CHAPTER 18.6
ADVANCED COMPUTER TECHNOLOGY

BACKGROUND

Early computer systems were tightly integrated with locally attached I/O facilities, such as card readers and punches, tape readers and punches, tape drives, and discs. Data had to be moved to and from the site of the programming system physically. For certain systems, the turnaround time in such processes was considered excessive and it was not long before steps were taken to interconnect *remotely located* I/O devices to a computer site via telephone and telegraph facilities.

Telecommunications today means any form of communicating that exists to support the exchange of information between people and application programs in one of the three following combinations: person to person, person to process, or process to process. Thus, today, telecommunications encompasses telephony, facsimile transmission, television, and data communications. The impetus for this change has been continual advancement in digital technology, a common technological thread running through all the previously mentioned disciplines.

TERMINALS

Terminals are the mechanisms employed by individuals to interface to communications mechanisms and to represent them in their information exchange with other individuals or processes. Since the early advent of telecommunications, many terminal device types have come in the market. The earliest and most popular devices were the *keyboard printers* made by Teletype Corporation and other manufacturers. These electromechanical machines operated at speeds from 5 to 11 characters per second.

Another popular type of terminal device is the *cathode-ray-tube* (CRT) *visual display* and keyboard. This *dumb terminal* operates at speeds from 1200 to 9600 b/s across common-carrier telephone facilities or at megabit rates directly attached to the local channel of a processor. Displays generally are alphanumeric or graphic, the preponderance of terminals being alphanumeric. Many such displays can be attached to a single *control unit*, or *node*, which can greatly reduce the overall costs of the electronic devices required to drive the multiple devices. The control unit can also reduce communications cost by concentrating the multiple-terminal data traffic from the locally connected drives into a single data stream and sharing a single channel between the controller and a *host processor.* Some controllers support the attachment of hard-copy printers and have sufficient logic to permit printout of information of a display screen without communicating with a host computer. Displays are generally used in conversational or interactive modes of operation.

In recent years PCs have had a profound impact on the quantity of this type of display. Although the personal computer really is an *intelligent workstation*, most PCs can employ communications software subsystems to emulate nonintelligent visual display and keyboard devices. In this way, they can communicate with host software.

Many specialized *transaction-type terminals* are designed for specific industry applications and form another category of terminals. Special point-of-sale terminals for the retail industry, bank teller and cash dispensers, and airline ticketing terminals are examples of transaction-type terminals.

A category of terminals that incorporates many of the features of previous categories, the *intelligent workstation*, is really a remote mini- or microcomputer system that permits the distribution of application program functions to remote sites. Such *intelligent terminals* are capable of supporting a diversity of functions from interactive processing to remote batched job entry. Some of these terminals contain such a high level of processing capability that they are, in fact, true host processors. With the expanded scope of telecommunications, television and telephones are beginning to play an important role as terminals. Not that they were not terminals before, but rather, they are now recognized as an important part of the terminal types to be found in the world of information. Terminals now support voice, data, and video communications within one single integrated package.

HOSTS

When people communicate with machines via their terminals, they are communicating with application programs. These programs offer services to the user, such as data processing (computation, word processing, editing, and so forth) and data storage or retrieval. In such applications as message switching and conferencing, hosts often act as intermediates between two terminals. Thus they may contain application software that stores a sender's message until the designated receiver actively connects to the message application or to some program that has been made aware of the person's relationship to the host service.

Host applications also may have a need to cooperate with other host applications in *distributed processors.* Distributed processing and distributed database applications typically involve host-to-host communications. Host-to-host communications typically require much higher-speed communication channels than terminal-to-host traffic. Within recent years, host channel speeds have increased to tens of megabits per second, commensurate with the increased millions-of-instructions-per-second (MIPS) rate of processors.

Personal computers can also assume the role of a host. The difference between being a terminal or a host is defined by the telecommunications software supporting the PC. Acceptance of this statement should be easy when one recognizes that PCs today come with the processing power and storage capacity attributable to what was once viewed as a sizable host processor.

COMMUNICATIONS SYSTEMS

For communications to occur between end users, it is essential that two aspects be present: (1) There must be interconnectivity between the communicating parties to permit the transference of signals and bits that represent the information transfer, and (2) there must be commonality of representation and interpretation of the bits that represent the information.

In the early years of telecommunications, the world of *connectivity* was divided and classified as *local* and *remote.* Local implied limited distances from a host, usually with relatively high-speed connections (channel speeds). Terminals were connected to controllers that concentrated the data traffic. Remote connections depended on the services available from common carriers. These worlds were separate and distinct.

Evolving standards obscure the earlier distinction between local and remote and introduce the new concept of *networking.* In the telecommunications world, networking is the interconnection and interoperability of systems for the purpose of providing communications service. The types of communications services to be found in modern networks vary with the needs of subscribers and the service characteristics of the media available. The end users impose requirements in the form of service classifications. Examples of requirements are capacity, integrity, delay characterizations, acceptable cost, security, and connectivity. Each medium imposes constraints for which the systems may have to compensate. Thus a medium may have a limited capacity, it may be susceptible to error, it may introduce a propagation delay, it may also lack security, and it may limit connectivity.

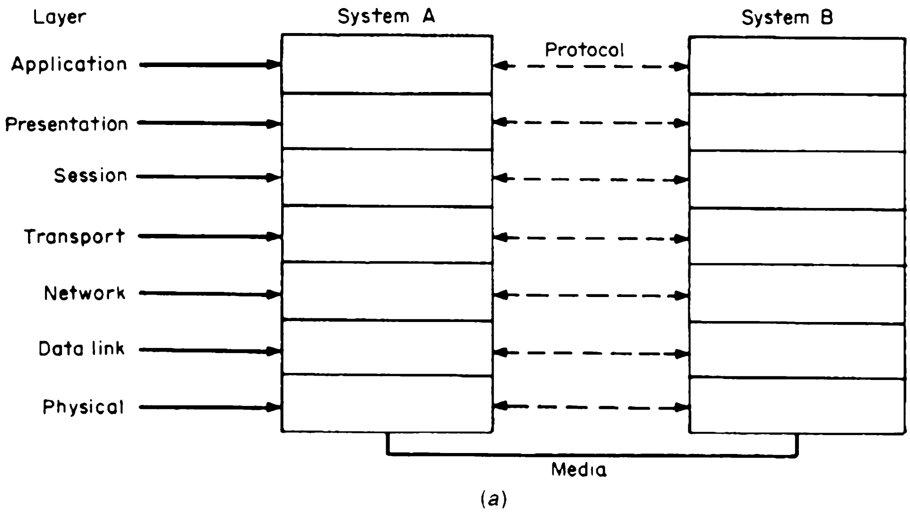

FIGURE 18.6.1*a* ISO-OSI model.

Most early communications networks were designated to meet specific subscriber needs, as was the case with the early telephone system, airline reservation systems, and the early warning system. Computer and transmission technology have changed this concept. The introduction of digital technology introduces a common denominator to the field of information communications that eases the sharing of resources used in the creation of communications networks. However, the existence of millions of terminals and tens of thousands of processors designed to operate within the construct of their own private communications world, and the need for innovation to accommodate new and heretofore unanticipated subscriber needs, presents a formidable challenge to the information communications industry.

In an attempt to bring about order, the International Standards Organization (ISO) has developed standards recommendations for an *open system*. An open system is one that conforms to the standards defined by ISO and thus facilitates connectivity and interoperability between systems manufactured by different vendors. Figure 18.6.1 depicts the ISO open system interconnect (OSI) model.

OSI REFERENCE MODEL

The OSI reference model describes a communication system in the seven hierarchic layers shown in Fig. 18.6.1. Each layer provides services to the layer above and invokes services from the layer below. Thus the *end users* of a communications system interconnect to the *application layer*, which provides the user interface and interprets user service requests. This layer is often thought of as a *distributed operating system*, because it supports the interconnectivity and communicability between end users that are distributed. The model is a general one and even permits two end users to use the application layer interface of a common system to communicate, instead of a shared local operating system. By hiding the difference between locally connected and remotely connected end users, the interconnected and interrelated application layer entities assume the role of a *global operating system*, as shown in Fig. 18.6.2.

In a single system, the operating system contains *supervisory control logic* for the resources—both logical and physical—that are allocated to provide services to the end user. In a distributed system, such as a communications system, the global supervisory service for all the layers resides in the application layer, hence, the reason to view the layer as a global operating system.

Note that the model applies equally as well to telephony. An end user, in requesting a connection service from the communications system, communicates with a supervisory controller. This controller is in the local

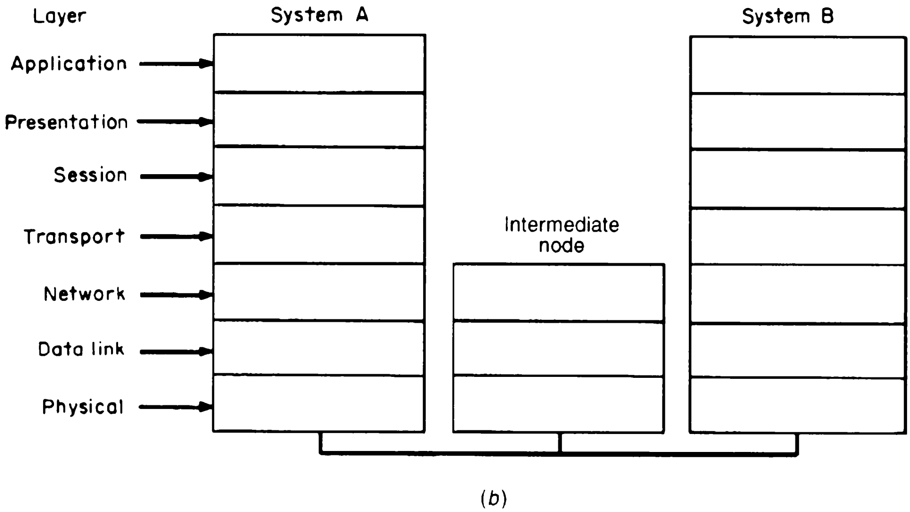

FIGURE 18.6.1*b* ISO-OSI model with an intermediate node.

exchange of a telephone operating company. The cooperating efforts of the distributed supervisory control components of the telephone systems are an analog of the distributed application layers of a data network, as shown in Fig. 18.6.1*b*.

A user views the application layer as a global server. Requests for service are passed from the user to the communications system through an interface that typically has been defined by the serving system. Even though systems differ in their programs and hardware architectures, there is a growing recognition of the necessity for the introduction of standardization at this critical interface. Consider the difficulty in making a telephone call when traveling, if every telephone company had chosen a different interface mechanism. This would require a knowledge of all the different methods, as is the case for persons who travel to foreign countries.

The services available from the communications systems can be quite varied. In telephony, a basic transport and connection service is prevalent. However, as greater intelligence was placed within the systems of

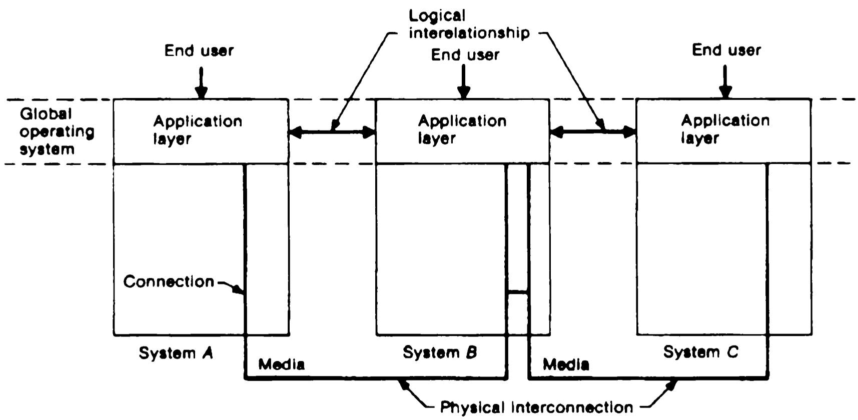

FIGURE 18.6.2 Application layers as a global operating system.

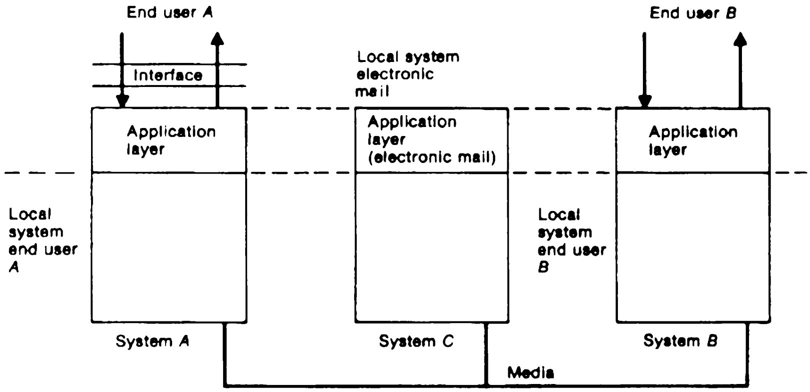

FIGURE 18.6.3 Example use of the application layer.

the telephone networks, the operating companies have increased the types of services they provide. Systems are operational in the United States, which integrate voice and data information through a common interface mechanism and across a shared medium. That medium is the existing twisted-pair wire that once carried only analog voice signals, or optical lines, which carry a much greater volume of data. Carrier networks offer *electronic mail*, *packet switching*, *telemetry services*, *videotex*, and many other services. The limit on what can or will be provided will be determined by either government regulations or market demand.

The layers that lie below the application layer exist to support communications between end users or the communications services of an application layer that exist in a distributed system, as is shown in Fig. 18.6.3. The application layer of system *A* can contain knowledge of the electronic mail server in system C and, on behest of end user *A* (EUA), invoke that service. The application layer of system *A* can also support a connect service that enables it to create a communications path between system *A* and its equivalent partner (*functional pair*) in system *B*, for the purpose of supporting communications between EUA and EUB.

Each of the layers of the OSI model in Fig. 18.6.1 contributes some value to the communications service between communicating partners, be they end users or communication systems distributed entities.

The *application layer* is a user of the *presentation service layer* and is concerned with the differences that exist in the various processors and operating systems in which each of the distributed communications systems is implemented. The presentation service layer provides the service to overcome differences in coded representation, format, and the presentations of information. To use an analogy, if one system's machine talked and understood Greek and another system's machine talked and understood Latin, the presentation services layer would perform the necessary service to permit the comprehension of information exchanged between the two systems.

The *presentation service layer* is a user of the session layer which manages the dialogue between two communicating partners. The session layer assures that the information exchange conforms to the rules necessary to satisfy the end user needs. For example, if the exchange is to be by the *two-way alternate* mode, the session layer monitors and enforces this mode of exchange. It regulates the rate of flow to end users and assures that information is delivered in the same form and sequence in which it had been transmitted, if that had been a requirement. It is the higher layer's port into the transmission subsystem that encompasses the lower four layers of the OSI reference model in Fig. 18.6.1*a*.

The *session layer* is the user of the *transport layer*, which creates a logical pipe between the session layer of its system and that of any other system. The transport layer is responsible for selecting the appropriate lower-layer network to meet the service requirement of the session-layer entities, and where necessary, to enhance lower-level network services by providing system end-to-end integrity, information resequencing, and system-to-system flow control to assure no underrun or overrun of the receiving system's resources.

The transport layer uses the *network layer* to create a logical path between two systems. Systems may be attached to each other in many different ways. The simplest way is through a single point-to-point connection. The network layer in such an example is very simple. However, witness the topology depicted in Fig. 18.6.4. To go from system *A* to system *B* involves passing through several different networks, each of which exhibits

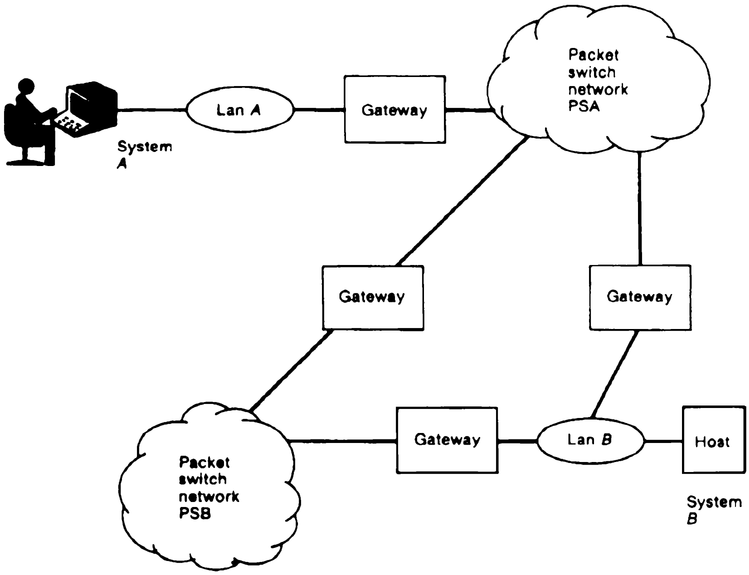

FIGURE 18.6.4 Creating a logical path between two systems.

different characteristics of transmission service and each of which may differ radically in its software and hardware design, topology, and *protocol* (rules of operation).

Such a network interconnection is rather typical. In fact, many interconnections can be far more complex. Consider the effect of the inclusion of an alternate packet-switch network PSB between local area network (LAN) *A* and PSA. The logic to decide which network or sequence of networks to employ must be dealt with within the network layer. This function is referred to as *routing*. However, to hide the presence of network complexity from the transport layer and thus provide the appearance of a single network, a unifying sublayer, called the *internet layer*, is inserted between the transport layer and subnetworks, as shown in Fig. 18.6.5.

Because networks differ with regard to the size of data units they can handle, the network layer must deal with the breaking of information frames into the size required by individual subnetworks within the path. The network layer must ultimately be capable of reassembling the information frames at the target system before passing them to that system's transport layer. The network layer must also address the problem of congestion caused by network sources being shared by large numbers of users attached to different systems. Because the end users of these

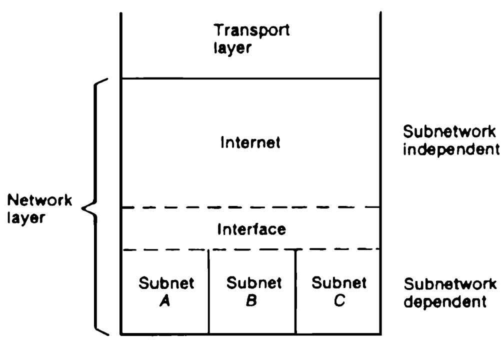

FIGURE 18.6.5 Network layer structure.

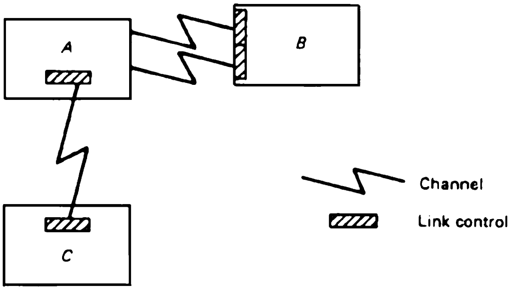

FIGURE 18.6.6 A new link control for each new channel.

different systems are independent of each other, it is possible they may all attempt to access and use the same network resources simultaneously. Congestion can result in deadlock, and such an occurrence can bring a network to a halt. Thus network layers must offer means of deadlock avoidance or detection and correction.

The network layer is a user of the *link-control layer*, which is responsible for building a point-to-point connection between two system nodes that share a common communications circuit. Link control is aware only of its neighboring node(s) on the shared channel. Each new circuit requires a new link control, as illustrated in Fig. 18.6.6.

It is possible to hide the existence of multiple circuits between two nodes by the inclusion of a multilink sublayer above the individual link-control layers. Link control performs such functions as error detection and correction, framing, flow-control sequencing, and channel-access control.

Link control is the user of the *physical layer.* The physical layer is responsible for transforming the information frame into a form suitable for transmission onto the medium. Thus its major function is signaling, i.e., putting information onto the medium, removing it, and retransforming it into the code structure understandable by the link control.

REAL SYSTEMS

It is important to understand that OSI describes a layered model that allocates functions necessary in the process of communications to each of the layers. However, the actual implementation of any system to attain conformance with the model is left to individual system vendors. Thus, whether there are layers and where a function is actually executed within a single system are matters beyond the scope of ISO. The test of conformance is the successful interoperability between systems. However, one can use the model to place in proper context existing communications protocols, associated entities, services, and products. For example, modems are entities of the physical layer. A data service unit is another such entity, and LAN adapter is still another.

For the network layer, the list is still growing. There are many different subnetworks, each with its own routing schemes to effect the switching of information through the nodes of its unique communications subnetwork. Thus, when one looks at some of the network service providers, such as Telenet or Tymnet, different logical and physical entities performing the same services are observed. Agreement exists among vendors and carriers that if systems are to interconnect, there is a need for a unifying network address structure to avoid ambiguity in identifying systems. There must also be a way of shielding the transport layer entities from various differences within the possible networks that could be involved in achieving end-to-end communications. Such shielding is implemented in the protocols of the Internet and associated software, such as TCP/IP.

PACKET SWITCH

A packet switch is designed to provide the three lower-layer services of the OSI model to its subscribers (physical, link, and network). The interface to access these services is X.25. (See Fig. 18.6.1*b*). When one observes the implementation of various vendor packet switches, it is difficult to see the layers. Most vendors tend to integrate their layers and thus do not clearly define the interfaces that would demonstrate the layer-to-layer independence required. However, because most packet-switched networks are in themselves closed systems, and each generally has its own unique routing algorithms and congestion and flow-control mechanisms, OSI is concerned only with conformance at the top-layer service interface (X.25) and at the gateway between different packet networks (X.75).