Classification of Telecommunication Hardware and Software Systems

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PREFACE

This working paper is part of the IIASA study "Telecommunication Equipment and Administrative Procedures Relevant to Experimental and Operational East-West Computer Connections" supported by the Control Data Corporation, Minneapolis, USA and the Austrian Ministry for Science and Research in Vienna.

The main aim of this chapter is to describe the essential basics of data communication and computer networking for those readers less familiar with these topics, and is, therefore, a condensed, combined version of other known sources and our own work. As much of the information contained herein is also often required as a reference for our own work, it seemed advisable to publish this chapter as a separate working paper.

CONTENTS

0. INTRODUCTION	1
1. BASIC DATA COMMUNICATION FUNCTIONS	1
2. BASIC NETWORK FUNCTIONS	12
2.1. Layers of Control	15
2.2. Computer Maufacturers' and PTTs' Network Architecture	25
2.3. Interfaces Between Layers	33
3. THE ROLE OF THE PTTS AND OF THE COMPUTER SYSTEM MANUFACTURERS	41
4. PACKET SWITCHING VERSUS CIRCUIT SWITCHING	43
4.1. Packet Switching	43
4.2. Circuit Switching	46
REFERENCES	51

CLASSIFICATION OF TELECOMMUNICATION HARDWARE AND SOFTWARE SYSTEMS

I. Sebestyen

0. INTRODUCTION

This chapter is aimed at readers less familiar with data communication and computer networking terms or who are in doubt about how these terms are applied in this study. In the first part of the chapter an introduction is given to the basic elements of data communication, followed by a description of the basic computer network functions and finally the roles of the PTTs and the manufacturers in this process.

1. BASIC DATA COMMUNICATION FUNCTIONS

Computers and their peripherals were linked together over telecommunication circuits practically from the first days of computers in the early 1940s. The functional components of a data-communication system are shown in Figure 1 and Table 1. Data input and output devices, which in almost all cases are provided by the users and not the telecommunication authorities, are connected to some kind of communication control units which perform several important functions of the data communication subsystem (Table 2).

These functions may be performed entirely by hardware devices (such as concentrators, multiplexors) in a hard wired manner, or they may be performed entirely by software devices (such as programs in mini and microcomputer systems). They can also be performed by a combination of hardware and software devices (such as communication processors, front-end processors). In the majority of cases these functions are performed by systems which are installed and operated by the users.

The two communication control units to be linked are interconnected by telecommunication channels. The technically appropriate link between the telecommunication channel and the communication control units is provided through so-called modems. In analogue, voice telecommunication networks, the main task of the modem, is to transform the databits to be transmitted into a suitable signal format which can then easily be transmitted over a telephone network. This was not designed for digital data transmission but for the transmission of analogue signals in voice frequencies (Figure 2). For digital data network, other types of modulation methods are required (Table 3).

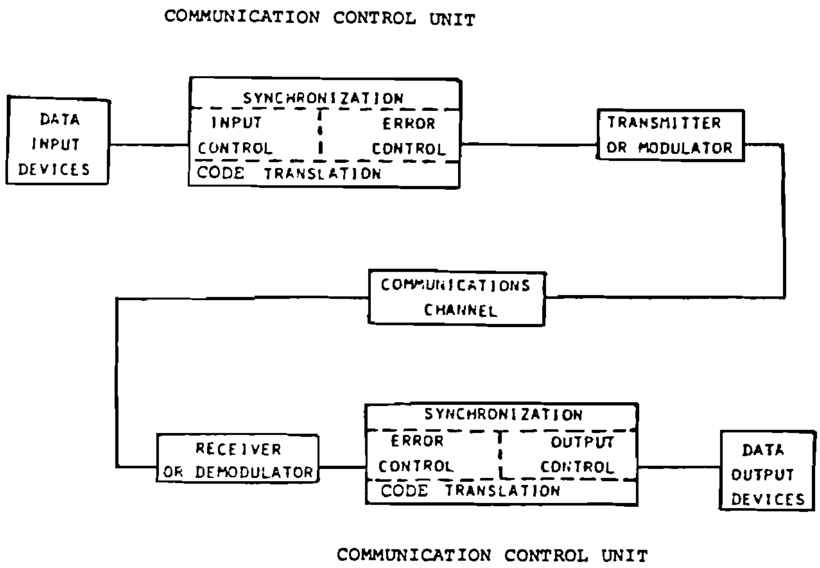


Figure 1. The data communications subsystem, often called the data link, consists of the indicated functional components which are required in every data communications system [1].

Depending on the type of PTT service, modems are provided by the PTTs or by the users. Modems provided by the PTTs are usually in digital data services--such as for the Austrian Datex or the Hungarian Nedix--whereas modems for data communication over analogue voice and telegraphic lines are usually provided by the users. However, to make sure that user modems are compatible with the telecommunication hardware (lines, amplifiers, multipliers, switches, etc.) of the telephone network, they have to be approved by the national PTTs. The national PTTs usually

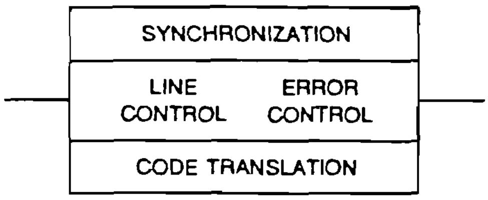
Table 1. System components of a data communications subsystem [1].

Data input or output devices	Communication control units
Keyboard	Memory or buffer storage
P/T reader (paper tape)	Magnetic core
C/R (card reader)	Magnetic drum
M/T unit (magnetic tape)	Shift registers
Facsimile	Delay lines
Badge reader	
Microfilm reader	
CRT/VDT (cathode-ray tube/visual display tube	
MICR (magnetic ink character recognition)	
CCR (optical character reader)	
Transducers	
Sensors	
A/D equipment (analog to digital)	
Computer processors	

Transmitters or receivers	Communication links	Data output devices
Modulators/demodulators	Telegraph lines	P/T punch
Modems	Telephone plant	Card punch
Datasets	Radio	Line printer
Acoustic couplers	Microwave	Teleprinter
Dataphone	Coaxial cable	Teletypewriter
Line adaptors	Wire pairs	M/T unit
		CRT/VDT
		Plotter
		Recorder
		Dials and gauges
		Computer processors
		COM (Computer output microfilm)

provide a list of approved modems in order to simplify the administrative procedure of the connection. Generally, it can be said that if the modems fulfill the appropriate recommendations of the CCITT of the International Telecommunication Union (ITU), they are in practice approved.

Table 2. The functions of the communications-control unit and some example [1].



Synchronization (timing considerations)
- Bit
- Character
- Message

Line control (line protocol, line discipline, "handshaking")
- BISYNC (binary synchronous communications)
- ASCII (American Standard Code for Information Interchange)
- SDLC (synchronous data link control)
- DDCMP (digital data communications message protocol)
- HLDC (high-level datalink control)

Error control (detection/correction)
- Parity—LRC, VRC (longitudinal, vertical redundancy check)
- Polynomial—CRC (cyclic redundancy check)
- ARQ vs. FEC systems (ARQ = automatic request for retransmission
  FEC = forward error correcting)

Code translation (communications codes)
- ASCII
- EBCDIC (extend binary coded decimal interchange code)
- Baudot

The modems and the telecommunication link together provide for actual data transmission. Some main characteristics of the telecommunication channel are given in Table 4, and Table 5 lists the major categories of communication lines. Advantages and disadvantages of the various transmission modes are then summarized in Table 6. The actual

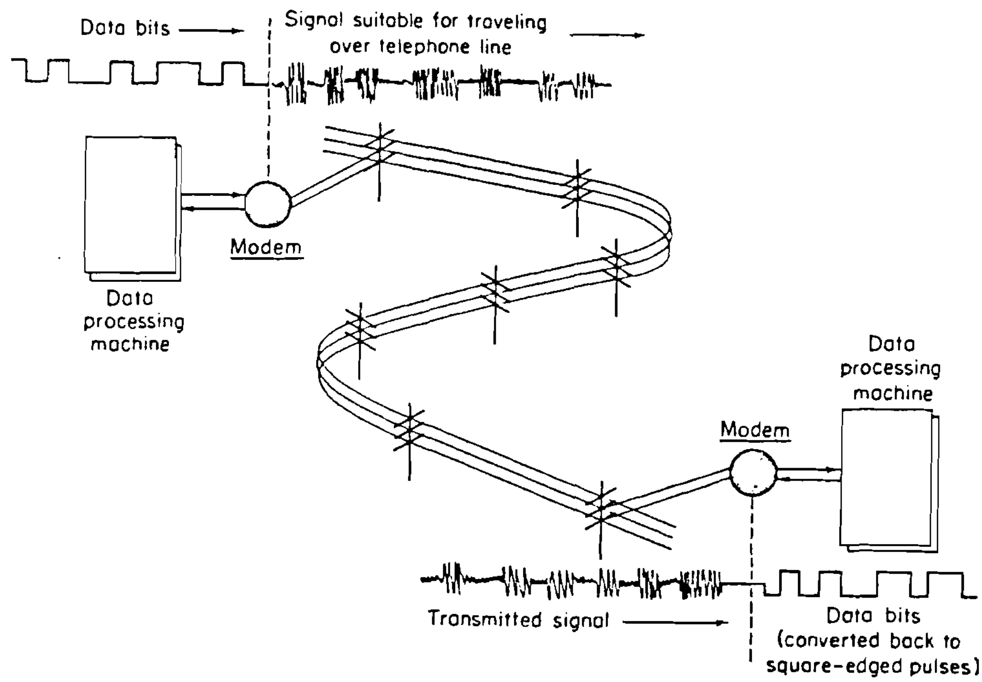
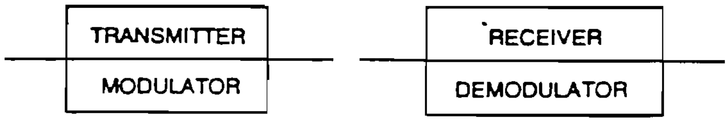


Figure 2. Use of modems [2].

telecommunication channels are always provided by the different PTTs or common carriers. They lease circuits to private users or provide data transmission services over public switched or dedicated telephone or data networks. Parameters of public PTT networks are also defined by appropriate CCITT recommendations.

A summary of the data communication subsystem with its components as discussed in this chapter is given in Figure 3.

Table 3. Modem functions and terminology [1].



Terminology	Modulation method
Transmitter/receiver	Analog
Modulator/demodulator	Amplitude modulation (AM)
Modem	Frequency modulation (FM)
Dataset	Phase modulation (ϕM)
Dataphone	Digital
Acoustic coupler	Pulse (PAM, PDM, PFM, PPM)
Line adapter—erroneous usage	Pulse code modulation (PCM)

There are several distinct ways in which a communications facility (or data-communications system) may be arranged according to topological and utilization considerations. Topologically an organization may be either point-to-point, multipoint, or a network. In terms of utilization a system may be either switched, nonswitched, or a message-switched network. Each of these is discussed in the following paragraphs.

The simplest arrangement is *point-to-point*, which defines the existence of a channel between two stations. Point-to-point service, is indicative only of the kind of connection between two stations, and not what kinds of links make up that connection.

Another type of arrangement is known as *multipoint* or *multidrop* and is comparable to a telephone party line service. In a multidrop sys-

Table 4. Communication channel characterizations [1].

COMMUNICATIONS CHANNEL

Channel modes	Facilities organization type
Simplex	Point-to-point
Half-duplex (HDX)	Multidrop
Full-duplex (FDX)	Switched
Transmission speeds	Network
Bits per second (bps)	Channel type
Characters per second (char/s)	Baseband
Words per minute (wpm) (note: one word contains six characters)	Narrowband
Baud (note: Baud is the plural)	Voiceband
Transmission method	Wideband
Serial-by-bit } Asynchronous or	Multiplexed (FDM/TDM)
Parallel-by-bit } synchronous	Carrier service
Facilities types	Transmission link
Wholly owned private system	
Private leased (PL)	
Public system (DDD)	

tem, any station can communicate with all other stations. Therefore, each station must have the capability of recognizing its own address so that it can respond to messages addressed to it and ignore all other messages.

The third type of arrangement is the *network* where many point-to-point connections exist among three or more stations. In a network arrangement, each station usually has the capability of relaying messages on to other stations, in addition to transmitting and receiving its own

Table 5. Categories of communication line based on [2].

Types of Links	Comments
Digital link	Designed for digital transmission. No modem required. Are code-sensitive in some cases.
Analog link	Transmits a continuous range of frequencies like a voice line. Modem required.
Switched public	Cheaper if usage is low. Switched telephone and data lines are universally available.
Leased (sometimes called "private")	Cheaper than the public lines if usage is high. May have lower error rate. Higher speeds possible on leased telephone lines than switched ones.
Leased with private switching	May give the lowest cost. Combines the advantages of leased lines with the flexibility of switching. Public switched wideband lines may not be available.
Private (noncommon-carrier)	Usually only permitted within a subscriber's premises. See next item.
Private (noncommon-carrier) links:	
In-plant	Very high bit-rates achievable.
Microwave radio	Permissible in special cases for point-to-point links.
Shortwave or VHF radio	Used for transmission to and moving vehicles or people.
Optical or infrared	Used for short links - e.g., intercity - at high bit rates (250,000 bps, typical). No license required. Put out of action by fog or very intense rain.
Speeds	
Baseband	Originating frequencies, for links up to 600 m signals over wire pair do not require modulation.
Subvoice grade	Usually refers to speeds below 600 bits per second.
Voice grade (Narrowband)	Usually refers to analog voice lines using modems of speeds from 600 to 10,500 bits per second.
Wideband	Speeds above those of voice voice lines, most commonly 19,200, 40,800, 50,000, and 240,000.
Multiplexing	
FDM	In frequency-division multiplexing (FDM), a channel carries the signals of several lower speed subchannels. Each of the subchannels is allocated to a specific frequency range.
TDM	Time-division multiplexing (TDM) is a technique where each subchannel is allocated a portion of the transmission time.

Table 6. Modes of transmission [2].

DISADVANTAGES OF THE VARIOUS TRANSMISSION MODES

MODE OF TRANSMISSION	ADVANTAGES AND DISADVANTAGES
Four-wire	Permits full-duplex transmission.
Two-wire	Full-duplex transmission still possible with separate frequency bands for the two directions.
Simplex	Rarely used for data transmission, as there is no return path for control, or error signals.
Half duplex	Commonly used for data transmission, though a full-duplex line may cost little more.
Full duplex — Data in both directions at once	System sometimes cannot take advantage of this, as data cannot be made available for transmitting in both directions simultaneously. Can substantially reduce the response time, however, on a conversational multidrop line. Often requires a more expensive terminal. Commonly used on a link between concentrator and computer.
Full duplex — Data in one direction; control information in the other	A common arrangement, though, as data are still only being sent in one direction at a time, half-duplex transmission may give better value for money at low character rates. With high character rates the line turnaround time may be long compared to the character time and full-duplex operation may eliminate most turnaround delay.
Serial-by-character Parallel-by-bit — Separate wires	Low transmitter cost, but high line cost. Economical for in-plant use. Line costs too expensive for long distances.
Serial-by-character Parallel-by-bit — Separate frequencies	Used on voice lines to give a slow but inexpensive terminal. For efficient line utilization, however, data set costs are high, and receiver cost can be high.
Serial-by-character Serial-by-bit	The most common system, especially on long lines.
Serial-by-character Serial-by-bit — Start-stop transmission	Inexpensive terminal, e.g., telegraph machines. Only one character lost if synchronization fails. Not too resilient to distortion at high speeds.
Serial-by-character Serial-by-bit — Synchronous transmission	More expensive terminal. Block lost if synchronization fails. Efficient line utilization. High ratio of data to control bits. More resilient to noise and jitter than start-stop transmission, especially at high transmission speeds. The most common system on lines of 600 bits per second and faster.
High-speed pulse train	In-plant or private wiring only at present. Low wiring cost with low terminal cost. High accuracy.

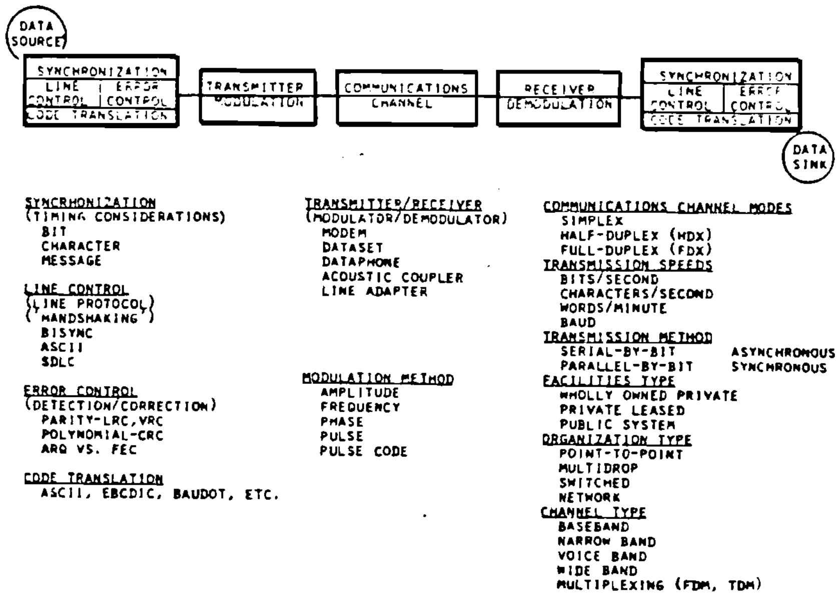


Figure 3. The data communications subsystem with its components as discussed in this chapter [1]

message traffic. These kinds of networks are called *message- switching networks* (or systems).

Networks may topologically be categorized as centralized (or star) networks, decentralized (or distributed) networks, and loop networks. Typically, where an installation consists of one large computer system with connections to a number of data terminals, we see the *centralized network* as the organization type. Systems containing several large computers with a large number of terminals may be arranged as *decentralized networks*. The term *distributed computing* describes an organization consisting of a (mini-) computer-driven message-switching network connected to several large computers (called host computers). Many data terminals provide the capacity for concurrent execution of jobs on more than one host computer. A type of arrangement known as a *packet-switched network* is an implementation of a computer message-switched system, which will be explained in some length later.

The communications system may be either *switched* or *nonswitched* in its utilization. Switched means that station calling capability exists (usually by dialing). A switched system implies that the communications channel exists only for the duration of the call, or message transfer, and does not exist at other times. This differs from systems described as point-to-point or multidrop nonswitched where the communications channel exists even though there is no message transfer taking place.

2. BASIC NETWORK FUNCTIONS

(The following part of this chapter has mainly been adopted from J. Martin's work on computer networks and distributed processing [3]).

In this study we are basically concerned with networks for communication between intelligent machines--some more intelligent than others. We use the word *session* for machines in communication. There are three main phases to communication: establishing the session, conducting the session, and terminating the session.

As with a telephone call, establishing the session involves two separate operations. The first is the process of establishing the telecommunications path so that information can be interchanged. The second is the process of identifying the parties and having them agree to communicate, using specified procedures and facilities.

There are thus five processes:

1. Connecting the transmission path.(physical process)
2. Establishing the session.
3. Conducting the session.(logical process)
4. Terminating the session.
5. Disconnecting the transmission path.(physical process)

Connecting and using the transmission path is an operation entirely separate from that of setting up the session once the path is connected. On the telephone system the former involves the transmission and switching equipment. In computer networks the transmission links and their operation can be regarded separately from the session services and applications which employ them. We will refer to a *transport subsystem* in computer networks which passes messages between the communicating machines. External to this are the *session services*.

We will refer to the collection of services of functions which exist *external tq the transport subsystem* as the *termination subsystem* (see Figure 4).

The termination subsystem consists of software (and possibly some hardware or microcode) in any of the following five places:

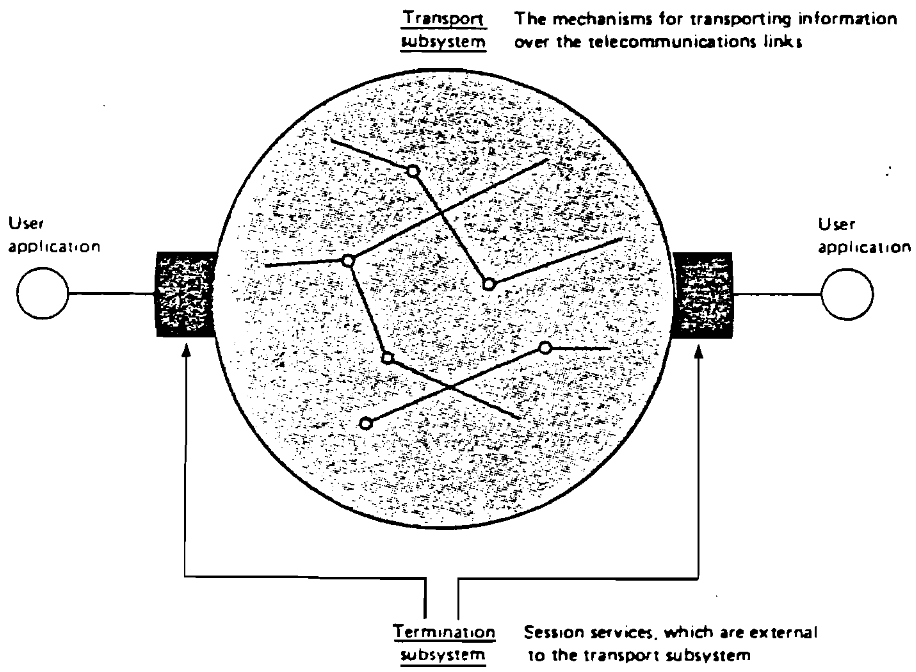


Figure 4.

1. A host computer

2. A front-end communications controller.

3. A terminal concentrator.

4. A terminal controller.

5. An intelligent terminal.

Session services fall into two types: those used when setting up the session and those used when the session is in progress. Networks for distributed processing and computer resource sharing can employ many types of services external to the transport subsystem. They include the editing of data, code conversion, data base services, cryptography, or other techniques for achieving security.

Session services are used prior to the interchange of data to ensure that the communicating parties

- are authorized to communicate,
- have the facilities they need to communicate, and
- agree upon the manner in which they shall communicate.

2.1. Layers of Control

For distributed processing, in which distant machines are interconnected, certain layers of software (or hardware or microcode) are needed around the telecommunications links to make these more useful, to hide the complexity from the network users, and to separate the functions into more manageable slices.

Figure 5 illustrates four types of layers which are fundamental to advanced teleprocessing systems.

The innermost layer is the *physical (electrical) connection* between the data machine and the telecommunications circuit.

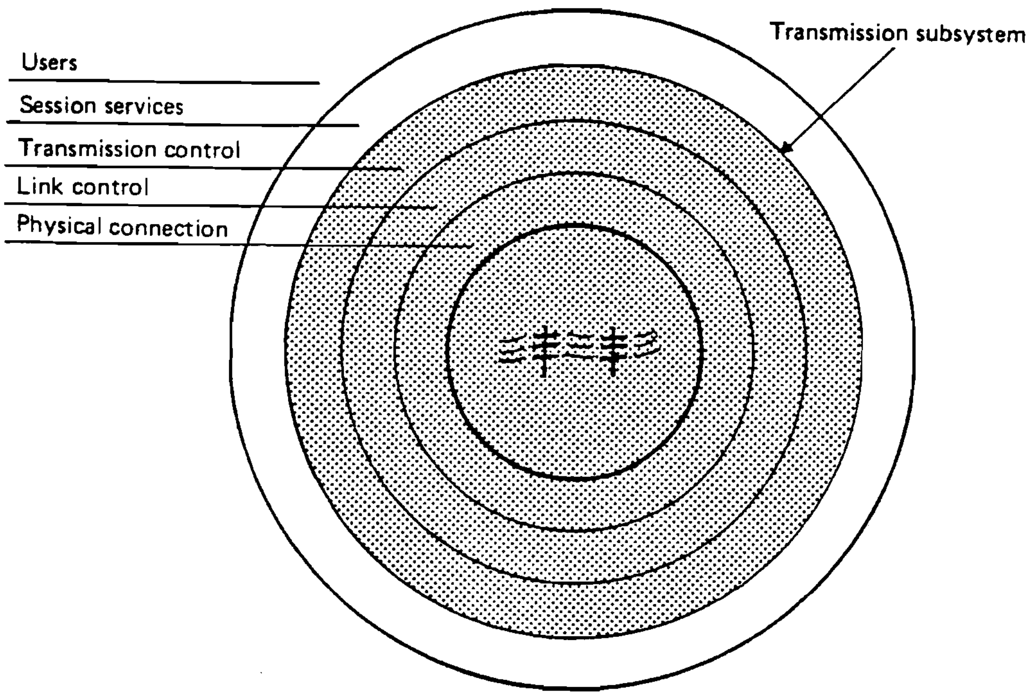


Figure 5. The layers of control for communications are intended to make the physical communications links more capable and more useful.

The next layer is the *link control* which relates to how data are transmitted over a physical line. Throughout the history of teleprocessing there have been many different forms of link control. Some were character-oriented--telex line control, start-stop line control with an

ASCII character set. Some were oriented to blocks of characters--binary synchronous line control, line control for specific terminals, line control for specific applications such as airline reservations. More recently the bit-oriented line control procedures have emerged--HDLC, SDLC, etc.

The third layer, *transmission control*, in conjunction with inner layers, provides the transmission network--the transmission subsystem. The transmission network can be regarded as an entity which the higher levels employ for moving data from one user machine to another through multiple intermediate nodes such as concentrators, packet switches, line controllers, etc.

The layer external to the transmission subsystem in Figure 5 provides a variety of services which are used to establish and operate sessions between the using machines.

These four layers are fundamental to data networking and distributed systems. They are found in all of the computer manufacturers' architectures for distributed processing. Their detail differs somewhat from one manufacturer to another especially in the outermost layer.

Given the immense proliferation of machines that is now occurring, one of the activities most important at present and to the future of data processing is the setting of standards to enable machines of different manufacturers and different countries to communicate. As a start in the setting of such standards ISO, the International Standards Organization, has defined seven layers, further subdividing the four layers of Figure 5. These are shown in Figure 6.

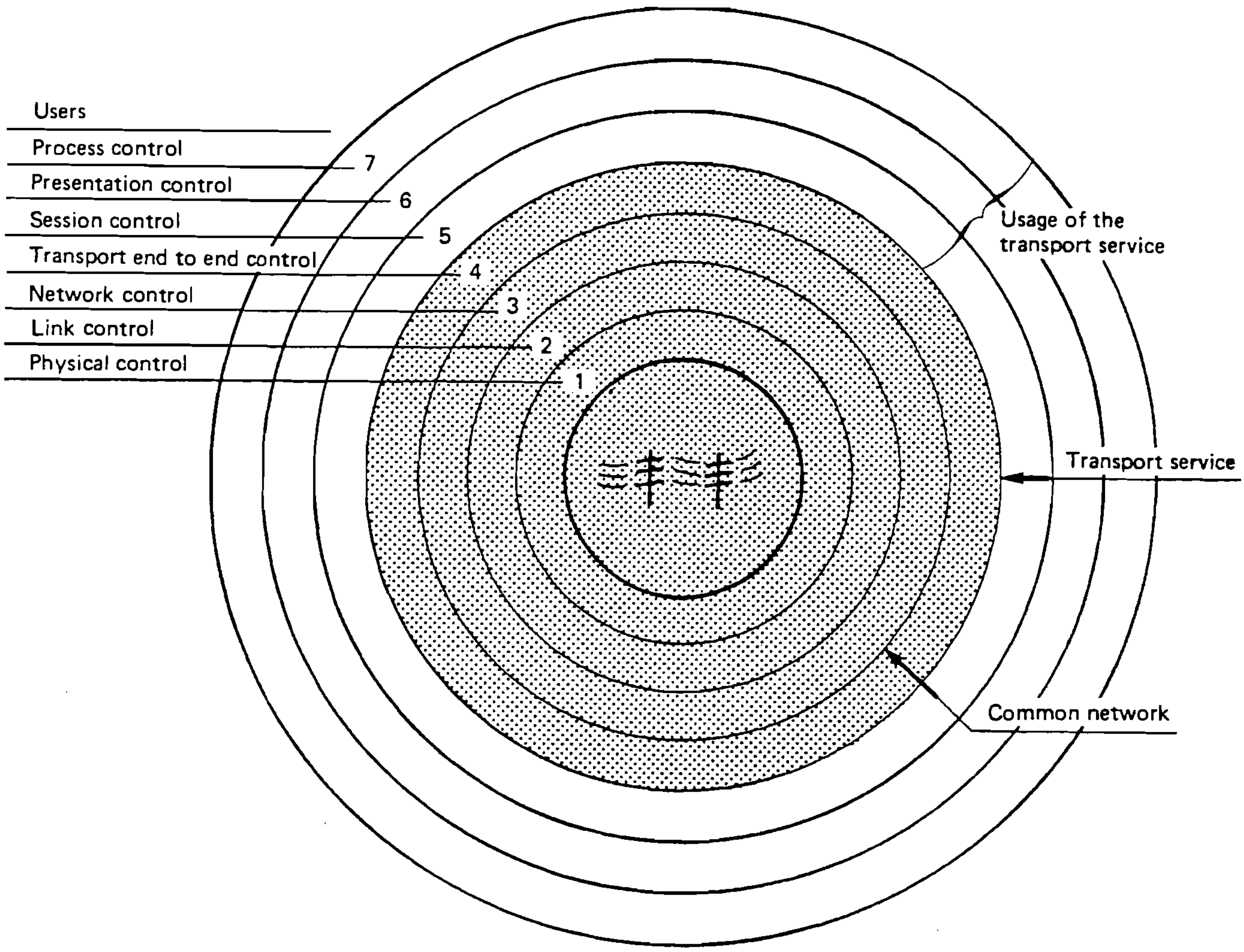


Figure 6. The International Standards Organization's seven layers of control for distributed processing.

Their functions are as follows:

Layer 1: Physical Control

The innermost layer relates to setting up a physical circuit so that bits can be moved over it. It is concerned with *the physical, electrical, functional, and procedural characteristics to establish, maintain, and disconnect the physical link*. If the user machine employs an analog circuit like a conventional telephone line, it will be connected to a modem. Its inteface with the modem is a generally accepted standard, e.g., EIA RS 232-C and CCITT Recommendation V.24. If a digital circuit is used, a newer Recommendation for the physical interface, CCITT Recommendation X.21 can be used, or support for a V.24 interface can be achieved through the use of X.21 *bis*.

Layer 2: Link Control

This layer relates to the sending of blocks of data over a physical link. It is concerned with issues such as:

- How does a machine know where a transmitted block starts and end?
- How can transmission errors be detected?
- How can recovery from transmission errors be accomplished so as to give the appearance or an error-free link?
- When several machines share one physical circuit how can they be controlled so that their transmissions do not overlap and become jumbled?
- How is a message addressed to one of several machines?

The transmission of physical blocks of data requires a *physical link control* procedure which specifies the headers and trailers of blocks which are sent, and defines a protocol for the interchange of these blocks. Such procedures have been used since the earliest days of data communications. For distributed processing a more efficient line control procedure than start-stop or binary synchronous is desirable, which permits continuous transmission in both directions, of data which can contain any bit pattern. The ISO has specified such a line control procedure, HDLC (Higher-level Data Link Control). The CCITT, and various computer manufacturers, each have their own variants of this which differ slightly in subtle details.

Layer 3: Network Control

Prior to 1975, Layers 1 and 2 were all that were specified. These were adequate for communication between machines connected to the same physical line. The world of distributed processing and computer networks requires more layers, and these are substantially more complex.

Layer 3 relates to *virtual circuits*, sometimes called *logical circuits* or *logical links*. These are make-believe circuits. They do not exist in physical reality but Layer 3 pretends to the higher levels that they do exist.

The path between computers may at one instant be via a number of physical lines as shown in Figure 7. Each physical line spans two network machines which must use the Layer 1 and Layer 2 procedures to exchange data. The users do not wish to know what route the data travels or how many physical lines it travels over. The user machines want a simple interface to a virtual circuit. The Layer 3 of control creates the virtual circuit and provides the higher levels with an interface to it.

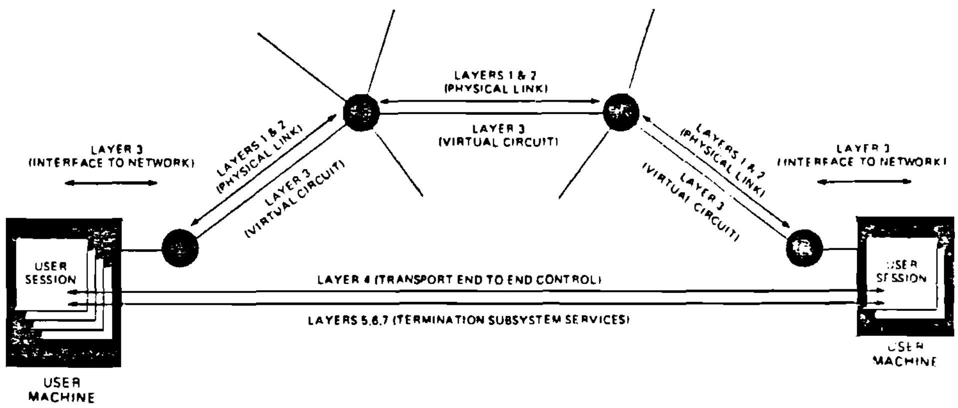


Figure 7.

On some systems, the route on which data travels between two user machines varies from one instant to another. The network machines may reqire that users' messages be divided into slices, called packets, no greater than a certain length. The packets become out of sequence during transmission. The packets must be reassembled into messages after transmission. On some networks the packets become out of sequence during transmission. The rules for Layer 3 state that the network must deliver the packets to the user machine in the same sequence as that in which they were sent by a user machine.

There are many such complications in the operation of a virtual circuit. Layer 3 provides a standard interface to the virtual circuit, and as far as possible hides the complex mechanisms of its operation from the higher layers of software.

Layer 4: Transport End-to-End Control

The inner three layers of Figure 6 represent a common network which many machines may share, independently of one another. It is possible that a service might occasionally lose a "message". To ensure that this has not happened, two users might apply their own end-to-end controls, such as numbering their "messages". Layer 4 is concerned with similar end-to-end controls of the transmission between two users having a session.

Figure 7 illustrates that whereas Layer 3 is concerned with the interface between the user machine and the network, Layer 4 (and the higher layers) is concerned with the end-to-end integrity controls to prevent loss or double processing of transactions, flow of transactions, and addressing of end user machines or processes.

The lower four layers—as mentioned above--provide a *transport* service. They are concerned with the transport of blocks of bits from one user to another, but not with the manipulation of those bits in any way. Some of the higher layers manipulate the bits.

The transport service takes many different forms. Sometimes it is a packet-switching network using the international standards from Layer 3 and below (CCITT Recommendation X.25, discussed later). Sometmes it is quite different--wideband point-to-point circuits, satellite circuits, and so on. The interface from higher layers or from user machines to Layer 4 is intended to provide a *standard interface to users of the transport service independent of what network type is used.*

Layer 5: Session Control

The task of setting up a session between user processes can be complex because there are so many different ways in which machines can cooperate.

Layer 5 standardizes this process of setting a session and of terminating it. If something goes wrong in mid-session Layer 5 must restore the session without loss of data, or if this is not possible terminate the session in an orderly fashion. Checking and recovery are thus functions of Layer 5.

In some types of sessions a dialogue takes place between machines and a protocol must regulate who speaks when and for how long. In some cases the two machines speak alternately. In others one machine may send many messages before the other replies. In some sessions one machine may interrupt the other; in other cases not. The rules for how the dialogue is conducted need to be agreed upon when the session is set up.

Layer 6: Presentation Control

Layer 6 contains functions relating to the character set and data code which is used, and to the way data is displayed on a screen or printer. A stream of characters reaching a terminal will result in certain actions to give an attractive display or print out.

There are many possible functions concerned with the presentation of data. These are carried out by Layer 6. Many of them relate to the character stream, its codes, and the ways they are used. In some cases application programmers perceive a *virtual terminal* or *virtual display space*. Input/output statements relate to this make-believe facility, and the Layer 6 software must do the conversion between virtual facility and the real terminal.

It is desirable that devices with different character sets should be able to communicate. Conversion of character streams may therefore be a concern of Layer 6. The character stream may be compacted into a smaller bit stream to save transmission costs. This may be a Layer 6 function.

Encryption and decryption for security reasons may also be a Layer 6 function.

Layer 7: Process Control

Layer 7 is concerned with higher level functions which provide support to the application or system activities, for example, operator support, the use of remote data, file transfer control, distributed data base activities, higher level dialogue functions, and so on. The extent to which these are supported in the network architecture and in the software external to the network architecture, such as data base software, will differ from one manufacturer to another.

When distributed files and data bases are used various controls are needed to prevent integrity problems or deadlocks. Some types of controls for this are strongly related to networking, for example, the timestamping of transactions and delivery of transaction in timestamp sequence (sometimes called pipelining).

Pacing is necessary with some processes so that the transmitting machine can send records continuously without flooding the receiving machine, or so that an application can keep a distant printer going at maximum speed.

2.2 Computer Manufacturers' and PTTs' Network Architecture

The architectures for distributed processing from the various computer and minicomputer manufacturers and the various PTT data services, contain all or part of the seven layers we have described. Layers 1, 2, and 3 are usually clearly distinguished, but the functions of Layers 4, 5, 6, and 7 may be intermixed and not broken into those layers recommended by the ISO. Increasingly, as distributed processing technology evolves, the clean separation of the layers is becoming a necessity.

At present there are two trends. According to one trend there is a strong tendency to set up international standards starting from the simplest and most basic Layer 1 to higher layers. International standards exist along these lines at present and are widely accepted for Layers 1, 2, and 3. They are employed not only by the computer industry but by the telecommunications industry in creating public data networks.

Partly because of the telecommunications industry use of Layers 1, 2, and 3, the computer industry is building hardware and software which employs these layers. Some computer vendors, however, have created their own incompatible versions of Layer 3. Old incompatible versions of Layer 2 are still in use and likely to remain so because old protocols take a long time to die.

At the higher layers different manufacturers are going their own way, and creating their own in-house standards. These are perceived by individual manufacturers as being extremely important because they make the many different machines in the product line interconnectable. But although machines of one manufacturer are interconnectable, those of different manufacturers cannot be interconnected at the higher layers. They can be interconnected only at Layers 1 and 2, and sometimes Layer 3.

Developments to further specify higher level protocols are proceeding well. The Institute for Computer Sciences and Technology of the U.S. National Bureau of Standards, for example, has recently specified Layer 4 (Transport) [4] and Layer 5 (Session) [5], which, after passing through the complicated and time consuming standardization procedure of the ISO and CCITT, might one day be widely accepted.

In a distributed processing network the layers may be spread across a variety of different machines. Figure 8 shows several types of machines. A central processing unit may be designed to contain all seven layers like the computer on the left in Figure 8, or, probably better, some of the layers may be removed to a separate *front- end* processor. A front-end processor may handle the lower three layers or it may handle

Layer 4 functions also.

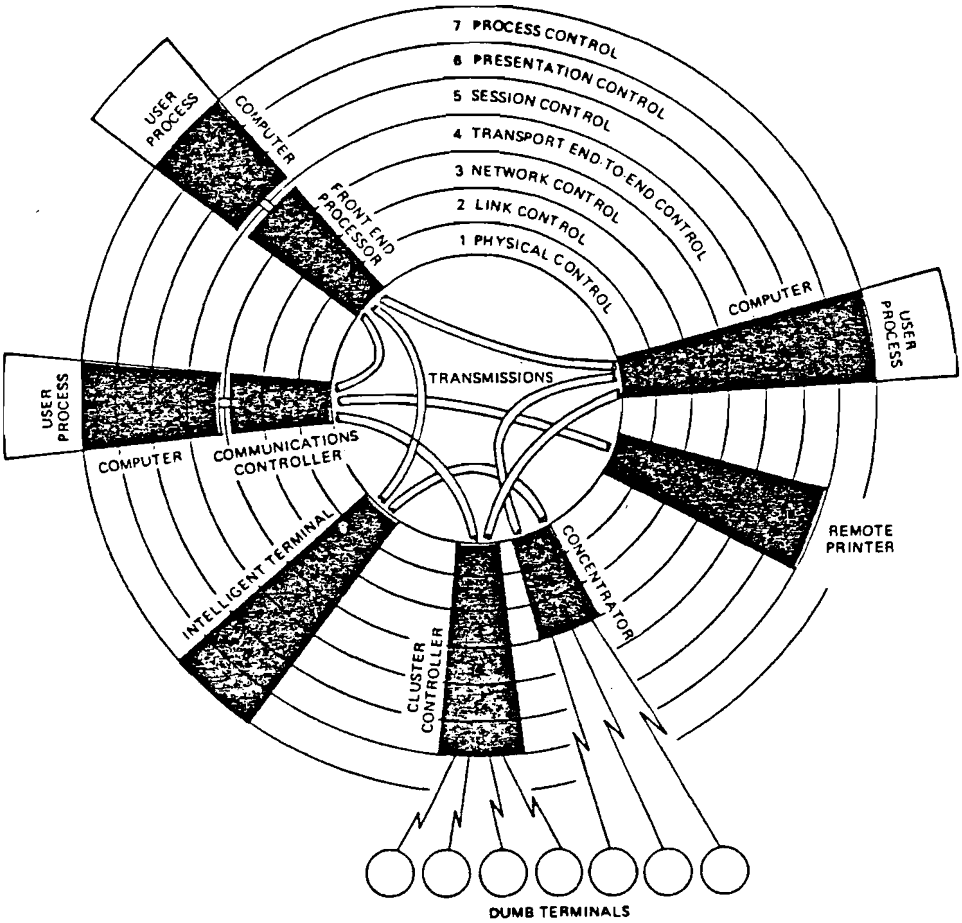


Figure 8. The layers of control are allocated between machines in different ways

Terminals containing microprocessors may have enough power to handle all the layers like the intelligent terminal in Figure 8. This is less complex than the networking software at a computer site because the terminal supports only one session at a time, uses only one logical channel, and contains few management functions. In many cases the terminals are simpler machines connected to a terminal cluster controller, and it is this controller which contains the networking software, as shown at the bottom of Figure 8. The terminals may be in the immediate vicinity of the controller, or they may be far away, connected by telecommunications, in which case the controller may be regarded as a concentrator. A concentrator may contain only the lower three layers.

Figure 8 does not show mid-network nodes such as packet-switching machines or concentrators. These may be part of the transport subsystem, with no Layer 5, 6, 7 or even Layer 4 functions.

The logical and physical Layers 1, 2, and 3 are found in almost all architectures. They are fundamental: the existence of an electrical interface to the transmission circuit (Layer 1), the existence of a link control procedure (Layer 2), and the separate existence of a common network to which many different machines can be connected (Layer 3).

The common network may be a public network or may be private. Layers 1, 2, and 3 are vital to public networks. Private networks may use the same standards and then they can be interconnected to public networks also.

End-to-end control of the movement of data in a particular session is often (but not always) important. This is done by Layer 4. Where one module of Layer 3 is needed in a machine which is connected to a network, one module of Layer 4 is needed *for each session* in that machine.

Session services are also needed for each session. The concept of a session services subsystem is fundamental. However in software architectures it is not always broken into Layers 5, 6, and 7. The architecture may have one layer for providing session services.

The second trend which can presently be observed is the definition and standardization of the services and functions of the higher layers (at the application and presentation levels). All other underlying layers have to ensure that those functions defined at higher layers can actually be fulfilled. Often a certain higher level function can be satisfied by quite different lower layer functions based on pragmatic solutions.

Examples of this trend are the present standardization efforts of the new types of public services such as teletex--the super fast computer supported telex, and videotex--a combination of telephone, television set, and computer technology.

The standardization effort for teletex on the Application Layer 7 and the Presentation Layer 6 has led to the sensible compromise that such services, according to the CCITT Recommendation F.200, can be provided over structurally different types of telecommunication networks (e.g., circuit-switching data networks, packet-switching data networks, or simple telephone networks), by a unified speed of international interconnections of 2400 bit/sec (Figure 9).

This philosophy has enabled all PTTs interested in introducing teletex services to begin building up their national systems with no restrictions on the type or status of their own telecommunication network.

The standardization of videotex services is also being concentrated on the highest layers. On lower layers different types of services can again be taken into account. Briefly, according to [7], each layer is

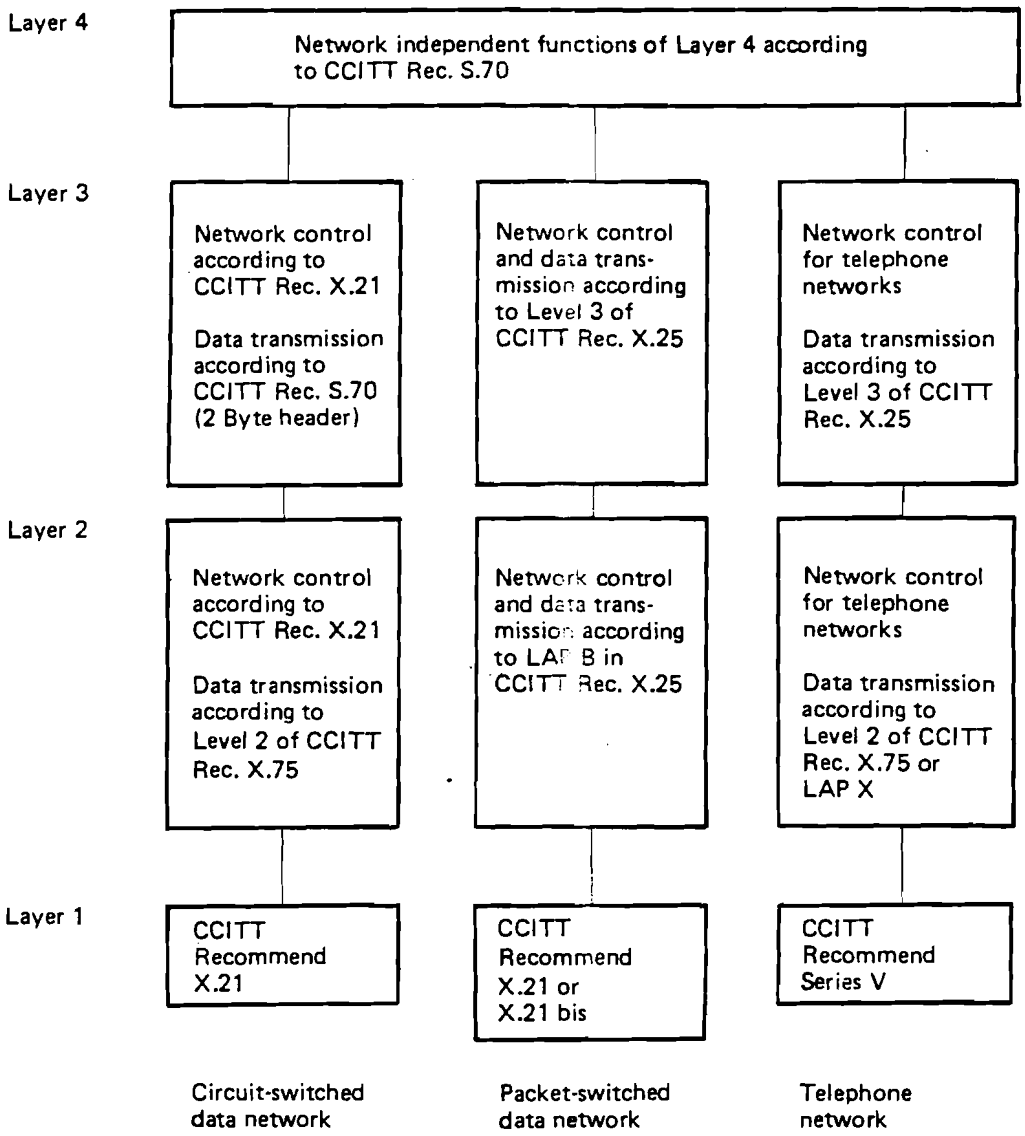


Figure 9. Protocol functions/interface definitons for teletext services over different types of networks (according to CCITT Rec. S.70)

described in terms of teletext and videotex services:

Application Layer (Layer 7). Protocols of this layer directly serve the end user by providing the distributed information service appropriate to each particular videotex application, i.e., the application layer defines the information service itself, e.g., Prestel, Bildschirmtext, Videotext.

Application standards define the way in which a user will be served by the teletext or videotex system. They concern the functions or services available to the user. They incude the control functions (to clear an unwanted entry), the service functions (to select an application provided by a videotex service), the retrieval functions (e.g., to obtain direct access to a page, to progress from frame to frame, to retrace the progression of the user's action), and the display options (24 rows or 20 rows, 40 or fewer columns).

Presentation Layer (Layer 6). The purpose of this layer is to provide the set of services that may be selected by the application layer to enable it to interpret the meaning of the data exchanged. These services are for the management of the entry, exchange, display, and control of structured data. For videotex systems, the presentation layer protocols define the character repertoire (sets of usable characters and their interpretation), text and graphics coding schemes (alphamosaic, alphageometric, alphaphotographic, and dynamically redefinable character sets), and attribute coding (coding/parallel attribute). Standard protocols at this layer allow applications in an Open Systems Interconnection environment to communicate without unacceptable costs in interface variability, transformation, or application modification.

Session Layer (Layer 5). The purpose of this layer is to assist in the support of the interactions between cooperating presentation entities, i.e., procedures for log-on, user identificaton, billing, and statistics gathering.

These two layers or levels, in particular the presentation level, are the most critical in the videotex debate as they relate to the protocols or procedures and are generally but not always invisible to the immediate user. They include graphics sophistication, serial/parallel attribute codes for graphics, bit-error rates, data transmission rates, and fixed or variable format transmissions.

The lowest four layers, also called Transmission Layers, are primarily the concern of the communications network provider. The transmission requirements for digital data over the three principal teletext/videotex communicaton media--telephone (two-way videotex), broadcast television, and cable television (one-way videotex or teletext)--differ, and therefore different standards are required for each. These standards would be transparent to the actual service provided.

Transport Layer (Layer 4). This layer provides transfer of data between two videotex systems or between a user's terminal and the videotex computer. Its task is to optimize the use of available communicatons services to provide the performance required for each intersystem connection at a minimum cost; e.g., if the communicatons network is a packet-switched network, the transport protocol defines the routing algorithm and the flow control procedures.

Network layer (layer 3). This layer provides functional and procedural means to exchange data between two videotex systems (or a terminal and the videotex computer) over a communication network connection; e.g., for packet-switched networks this protocol defines how data is assembled into packets (CCITT Recommendation X.25, level 3).

Data link layer (layer 2). The purpose of this layer is to provide the functional and procedural means to establish, maintain, and release data links in a communication network, e.g., SDLC (synchronous data link control), HDLC (high-level data link control).

Physical layer (layer 1). This layer provides mechanical, electrical, functional, and procedural characteristics to establish, maintain, and release physical communications between two videotex systems (or a terminal and and videotex computer); e.g., CCITT V.24, lines 15 through 18 of the vertical blanking interval.

On international level at present two recommendations on videotex standards--S.100 ("International Information Exchange for International Videotex", which deals with the characteristics of coded information and display formats) and F.300 ("Videotex Service", which describes the standard parameters for a public videotex service)--they were both ratified by the CCITT in October and November 1980. In May 1981 the European Conference of Post and Telecommunications announced the definition and adoption of a verified European videotex standard (CEPT, 1981) a presentation level protocol, followed by AT&T's announcement of the North American Videotex standard.

The above outlined two main trends actually lead to the emergence of two interconnected OSI-layer pyramids (Figure 10), one in normal standing position and one upside down. By this, for example, the same national packet switching network provides the lower layer services for two way videotex, for teletex, for closed user group networks, etc., on the other hand, a specific high layer application--such as videotex or teletex--can be built on different low layer services.

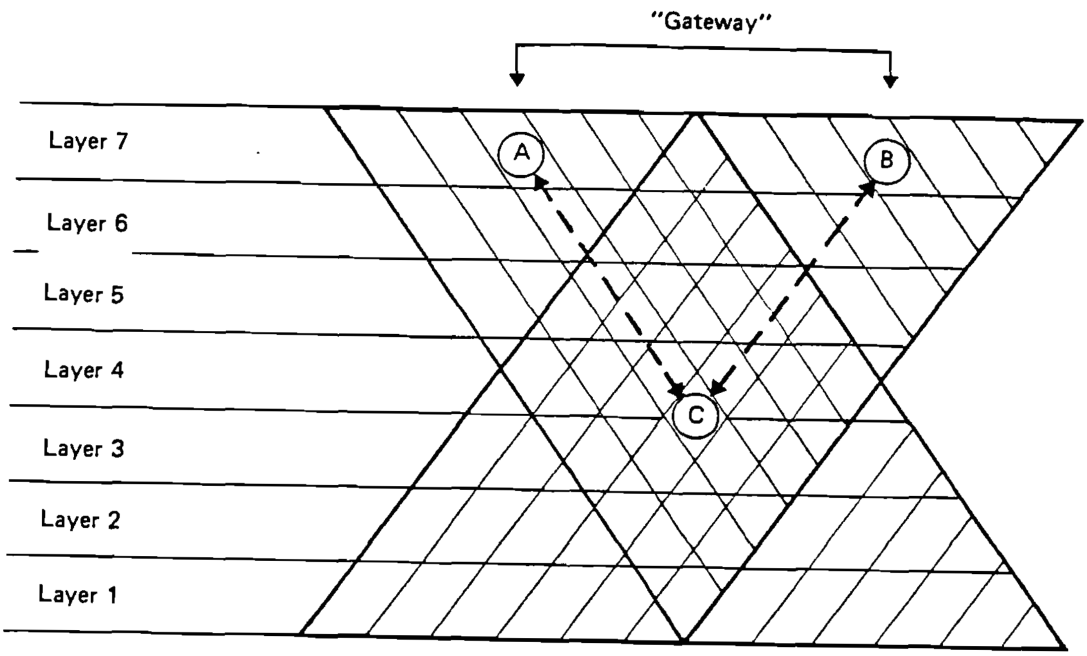


Figure 10. OSI-layer pyramids

Between two high layer services (A and B in our example) "gateway"--services can be developed and provided, if desired, such as a possible gateway service between videotex and teletex for message sending applications.

2.3. Interfaces Between Layers

Particularly important in a layered architecture are the interfaces between the layers. These must be precisely defined and adhered to rigorously. As mentioned earlier they are all canditates for standardization, either in the international standards arena or in the architectural standards employed by a major common carrier or computer manufacturer.

Each layer in an architecture for distributed processing communicates with an equivalent layer at the other end of a link (Figure 11).

Sessions take place between user processes. The higher layers (4, 5, 6, and 7) relate to these sessions. The lower layers are not concerned with the sessions, but with the movement of data through a network shared by many machines. Figure 12 illustrates this. Layers 4, 5, 6, and 7 provide end-to-end communication between the sessions in user machines. Layers 1, 2, and 3 provide communication with the nodes of a shared network. These nodes may be packet switched, communications controllers, concentrators, or other machines designed to make a data network operate.

Each layer of a layered architecture (except Layer 1) may add a header to the messages sent. This header is interpreted by the equivalent layer at the other end of the link.

Layer 2 frames contain a header to be used by the Layer 2 mechanisms at the other end of a physical link. They also contain a trailer which is used to indicate the end of the frame and to check whether the frame contains any transmission errors.

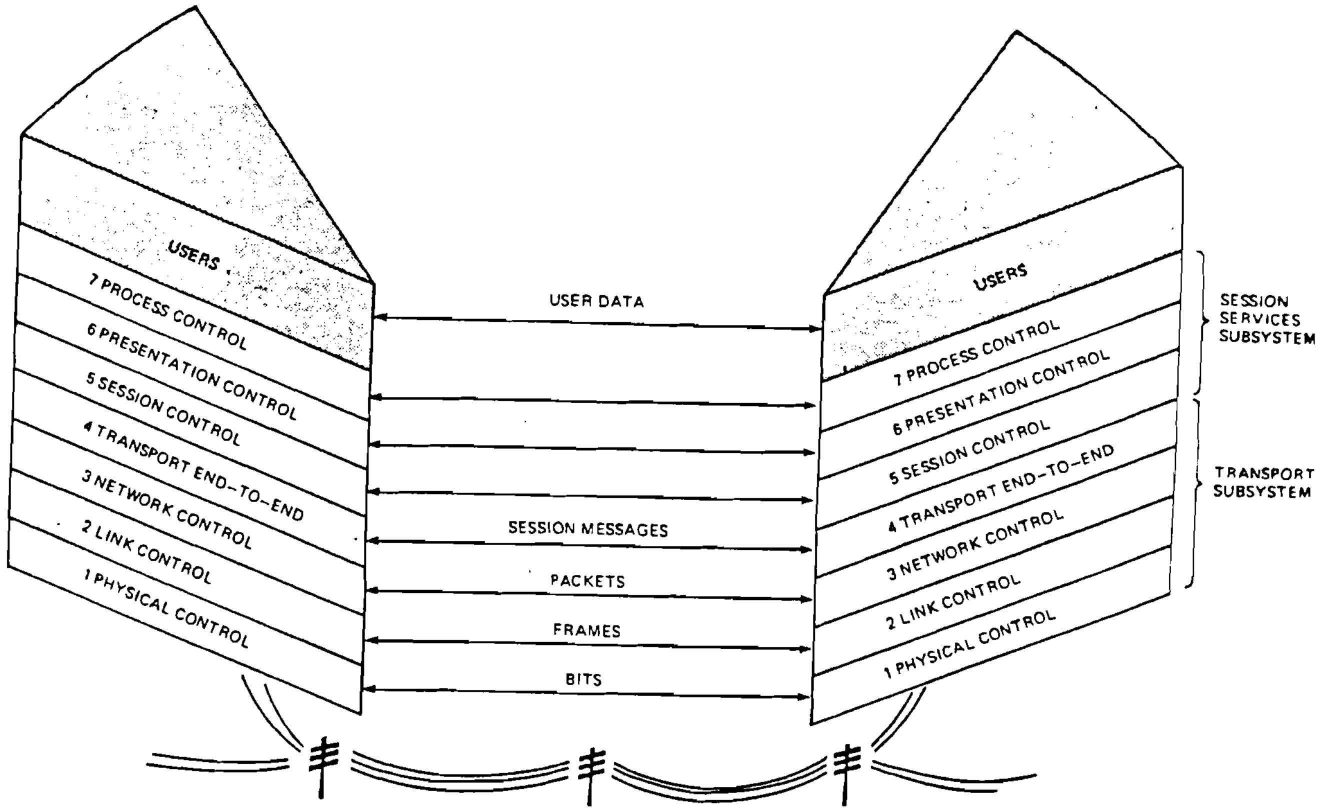


Figure 11. Each layer contains different functions. Each layer communicates with its peer in another machine

Layer 3 packets contain a header which directs the packet to its destination and is used by Layer 3 at that destination. Layer 4 messages may contain a header intended for use by the distant and complementary Layer 4 and so on.

In general, the Layer N header is not inspected by Layer N - 1. It appears like any other data being transmitted. Layer N - 1 then adds its

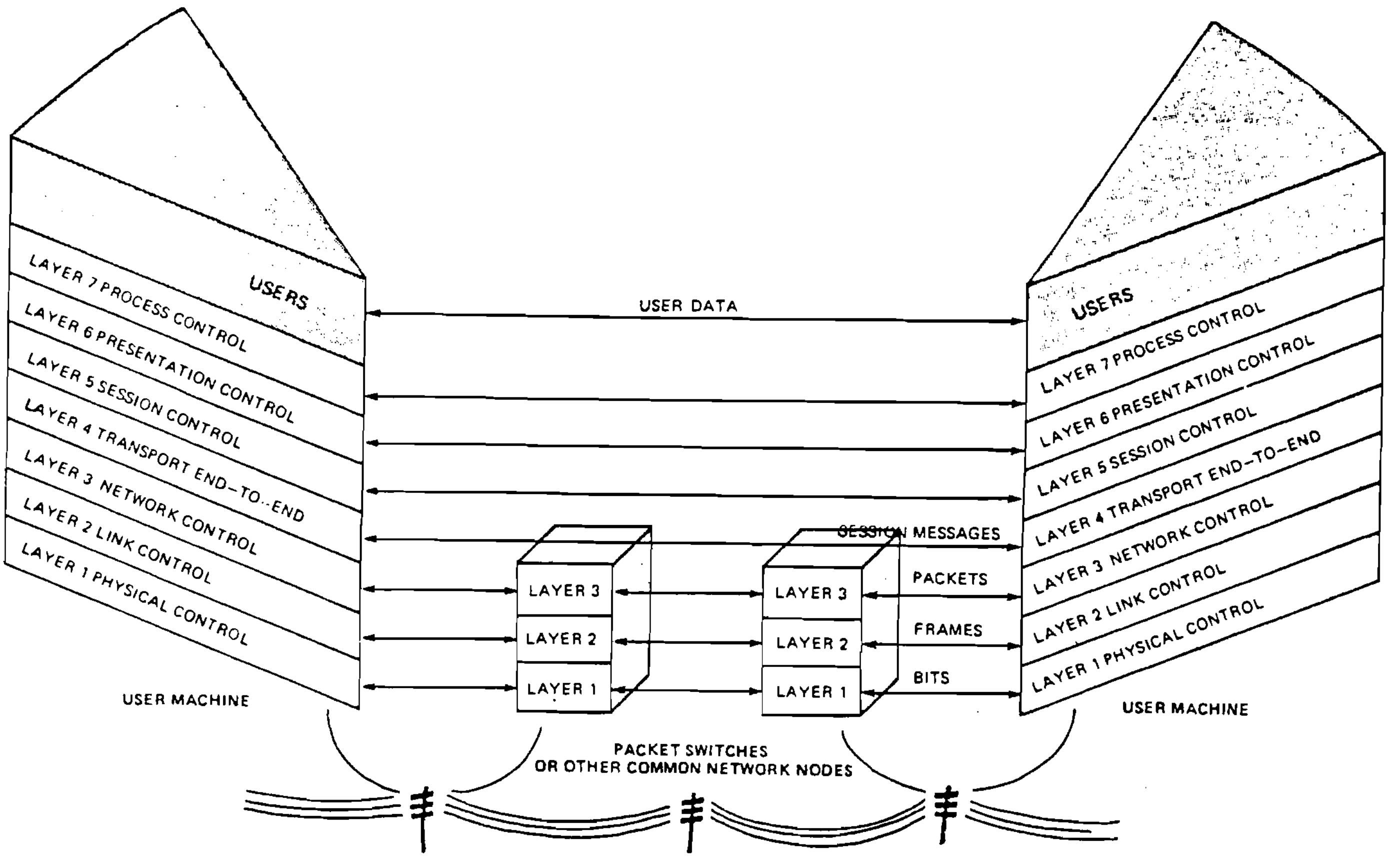


Figure 12. Layers 4 to 7 provide end-to-end communication between session software. Layers 1 to 3 provide an interface to a shared network

own header (shown in Figure 13).

The most commonly used two interfaces which are of importance for the PTT services are shortly mentioned in what follows:

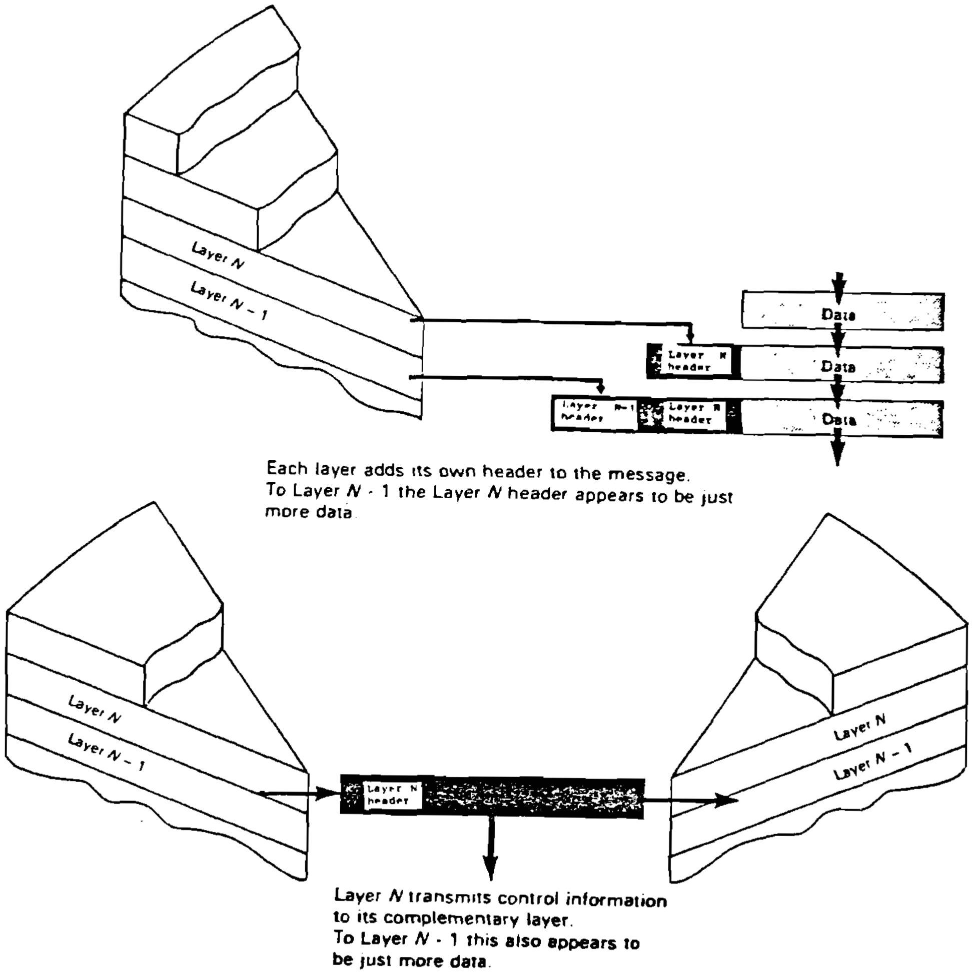


Figure 13. There are two firms of communication between equivalent layers: message headers for that layer, and control messages passed between the layers. These are, or will become, the basis of international standards

Layer 1 Interface

The innermost interface, Layer 1, is usually the well-established 25-pin plug connection to a modem or other transmission equipment. Any data machine, with or without software can send bits over it. A simple terminal may use start-stop transmission. If this terminal is connected to a computer network it will be via a concentrator or gateway processor such as that in Figure 14, and this machine will use the higher software layers.

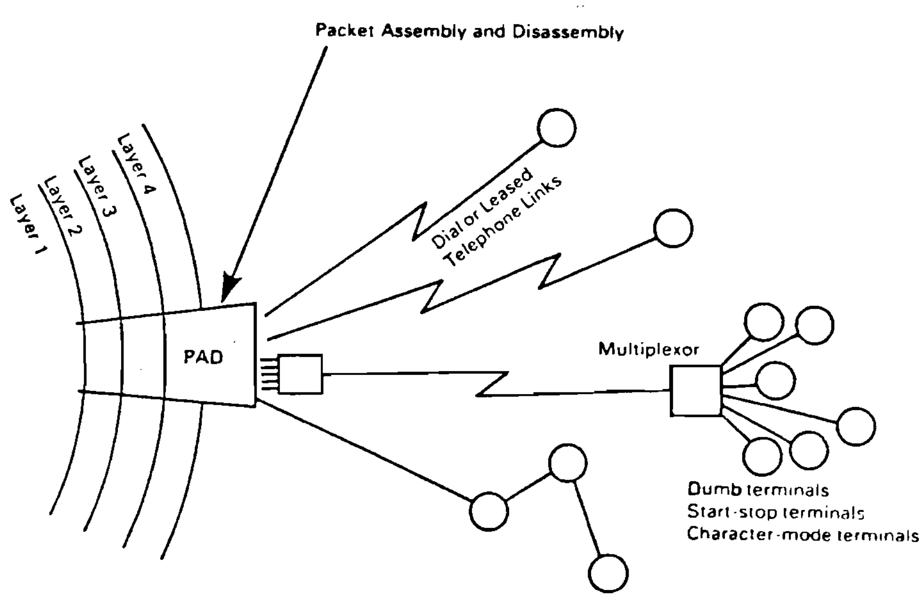


Figure 14. Dumb terminals connected to the network via a PAD (Packet Assembly and Disassembly) interface

Layer 2 Interface

In some cases machines drop down to the Layer 2 interface, *physical* data link control, as shown in Figure 15, i.e., they have no Layer 3 or higher layer. Layer 2 control is often built into a terminal.

Terminals are often connected to a computer via a network interface machine as shown in Figure 15. They may be remote from this network node; connected to it via a physical link such as a leased or dial telephone line. On this circuit Layer 2 link control is used. However, it might be different from the Layer 2 link control used by the network. Most networks employ an advanced data link control procedure (such as HDLC, SDLC, UDLC, etc.). Terminals may use simpler or older procedures. They may be *binary synchronous* or *start- stop* terminals.

Bypassing the Inner Layers

A channel of a distributed processing system may bypass all or some of the inner layers when components can be connected more directly. Two machines in the same building may be connected by a high capacity channel rather than a virtual circuit. Figure 16 shows user processes which employ the Session services layers but these modules are directly interconnected, bypassing the normal transmission subsystem layers. The session services subsystem uses the standard interface to Layer 4.

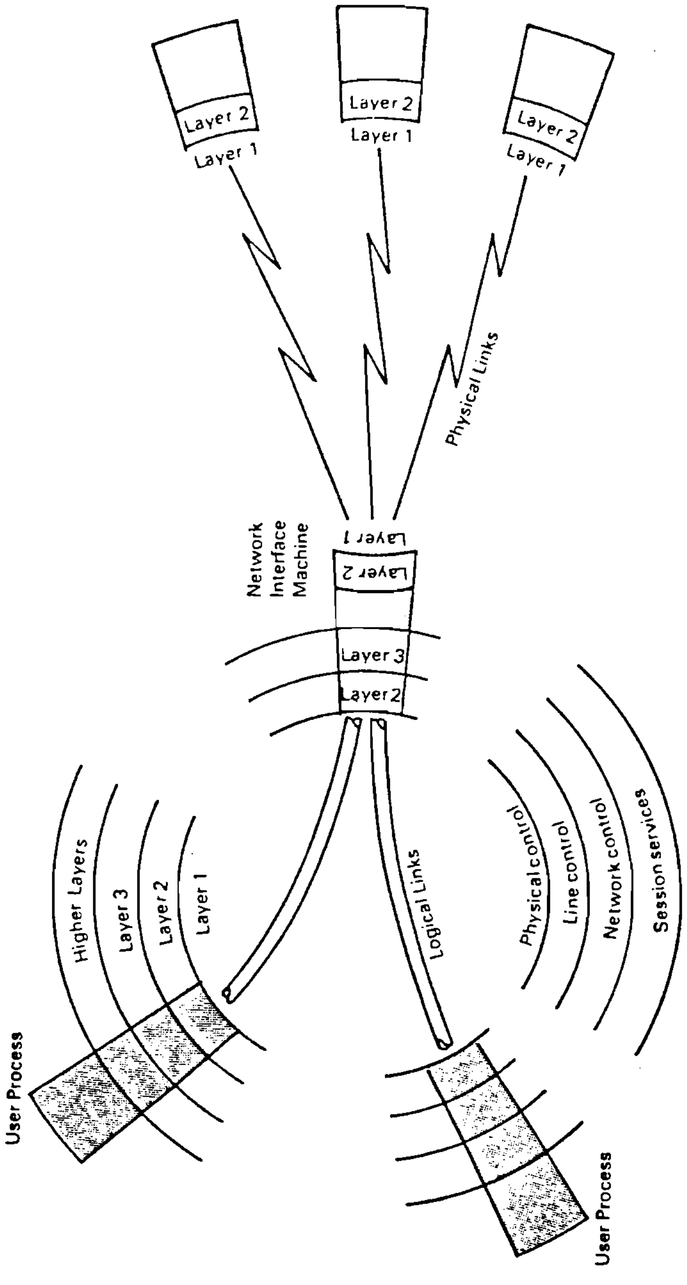


Figure 15. Terminals without Layer 3 software (or hardware) are connected to physical circuits going to a network interface machine

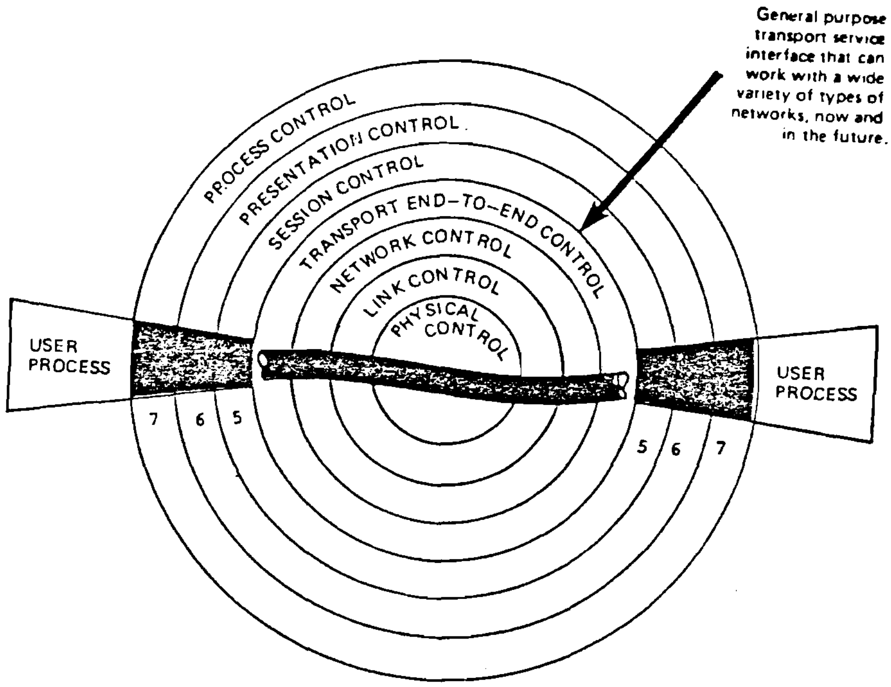


Figure 16. A system which uses the session services layers but not the transmission subsystem layers. It employs the ***standard interface to Layer 4***, but transmission does not use CCITT X.25 mechanisms or similar. It may be a wideband point-to-point channel, CATV, communication satellite network, office network, or merely a computer channel connecting machines in a building

The transmission media used in Figure 16 might be a point-to-point connection, or circuit-switched connection which does not need messages to be sliced into packets and which avoids the complications of Layer 3. It might be a communication satellite channel, an office network like a local wideband network, cable television, or merely a conventional computer channel connecting machines in building. Some digital circuit-switched facilities use CCITT X.21 physical control. The interface to Layer 4 is intended to be a general-purpose transport service interface which can work with a wide variety of different types of networks.

To the user processes it may make no difference whether or not Layers 4, 3, 2, or 1 are used.

3. THE ROLE OF THE PTTS AND OF THE COMPUTER SYSTEM MANUFACTURERS

The logical and physical functions of the OSI model layers can be with exception of Layer 1 (physical layer) performed in principle both by the PTTs and the computer system manufacturers. The physical layer is in all cases the "territory" of the PTTs. In which sense and to what extent this is actually done will be described in subsequent chapters dealing with the individual PTT administrations and their services.

The layers 2-7 can be performed to a certain extent by the PTT services as well. This depends on the type of service to be provided, but also on the general servicing policies of the respective PTT administrations.

As it will be shown in what follows there are PTT administrations, such as MINSVJAZ in the USSR, which has the policy to provide service only for layer 1 and leave the rest to the computer system manufacturers and above all to the users. The Hungarian and the Austrian PTT, on the other hand, adopted the policy to provide broad PTT services on certain higher layers as well. The Austrian Administration offers or plans to offer service (in addition to the physical layer service) for Layers 2 and 3 (public circuit and packet-switching networks), and application and presentation layer services, such as teletex and videotex. The Hungarian PTT, which offers much the same range of services, with the exception of Layer 3 services by means of a public packet-switching network. Because of policy and economical considerations, the Hungarian PTT administration leaves this service to the users and to the computer system manufacturers and only provides the required lowest layer on the physical level.

The provision of potential "gateway" services between high level PTT services (e.g., between teletex and videotex), does also depend on general policy of the PTT administrations.

4. PACKET SWITCING VERSUS CIRCUIT SWITCHING

Last but not least in this chapter a few words about packet and circuit switching services should be spent, because these two different network technologies are often mentioned in subsequent chapters.

4.1. Packet Switching

The CCITT definition of a *packet* is as follows: *A group of binary digits including data and call control signals which is switched as a composite whole. The data, call control signals, and possibly error control information are arranged in a specified format.*

The associated CCITT definition of *packet switching* is: *The transmission of data messages by means of addressed packets whereby a transmission channel is occupied for the duration of transmission of the packet only. The channel is then available for use by packets being* *transferred between different data terminal equipment. Note: the data message may be formatted into a packet or divided and then formatted into a number of packets for transmission and multiplexing purposes.*

The data split into packet is sent through the network in packets. There are two ways of doing it. Either first a so-called virtual channel is going to be established for the time of the process--a physical route between the two destination points in the network through which route packages are sent one after the other. It is possible through software multiplexing techniques to mix on the same physical network link between two network nodes packages belonging to different data messages. The other way is when no virtual channel is defined a priory, and each of the packages like separate lives, they may use different physical routes between the two destination points. At the final destination the packages are collected, put into right order and reassembled.

One of the most important standards for the computer industry is the CCITT Recommendation X.25. This defines the relationship between a transport subsystem, or common carrier packet-switching network, and user machines which employ it.

Figure 17 illustrates the concept of X.25 networks. Many user machines are interconnected by *virtual circuits* on which they communicate by means of packets. The virtual circuits are derived by sharing common communication facilities. The X.25 Recommendation says nothing about how the network shall be constructed, but it is oriented to conventional packet-switching on terrestrial lines on the types available in today's common carrier tariffs. It may need modification for satellites, packet radio, data broadcasting, or networks in advance of today's state of the art.

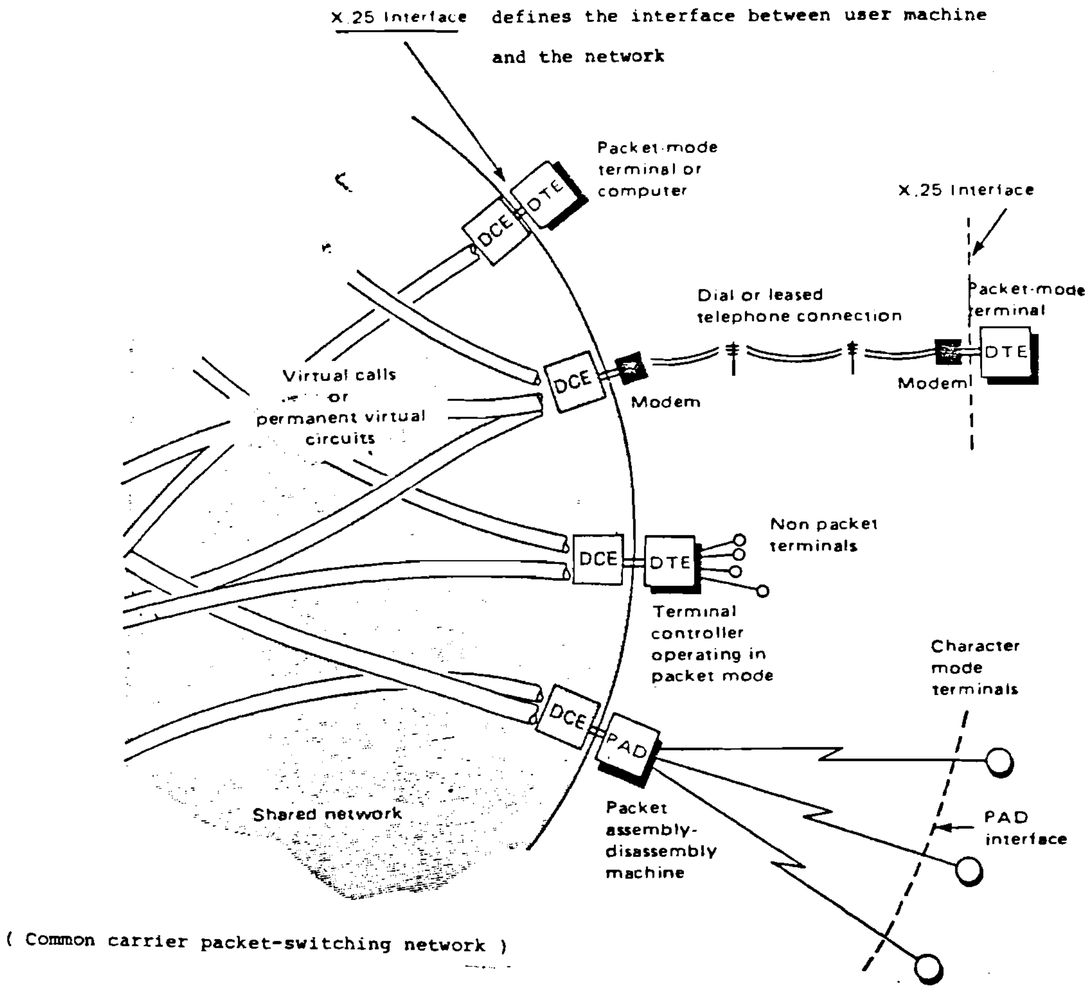


Figure 17. The user machine, DTE, can be computer, terminal, terminal controller, or interface to another form of teleprocessing. The PAD, packet assembly/disassembly machine, buffers characters to and from character-mode terminal (e.g., start-stop machines) and forms the requisite packets.

The PAD Interface

Many terminals transmit characters rather than blocks of data or packets. In some cases they use start-stop line control. Sometimes they are inexpensive devices. These terminals need to be connected to an interface machine which buffers the data they send and assembles and disassembles the packets needed for X.25 operation.

The interface machine could be a control unit controlling multiple terminals, which is part of a computer manufacturer's product line. It could be a concentrator to which remote character-oriented terminals are connected by either leased or dialed telephone lines.

Most common carriers operating X.25 networks provide an interface machine for connecting character-oriented terminals to the network. A standard for such an interface has been proposed. It is an extension to (but not part of) the CCITT Recommendation X.25, and is called the PAD (Packet Assembly/Disassembly) interface. It is illustrated at the bottom of Figure 17. The PAD machine receives characters for network transmission and assembles them into a packet. Conversely it disassembles packets and sends the resulting characters to the terminal which needs them. A protocol is defined for communication between the PAD machine and the character-oriented terminal. This protocl defines how characters are used for indicating the start and end of messages, requesting and confirming connections, and dealing with errors.

There can thus be *packet- mode* user machines which execute the X.25 protocols, and *character- mode* user machines which communicate via a PAD interface. Different types of character-mode machines can be used including HDLC machines and start-stop machines which use delimiter characters from CCITT alphabets to indicate the start and end of messages.

Layers of Control

The user/network interface is concerned with control Layers 1, 2, and 3 (Figure 18).

4.2. Circuit Switching

Computer networks which use circuit switching are also widely in operation and have major advantage for certain type of applications. Through this technique similar to traditional telephone networks predefined path between two network destinations are set up at the beginning of a session for the whole duration of data traffic. Once the channel allocated to a certain session unlike packet-switching it cannot be shared with other sessions.

Figure 19 shows a comparison of fast-connect circuit switching and packet switching over a route which employs four physical links.

With circuit switching a command must be sent through the network to set the switches. A signal returns indicating that they are set correctly and then the entire message is transmitted. When it has been received, and an acknowledgment is transmitted to the sender.

With packet switching the preliminary step of setting the switches is not needed. A packet could travel immediately to the first node, which would examine its address and route it onward. Usually however, the sender has to contact the recipient before transmission to reserve the

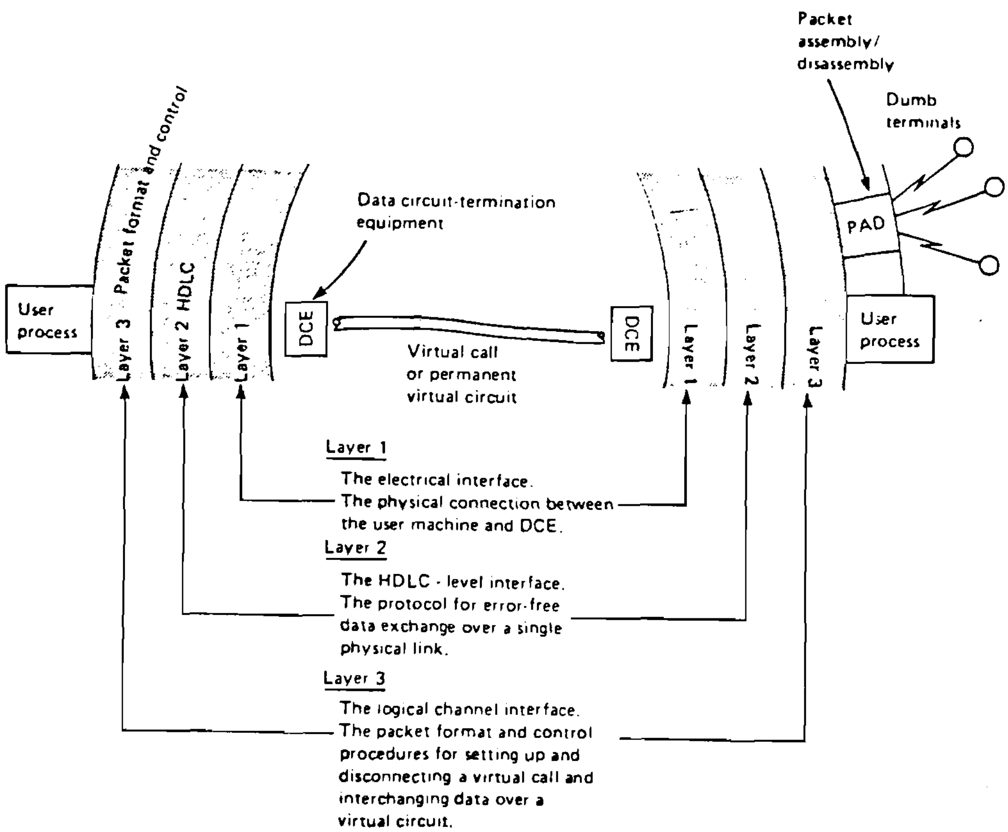


Figure 18. The CCITT X.25 user/network interface is subdivided into three level of interface

buffering needed for message reassembly or to ensure that the recipient is ready to receive. Then the packets travel to the destination and an acknowledgment is returned to the sender.

A comparison of the main characteristics between circuit switching and packet switching is shown in Table 7.

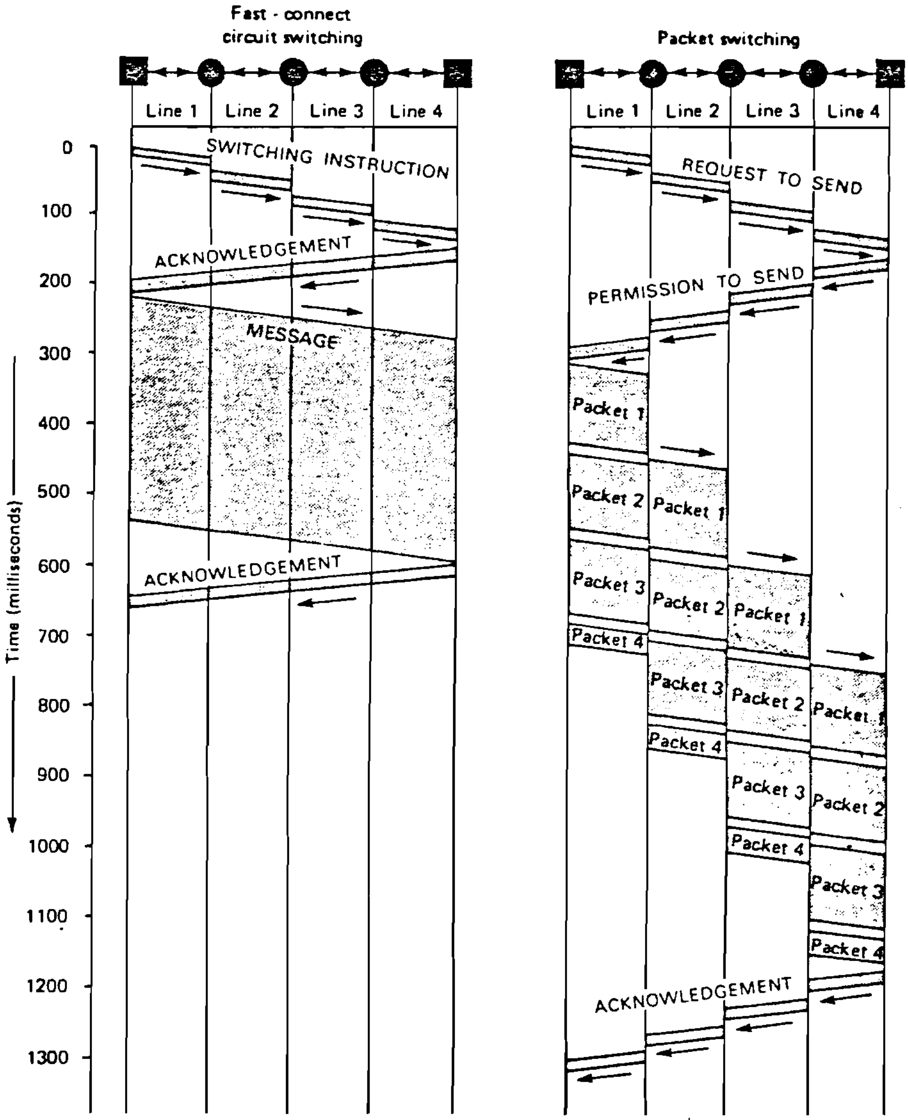


Figure 19. A comparison of the timing on packet switching and fast-connect circuit switching. In this illustration a 400-byte (3200-bit) message is sent on 9600 bps lines. The packet size is 1008 bits. No queuing delays are shown. If the lines were moderately highly utilized queuing delays would lengthen the end-to-end delay with packet switching more than with circuit switching.

Table 7. Comparison of the main characteristics of conventional telephone switching, and packet switching

Conventional Circuit Switching (e.g., telephone switching)	Circuit-Switching Data Networks	Packet Switching Data Networks
The equivalent of a wire circuit connects the communicating parties.	The equivalent of a wire circuit is connected between the end buffers for brief periods.	No direct electrical connection.
Real-time or conversational interaction between the parties is possible.	Real-time or conversational interaction between the parties is possible.	Fast enough for real-time or conversational interaction between data machines.
Messages are not stored.	Messages are not stored.	Messages are stored until delivered, but not filed.
Designed to handle long continuous transmissions.	Designed to handle short sporadic transmissions.	Designed to handle bursts of data.
The switched path is established for the entire conversation.	The switched path is repeatedly connected and disconnected during a lengthy interaction.	The route is established dynamically for each packet.
There is time delay in setting up a call and then negligible transmission delay.	A delay which ought to be less than one second, associated with setting up the call and delivering the message.	Negligible delay in setting up the call. Delay of usually less than one second in packet delivery.
Busy signal if called party is occupied.	Delay, or busy signal, if called party is occupied.	Packet returned to sender if undeliverable.
Effect of overload: Increased probability of blocking, causing a network busy signal. No effect on transmission once the connection is made.	*Effect of overload:* Increased delay and/ or increased probability of a busy signal.	*Effect of overload:* Increased delivery delay (but delivery time is still short). Blocking when saturation is reached.
Any length of transmission is permitted.	Any length of transmission *may* be permitted.	Lengthy transmissions are chopped into short packets. Very long messages must be divided by the users.
Economical with low traffic volumes if the public telephone network is employed.	High traffic volumes needed for justification.	High traffic volumes needed for economic justification.
The network cannot perform speed or code conversion.	*May* provide speed or code conversion.	The network can perform speed or code conversion.
Does not permit delayed delivery.	*May* permit delayed delivery if the delay is short.	Does not permit delayed delivery (without a special network facility).
Fixed bandwidth transmission.	Users effectively employ small or large bandwidth according to need.	Users effectively employ small or large bandwidth according to need.

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