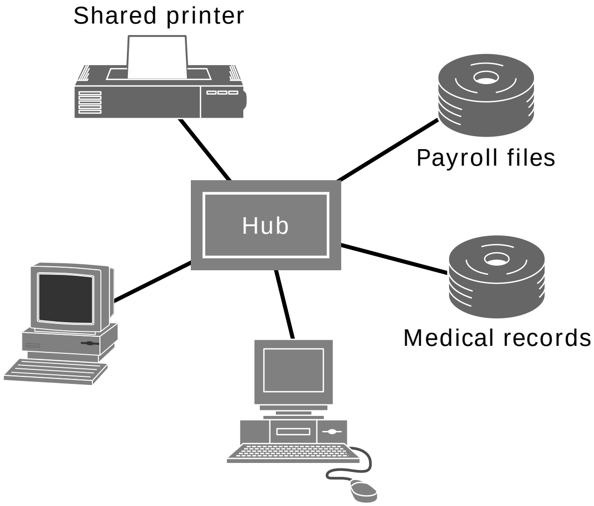


***Figure 1.5***
*A local area network.*

The software that runs local networks is called *LAN network operating systems* and is located on servers connected to the LAN. Most operating systems in use today are built on the client–server model. Clients (PCs) request services such as printing and access to databases. Applications called servers run access to services (e.g., printers and databases). The network operating system controls access to the LAN where resources such as files, printers and modems are located. Examples of client–server-based LAN network operating systems are Microsoft NT and Novell NetWare.

Devices on local area networks are all connected to the LAN. Each device on a local area network can communicate with every other device. The connections between devices may be any of the following: twisted pair, coaxial cable, fiber optics or wireless media. For the most part, devices are connected to a LAN by twisted pair cabling that is similar to but sometimes of a higher quality than that used to tie business telephones together. (Media options are covered in Chapter 2.)

When local area networks became popular in the 1980s, many individual departments purchased their own LANs independent of the central computer operations staff. As the need arose to tie these LANs together for e-mail and file sharing, compatibility between LANs from different manufacturers became a problem. The TCP/IP suite of protocols became a popular choice for overcoming these incompatibilities. Devices called bridges and routers were also developed to send data between LANs.

## Hubs

Hubs enable devices on LANs to be linked together by twisted copper pair wire instead of the heavier, thicker coaxial cable typically used in the cable TV industry. When LANs were initially implemented, they were installed using coaxial cable to interconnect devices on the LAN. Coaxial cable is expensive to install and to move. It is not unusual in large organizations for entire departments and individuals to move at least once a year. The use of coaxial cabling resulted in running out of space in dropped ceilings and conduit for the cable.

With a hub, instead of wiring devices to each other, each node or device is wired back to the hub in a star pattern. Using a hub changes the topology of a LAN. The hub creates a star design or topology. (Topology is "the view from above"—in the case of hubs, a star where each device is connected to a central device.) Without a hub, each

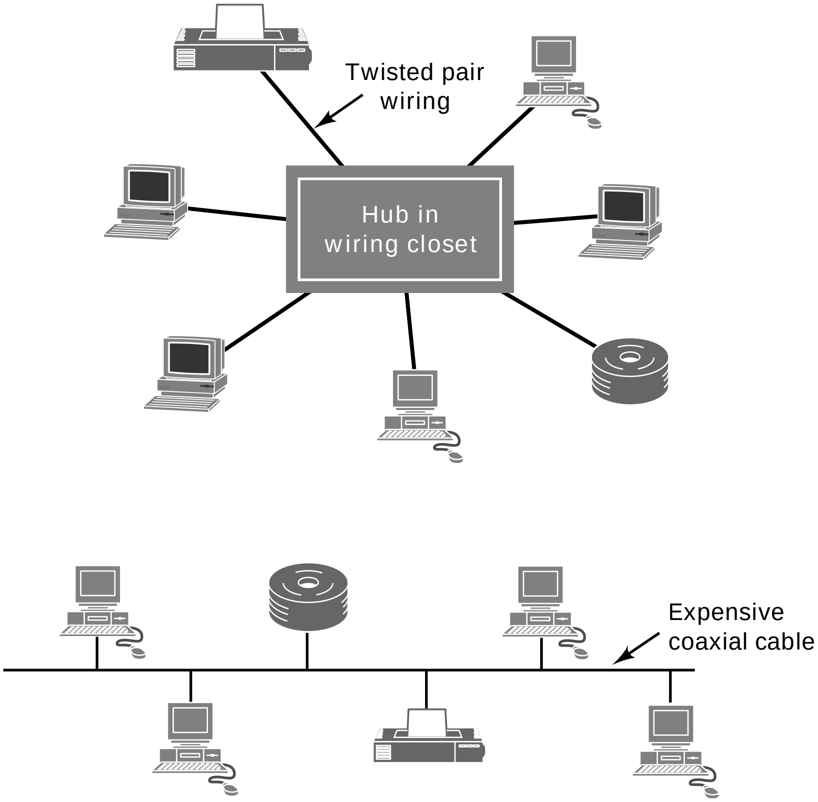


**Figure 1.6**

*Top: LAN with a hub to link devices with twisted pair wiring. Bottom: LAN without a hub.*

device in a LAN is wired to another device in a "bus" arrangement. In the bus topology, if one device is taken out of the line or bus, or if there is a break in the line, each device is affected. Conversely, by employing a hub, moving a device does not impact the other devices. A hub is kept in the wiring closet of each floor within a building, as shown in Figure 1.6.

## Bridges

Bridges became available in the 1980s as a way to connect a small number of LANs together. They were used most often in the mid-1980s. Bridges provide one common path over which multiple LANs may be connected together (see Figure 1.7). For example, if an organization has two locations in different cities that need to exchange data, a bridge can be used. Bridges can connect two Ethernet LANs, or an IBM token ring network to an Ethernet LAN. In addition to connecting distant LANs to each other, bridges were used extensively in the mid-1980s to connect LANs in the same building or campus.

The advantage of bridges is that they are easy to configure. There are a limited number of choices in configuring a bridge. Each piece of data sent via a bridge takes the same path. This is also a disadvantage. Each piece of data not only takes the same path, it is also sent to each device on the network. The lack of routing and congestion control puts bridges at Layer 2 in the OSI model. Only the device to which the message is addressed takes the message off the network. This broadcast feature of bridges can choke the network with too many messages, slowing down the network for everyone. As LANs proliferated and router prices dropped, people turned to routers rather than bridges.

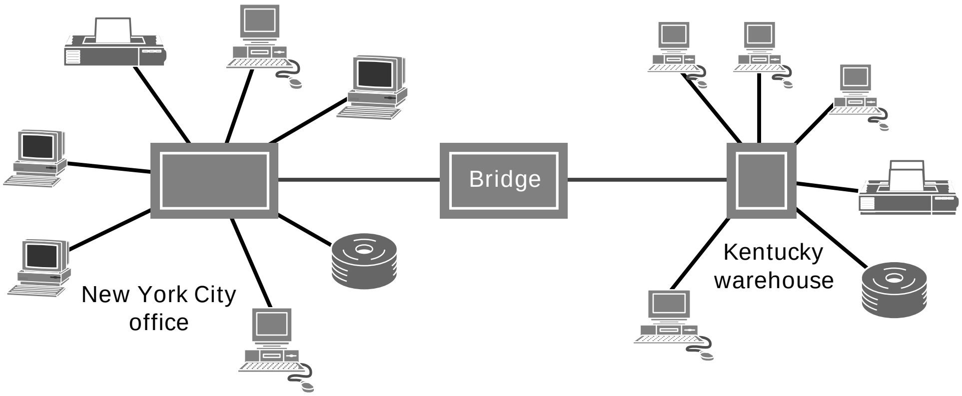


***Figure 1.7***

*A bridge connecting two local area networks.*

## Routers

Routers are also used to connect multiple local area networks. These LAN connections are usually between LANs located in distant buildings on a campus or in different buildings in diverse cities. However, routers also connect multiple LANs within large campuses spread out across cities. Routers are more sophisticated and have additional capabilities not available in bridges. A major advantage of routers is their ability to forward differing protocols from varied departmental local area networks. It is important to note that routers do not translate application protocols. A UNIX computer cannot read a Microsoft Windows word processing document. The router merely allows differing LAN protocols to be transported via a corporate network infrastructure.

Router capabilities include:

- **Flow control:** If the path the data should take is congested, the router can hold the data until capacity is available on the path between the routers.
- **Path optimization:** The sending router selects the best available path. It checks routing tables contained within the router for this information.
- **Sequencing:** Routers send data in packets, or envelopes. These packets may arrive out of order at the end router. The receiving router knows by information in the packet the correct order and arranges the data accordingly.
- **Receipt acknowledgment:** The receiving router sends a message to the sending router letting it know that data was received correctly.

The intelligence inherent in routers leads to two major disadvantages. In the first place, routers are complex to install and to maintain. Every router in an organization's network must have up-to-date address tables. Each device on a LAN is called a node and has an address. For example, if a printer or PC is moved from one LAN to another, the router table must be updated or messages will not reach that device. To illustrate the complexity of managing routers, it is common to hear of consultants with full-time contracts to update router tables for organizations. Secondly, routers are slower than bridges. The need to look up tables within the router slows down the router's speed. The above functionality of congestion control, sequencing and receipt acknowledgment make routers network Layer 3 devices in the OSI model.

## Switching Routers

Switching routers are faster than non-switching routers. They do not look up each address of each packet that they route in the router's table. Rather they place each packet's address in silicon on the circuit pack. Most new routers installed on LANs are switching routers. Some new routers are so fast that they are referred to as terabit routers. They operate at a thousand gigabits per second.

## *WANs—Wide Area Networks*

The term WAN refers to connections between organizational locations over long distances via telephone lines. For example, a warehouse in Alabama connected to a sales office in Massachusetts by a telephone line is a WAN, or wide area network connection. In contrast to a local area network, a WAN is not contained within a limited geographical location. The variety of WAN connections available is complex. Selection of an appropriate WAN connection depends on the amount of traffic between locations, quality of service needed, price and compatibility with the computer systems located within the organizations. WAN technologies and WAN vendors are reviewed in Chapters 6 and 7. These include ISDN, T-1, T-3, ATM and frame relay, as well as wireless services.

## *MANs—Metropolitan Area Networks*

Metropolitan area networks, or MANs, are connections between local area networks, which occur within a city or over a campus. Campus MANs are spread out over many blocks of a city. Examples of MANs are those of large hospitals and university complexes. For example, a hospital in downtown Boston keeps its x-rays and other records in a nearby section of the city. Instead of trucking records and x-rays between the two sites, the hospital leases high-capacity telephone lines to transmit records and images. The connections between these two sites are metropolitan area connections. These connections can be leased from a telephone company or constructed by the organization. They may be fiber optic, copper or microwave-based services. They may also include the same services mentioned for WANs, such as ISDN and T-1.

## *LAN and WAN Congestion*

### *New, High-Bandwidth Applications*

Original LAN designs lent themselves to "bursty" traffic. Bursty traffic includes e-mail and text messages. Bursty traffic is not a steady stream of data. With typical LAN protocols, such as Ethernet and token ring, only one message at a time can be carried on a LAN that has a speed of ten megabits. New applications are causing delays and congestion on LANs. Applications adding high-traffic volumes to LANs are desktop video conferencing, computer-aided design, computer aided manufacturing and graphics downloaded from the Internet.

Not only are these applications adding traffic to LANs, but the traffic is no longer the short, bursty type of traffic. Bursty traffic sends a group of messages and then has a pause. This pause gives other devices that share the network a chance to transmit data. Video, however, is an application that requires constant use of the network. People participating in a conference don't want a blank screen while someone else on the LAN accesses the Internet. Video requires constant network capacity during the video conference.

## More Powerful PCs

In addition to applications which require large amounts of data to be transmitted over organizations' LANs, the capability of PCs impacts LAN requirements. In the 1980s when LANs were first implemented, people had computers with 286 chips on their desks with small amounts of memory and hard disks. In recent years, staffs have Pentium computers with 64 megabits of memory and Gigabit-sized hard drives. These powerful PCs have multimedia capability. This allows them to participate in desktop video conferences, download large files from the Internet and share large spreadsheet files. All of this traffic is carried over the LAN.

## Sharing the LAN

Router-based and hub-based campus networks and LANs are shared media networks. Everyone has a turn to send and receive data, but sharing is required. Only one message at a time can be carried. The speed on these networks is high—10 megabits. But the assumption is that messages will be bursty, allowing other transmissions to send without causing large delays. When LANs were first implemented, in addition to assumptions regarding burstiness, it was assumed that applications such as e-mail would not require immediate response. This is not true for newer applications such as Internet access. People do not want delays when downloading information from the World Wide Web. For these reasons Layer 2 switches and switching routers with dedicated bandwidth for individual users are being implemented in LANs.

## Congestion within LANs, LAN-to-LAN and LAN-to-WAN

Congestion on networks occurs both within a local area network, between LANs in a building or campus and between a LAN and a WAN. New technologies are emerging which provide greater capacity in these areas.

## Higher Speed Services for LAN Traffic (All Require Hub Upgrades)

- **Fast Ethernet:** Fast Ethernet is a shared protocol. However, it has a speed of 100 megabits—ten times the speed of standard Ethernet, the most prevalent LAN protocol. Standard two pair wiring is used. New cards are required in each PC to access the LAN.
- **100 megabit Switched Ethernet:** Switched Ethernet is a non-sharing service. Devices with high transmission needs are given their own dedicated paths within a LAN. Standard wiring, bridges and routers can be used. This frees up high bandwidth users from "hogging" LANs.

## Higher Speed Services for LAN-to-LAN Backbone and LAN-to-WAN Traffic

- **Gigabit Ethernet:** Works with existing LAN protocols. Because of its high speed, 1000 megabits, gigabit Ethernet requires either Fiber optic cabling or extended level 5 unshielded twisted pair. On LANs, it is mainly the servers that have the high-capacity gigabit Ethernet connections because of the high traffic levels to servers.
- **Routing Switches:** Routing switches forward packets on a packet-by-packet basis. They put the first of a series of packet addresses in the silicon memory of a card in the router to avoid having to look up each address in the router's table. Routing switches perform Layer 2 as well as Layer 3 switching. The Layer 3 functions route between networks and network segments. The Layer 2 function routes the packet to the end node—that is, PC or printer. Nortel Networks, through their acquisition of Bay Networks, supplies these routing switches.
- **Tag Switching:** Supported by Cisco. A proprietary protocol based on multi-protocol label switching to increase the speed of connections between LANs. In tag switching, bits representing the address are placed in the router's short-term cache memory. A fixed-length tag is added to each packet. Subsequent routers do not have to examine the entire header of the packet. They merely look at the tag for routing instructions. This shortens the amount of time required to route packets. It speeds up routing.

## New Devices for Carrier and Internet Service Provider Networks

Manufacturers are developing new high-speed routers for the anticipated growth in the amount of data versus voice carried in the public network. They envision a network of the future that will carry a preponderance of data, video and audio rather than voice traffic. Data communications equipment manufacturers such as Cisco Systems and 3Com are developing high-speed routers that they would like to sell to carriers and Internet service providers. They see their equipment as being primarily designed for data traffic but also fast enough to carry voice and video without any degradation in the quality of the voice or video.

Traditional manufacturers of central office equipment designed to carry voice are developing new equipment to carry data more efficiently. These manufacturers include Siemens AG, Lucent Technologies and Nortel Networks. All of these organizations have purchased companies who specialize in equipment that can carry high-speed data services. For example, Lucent has purchased Yurie Systems and Ascend Communications. Ascend Communications had previously bought Cascade, a manufacturer of ATM switches, and Stratus. Nortel bought Bay Networks and Aptis. It also owns a 20% stake in Avici Systems, a developer of terabit routers. Avici System's routers are described below. Avici is introducing their routers on the market in mid-1999.

### Availability vs. Reliability

*When carriers purchase telephone company equipment, key criteria for purchases are reliability and availability.*

- *Reliability refers to how often a device breaks. Carriers typically require NEBS Level 3 compliance on equipment they purchase. NEBS stands for Network Equipment Building Standards. Bellcore, the former R&D arm of the Regional Bell Operating Companies developed NEBS standards. The standards include compliance with thermal, electrical, redundancy and earthquake resistance tests.*
- *Availability refers to how long it takes to repair equipment or to having the equipment in service even though part of it is not working. For example, if ports are inoperable, the other ports should be available to route calls normally handled by the inoperable ports. In the same vein, back-up central processing units, CPUs, should be able to automatically take over if the main CPU goes down.*

## Terabit Routers

The term terabit router was coined by Avici Systems in 1997. Terabit routers route packets at trillions of bits per second (1,000,000,000,000). Terabit routers are generally geared toward the Internet service provider and carrier market. In planning for and designing their routers, Avici Systems spoke with carriers who stated that they wanted hardware that would be capable of handling the huge amounts of data they expected on the public network from applications such as virtual private networks. (See Chapter 9 for VPNs.) They felt that VPNs would be handling a large amount of e-commerce, extranet and Intranet traffics in the near future.

Avici's terabit routers are computers made on the model of super computers. The switching fabric is made up of up to 560 routers in a single device. If any one of the 560 computers fail, the router will still function and use the input/output ports associated with the remaining computers. The router uses MPLS, multi-protocol label switching. The smaller headers associated with MPLS enable routers to forward packets at high speeds. With MPLS, short, fixed-length "labels" tell the router how to route each packet so that the router does not have to examine the entire header of each packet. Avici Systems envisions their terabit routers replacing ATM switches in the backbone of service providers' networks. ATM switches switch voice, data and video in the backbone of the public network. The backbone is the high-traffic area of a network into which lower usage paths are routed. Avici routers simultaneously support 100 OC 192, plus 400 OC 48 streams of traffic. The term OC stands for Optical Carrier speeds that are transported over fiber optic cables. OC 48 = 2,488 million bits per second and OC 192 = 10,000 million bits per second.

Other manufacturers of new high-speed routers include Torrent Networking Technologies, Pluris, NetCore Systems, Unisphere Solutions, Inc. and Juniper Networks, Inc. Many of these router manufacturers are vying to replace traditional central office equipment with their routers. They envision a programmable switch (see Chapter 9 for programmable switch), converting public network voice traffic to Internet Protocol (IP) packets and handing them off to high-speed routers to be transported over high-capacity fiber optic networks. (See Chapter 2 for dense wave division multiplexing on fiber optic networks.)

## Edge Routers

Edge routers connect organizations' networks to carriers' switches and routers. They are located at the edge of both carrier and enterprise networks. Ennovate Networks, Inc. of Boxborough, MA manufactures a new edge router that they market to carriers for use in their IP data networks. The router has what the company calls *virtual router architecture* composed of up to 80 routing tables. Standard routers have one routing table. Ennovate states that multiple routing tables gives their equipment the flexibility and capacity to offer many more IP addresses to large customers who may want to use carriers for VPN service. Some VPNs require that customers change their computer addresses because of limitations in the router-based address tables. VPNs (virtual private networks) have most of the functionality of private networks. However, the network provider manages the network for the customer.

Security is also an issue. Ennovate feels that large customers' traffic will be more secure if their computer addresses are in tables separate from other customers. Moreover, the Ennovate router provides carriers with the capacity of multiple devices in one "box." It obviates the necessity of carriers having to support multiple routers.

## APPENDIX . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

| Compression Standard | Description |
|---|---|
| MNP 5 | Microcom Network Protocol compression protocol developed by Microcom for modems. Provides 2:1 compression. |
| V.42bis | Data compression protocol for modems. Provides 4:1 compression. |
| H.320 | A family of standards for video adopted by the ITU (International Telecommunications Union). Quality is not as high as proprietary video compression algorithms. Most video codecs employ both proprietary and standard compression algorithms. The proprietary compression is used to transmit to another "like" video unit and the standard algorithm is used when conferencing between differing brands. |
| H.323 | A family of standards for video adopted by the ITU (International Telecommunications Union) for sending video over packet networks. Microsoft Corporation and Intel Corporation adopted the standard in 1996 for sending voice over packet networks. It is installed on Windows® based personal computers and used to packetize and compress voice when callers with PCs make calls from their computers over the Internet. See Chapter 9. |
| MPEG3 | Moving Picture Experts Group 3 is Layer 3 of MPEG1. It is a compression standard for streaming audio. MPEG3 is the compression algorithm used to download audio files from the Internet. For example, some Internet e-commerce sites allow people with compression software to download samples of music so they can decide if they wish to purchase a particular CD. In addition, people with multi-media computers are playing CDs on their computers or on CD burners and distributing copies to friends without paying royalties. |
| MPEG2 | A Moving Picture Experts Group standard approved in 1993 for coding and decoding video images. MPEG2 uses past images to predict future images and color and transmits only the changed image. For example, the first in a series of frames is sent in a compressed form. The ensuing frames send only the changes. A frame is a group of bits representing a portion of a picture, text or audio section. |