Chapter 7

Telecommunications, the Internet, and Information System Architecture

7.1 Telecommunications Networks and their Scope

The electronic transmission of information over distances, called telecommunications, has become virtually inseparable from computers: Computers and telecommunications create value together.

Components of a Telecommunications Network

Telecommunications are the means of electronic transmission of information over distances. The information may be in the form of voice telephone calls, data, text, images, or video. Today, telecommunications are used to organize more or less remote computer systems into telecommunications networks. These networks themselves are run by computers.

A ***telecommunications network*** is an arrangement of computing and telecommunications resources for communication of information between distant locations.

A telecommunications network includes the following components:

1. *Terminals* for accessing the network

2. *Computers* that process information and are interconnected by the network

3. *Telecommunications* *links* that form a channel through which information is transmitted from a sending device to a receiving device.

4. *Telecommunications* *equipment* that facilitates the transmission of information.

5. *Telecommunications* *software* that controls message transmission over the network.

Scope of Telecommunications Networks

Two principal types of telecommunications networks can be distinguished from the point of view of their geographical scope. They are:

1. Local area networks

2. Wide area networks

Local area network (LAN): is a privately owned network that interconnects processors, usually microcomputers, within a building or on a campus site that includes several buildings.

Characteristics of a LAN: [Figure 7.3][Slide 7-5]

a. LANs are the principal tool of workgroup computing

b. LANs ensure high-speed communication within a limited area and enables the users to share facilities (peripherals) connected to it.

c. Usually include a large-capacity, secondary storage device, where database and applications software are maintained, managed by a microcomputer acting as a file server that delivers data or

program files to other computers.

d. Facilities (peripherals) may include jukebox optical memory and fast printers

e. Frequently, one of the facilities (peripherals) in a LAN is the gateway hardware and software that give the network users access to other networks.

f. More group members may connect to the network from remote sites using wireless telecommunications.

g. Links and equipment of LANs are owned by the user company, and these networks are generally much faster than WANs.

h. LANs are generally composed of a network of microcomputers

Wide area network (WAN): is a telecommunications network that covers a large geographical area.

Characteristics of a WAN: [Figure 7.4][Slide 7-6]

a. The information system of an entire organization may be structured as a hierarchy. The WANs system architecture looks very much like an organization chart.

b. WANs connect all the divisional minicomputers to the headquarters mainframe with a variety of local microcomputers and terminals located at remote sites connected, in turn, to the minicomputers.

c. WANs provide the backbone through which all other nodes (computers and terminals) communicate.

d. WANs often use telecommunication links and equipment provided by specialized vendors, called *common carriers*.

e. WANs serve to interconnect multiple LANs and can make specific resources available to a large number of workstations.

Metropolitan Area Networks (MAN) - are telecommunications networks that interconnect various local area networks within a metropolitan area, that is, within approximately a 50-mile range.

Characteristics of a WAN: [Figure 7.4]

a. Purpose of MANs is to interconnect various LANs within a metropolitan area, that is, within approximately a 50 - mile range.

b. Generally, the speed of MANs is equal to that of LANs and they use similar technology.

Interorganizational Information Systems - are shared by two or more companies.

Characteristics of Interorganizational Information Systems: [Figure 7.5]

a. These systems help several firms share information in order to coordinate their work, collaborate on common projects, or sell and buy products and services.

b. Internet has emerged as a global public network of networks

c. Some interorganizational systems are employed in knowledge work

d. Can be used to connect a firm's computers to the information systems of its customers, suppliers, and business partners, and are also used to execute business transactions.

7.2 Telecommunications Links

Telecommunications links may be implemented with various communication media, with a corresponding variety of characteristics. The main feature of a medium is its potential transmission speed, also known as ***channel capacity***, which for data transmission purposes is expressed in bits per second (bps). An alternative measure of transmission channel capacity is bandwidth - the range of signal frequencies that can be transmitted over the channel.

Six potential media are employed to implement telecommunication links:

1. Twisted pair

2. Coaxial cable

3. Fiber Optics cable

4. Terrestrial Microwave

5. Satellite Transmission

6. Radio Transmission

Three of the above transmission media are classified as guided media - in which the signal moves along an enclosed path. Guided media require wiring. They include:

1. Twisted pair

2. Coaxial cable

3. Fiber optic cable

Three of the above transmission media are classified as wireless media - the signal is broadcast (radiated in many directions) over the air or space and received through an antenna. They include:

1. Terrestrial Microwave

2. Satellite Transmission

3. Radio Transmission

<u>Characteristics of Communications Media:</u>

Twisted Pair a communications medium consisting of a pair of wires.

Coaxial Cable a communications medium that consists of a relatively thick central conductor shielded by several layers of insulation and the second conductor just under the cable's shell

Fiber Optics high-capacity communications medium that consists of many strands of pure glass with a data carrying core in the middle, surrounded by a reflective coating and a protective sheath.

Terrestrial Microwave long-distance telecommunications by means of microwave signals travelling on the surface of the earth.

Satellite Transmission form of microwave transmission in which the signal is transmitted by an earth station to a satellite which rebroadcasts the signal to the receiving station.

Radio Transmission wireless communications technology that transmits voice or data over the air using a lower frequency band than microwaves.

Note: Transmission speeds keep on rising, particularly in the fiber optics area. We are now moving toward a global infrastructure of gigabit-speed fiber optic links relying on digital transmission. In this multimedia environment, data, text, voice, images, and video will travel at speeds of billions of bits per second.

Analog and Digital Communications [Figure 7.8][Slide 7-7]

Most of the lines in the telephone systems of the world at present are ***analog***. Signals are transmitted as continuous waves. This is a satisfactory way to transmit voice, but digital data sent by computers (sequences of pulses representing 0s and 1s) must be converted into an analog signal for transmission over an analog line. The analog data must then be converted back into digital before entering the memory of the receiving computer. The conversion of data from digital form into analog for transmission and then back into digital at the receiving end is done by a pair of interface devices called ***modems*** (***mo***dulator-***dem***odulator).

Modem-based telecommunications have created a significant bottleneck in an environment where computer and peripheral speeds have increased dramatically. The solution is end-to-end ***digital*** communications, in which signals are sent as streams of on/off pulses. Digital lines are capable of much faster communication and digital circuitry is now cheaper than analog. All the new equipment now installed in telephone networks is indeed digital.

Trend: There is a shift toward digital telecommunications is taking place throughout the world. A digital system for telecommunications, called ***TI carrier***, is in wide use in parts of the telephone network.

Future: Integrated Services Digital Network (ISDN) - a completely digital telecommunications network standardized by an international committee. Although ISDN services are available in some areas, including most of the US, worldwide ISDN is not expected to become operational until after the year 2000.

How to Reduce the Costs of Telecommunications Multiplexing and Signal Compression

With the geographical distribution of information systems, increased volumes of transmission, and the move to multimedia, the costs of telecommunications are a significant business concern. Two principal methods of reducing these costs are:

1. Multiplexing - the sharing of a high-capacity link by a number of transmissions

2. Signal Compression - using the link more efficiently by removing redundancies from the signal.

Multiplexing

Characteristics of multiplexing:

1. There are economies of scale in telecommunications systems: the higher the system capacity, the lower the unit cost of transmissions.

2. Many individual transmissions can share a physical channel through a variety of techniques collectively called **multiplexing**.

3. Multiplexing combines several lower-capacity transmissions into a single transmission, which is split at the receiving end.

Signal Compression

Characteristics of signal compression:

1. Signal compression is the reduction of the need for channel capacity by removing redundancies from the signal.

2. To reduce the transmission needs, we can remove the redundancies at the sender site, transmit the compressed signal, and then restore the signal at the receiving end.

3. Compression has an impressive effect on multimedia transmission needs.

7.3 Computer Networks

Computer networks differ in scope from relatively slow wide area networks, employed to transmit messages across vast geographic distances, to very fast local area networks that may connect computers located in the same building. System designers may select one of several arrangements for interconnecting network nodes, depending on an organization's requirement. There are several ways to establish a connection between the sender and the receiver of a message.

Network Topologies

Computers, switches, and terminals interconnected by network links are collectively called ***nodes***. The purpose of network control is to provide a connection between nodes that need to communicate. The arrangement of nodes and links in a network is called a ***topology***. A variety of arrangements are possible, each with its own advantages and drawbacks. Network topology has to fit the structure of the organizational unit that will use the network, and this topology should also be adapted to the unit's communication traffic patterns and to the way the databases will be stored in order to facilitate access to them.

The following topologies are the most widely used:

1. Hierarchical Network

2. Star Network

3. Ring Network

4. Bus Network

Hierarchical Network: [Figure 7.4]

a. A corporate host computer (often a mainframe), divisional minicomputers or powerful workstations, and workgroup support via micros.

b. This topology matches the organizational structure of many firms and is still frequently used in WANs.

c. The user workstations may be, in turn, interconnected using one of the LAN topologies.

d. Failure of the host does not disable divisional processing, which is a fail-safe feature.

e. Cost-effectiveness of micros and the growing importance of groupwork leads some downsizing firms to move away from hierarchical networks to client/server computing.

Star Network: [Figure 7.9a]

a. In a star network, a hub computer or switch (such as a PBX) interconnects a number of workstations.

b. The computer at the hub acts as the network server, providing access to the shared database and software. All communications between the workstations must go through this central mode.

c. The star network is rather easy to manage and expand, since in both cases it is largely the single central node that is affected in an expansion of a processing capacity.

d. The central node is a locus of vulnerability: it may be overloaded or it may fail, disabling the entire network.

Ring Network: [Figure 7.9b]

a. Each node in a ring network is connected to two of its neighbours.

b. The nodes are usually close to one another; this topology is frequently used in LANs.

c. When one node sends a message to another, the message passes through each intermediate node, which restores the signal, as signals deteriorate in transmission.

d. If a node fails, the ring is out of service, unless the ring contains two channels transmitting in opposite directions.

Bus Network: [Figure 7.9c]

a. The nodes on a bus network are connected to a common link such as coaxial cable. This arrangement is used in LANs.

b. A failing device does not affect the rest of the network; failure of the bus itself, of course, brings the network down.

Switching in Networks

Many users can be connected at the same time to a network of communication channels. ***Switching***devices establish connections between nodes that need to communicate over a network. Principal techniques for switching include:

1. Circuit Switching

2. Packet Switching

3. Fast Packet Switching

Circuit Switching:

1. The circuit switching technique is employed in a telephone network.

2. Communication links are connected to switching centers, which connect to one node to another on demand.

3. The circuit is established for the entire duration of the communication

4. Circuit switching is suitable for file transfers and similar longer transmissions

Packet Switching: [Figure 7.10]

1. Packet switching is of particular importance for data communication owing to its speed and its superior utilization of communication links when handling Abursty,@ intermittent, traffic. Indeed, data transmission involves short bursts of activity by a computer or a terminal when the data are sent, followed by long periods when there is no transmission.

2. Packet switching offers flexibility in connecting to a network. It is used by most of the public data networks provided by value-added carriers.

3. In packet switching, messages are divided at the source into fixed-length chunks, called ***packets***, that also include bits identifying the receiver. Typically, a packet contains 128 bytes of data.

4. Each packet, can be transmitted independently, with routing determined at each node the packet passes through (as opposed to circuit switching, where the route is predetermined).

Fast Packet Switching:

Traditional packet switching checks each packet for errors at every node the packet passes through. Modern telecommunications equipment is far more noise-free than that for which packet switching was originally designed. To take advantage of this, two fast packet-switching technologies are being introduced:

Frame Relay: Fast packet switching that checks a packet for errors only at the entry and exit nodes of the telecommunications network, thus reducing transmission delay.

Cell Relay: (asynchronous transfer mode, or ATM) transfers very short fixed-length packets, called cells, over fast LANs or WANs.

7.4 Communications Protocols in Computer Networks

Communication rules, called ***protocols***, enable dissimilar hardware and software to communicate over a single network.

Network Protocols [Figure 7.11][Slide 7-8]

Computer networks exist to provide connectivity among a variety of computers and access devices. To ensure orderly communication over a network, all the nodes in the network must follow a set of rules called ***protocols***. These rules are complex. They extend from the electric connection to the network and the format of the message, all the way to the interaction between application

programs that run on different nodes.

Explain to students that with the globalization of telecommunications, the International Standards Organization (ISO) has developed the OSI model in order to organizing protocols. The ***open system*** approach opens the field to a broad array of competing vendors, a situation that benefits users to ensure that they are not locked into a closed, proprietary protocol structure of a specific manufacturer.

1. Gives both users and vendors flexibility in conforming to a standard.

2. Users can select a protocol for any layer of the model, as long as the protocol performs the necessary services and provides the same interface to the adjacent layers.

3. If a layer has to be changed, only the hardware or software implementing that layer need be modified.

4. A protocol layer in one node interacts with the corresponding layer in another one.

Table 7.2 explains the functions of the seven layers of protocol in the OSI model. They include:

Layer and its Function

1.**Physical** Provides access to the telecommunications medium and ensures transmission of the bit stream over it

2.**Data** **Link** Ensures error-free transmission of frames (blocks) of data over a network link

3.**Network** Routes messages (or packets) from source to destination by selecting connecting links

4.**Transport** Provides reliable end-to-end connection between two communicating nodes. When packet switching is used this layer breaks a message into packets

5.**Session** Establishes, maintains, and terminates a connection (session) between two applications running on communicating nodes. A session lasts, for example, from a long-on to a specific application to a log-off.

6.**Presentation** Provides any necessary conversions of the character being sent (encryption/decryption, compression/decompression, or character code conversions). Issue requests for establishing and terminating a session to the session layer

7.**Application** Provides services to communicating application programs; examples include file transfer, running a remote program, allocating a remote peripheral, and ensuring integrity of remote databases.

Two protocol sets have gained importance:

SNA - IBM's Systems Network Architecture.

- its functions are broken down into five layers, basically performing the functions of the five middle OSI levels.

TCP/IP - Transmission Control Protocol/Internet Protocol

- its functions are broken down into five layers. TCP provides the higher-level services in connecting the communicating applications, while IP ensures the lower-level functions of routing and addressing, guiding the packets over the Internet.

Interconnections among Networks

As communication needs increase, network connectivity becomes a major issue as users want to access a remote computer. Gateways such as routers and bridges help solve the problem.

Interconnection between two networks of the same type is accomplished by a relatively simple ***bridge***, implemented in hardware and software. Interconnection between dissimilar networks, for example, a LAN and a WAN, is achieved through a more complex ***router***. A router is a device that accepts messages in the format produced by one of the networks and translates them into the format used by the other.

7.5 Local Area Networks

Organizations small and large use fast local area networks (LANs) to interconnect personal computers, and thus make a basic workgroup tool.

Local Area Network: Workplace for a Workgroup

A LAN interconnects computers within a single site, such as an office building, a manufacturing plan, or a corporate or university campus.

Characteristics of a LAN include:

1. Its scope is commonly measured in feet

2. Communication speeds are very high

3. Used as a local means of computing and communication among users in larger firms

4. Are owned by the organization

5. Afford a sense of control and the flexibility to meet the demands of the end users

A LAN gives its users the following capabilities:

1. Users can share resources, such as a fast printer or a database

2. Users can collaborate by communicating over their LAN. This collaboration may be facilitated by groupware that runs on a LAN

3. Users can access other networks within a firm or outside of it via bridges and routers

There are two principal LAN designs:

1. Peer-to-peer - peripherals are located at terminals and system administration is largely left up to the users

2. Server-based networks **-** shared resources are placed a dedicated server that manage a given resource on behalf of user workstations sharing the resource (file server, printer server, gateway, optical disk server). Most of the servers are dedicated to their task; using them as workstations degrades the performance of the net.

Local Networks Based on Private Branch Exchanges: [Figure 7.12]

A company with a large number of telephones (from 50 to over 10,000) often elects to own a computer-based ***private branch exchange*** (PBX), an electronic switchboard that interconnects its telephones and provides connections to the public network.

Characteristics of a PBX:

1. Gives a company control over the usage of its telephone system and offers a variety of features, such as call forwarding or voice messaging.

2. Maybe employed as a switch for data communications

3. Many newer PBXs use digital technology, eliminating the need for modems, and perform conversions needed to ensure connectivity between various equipment and telecommunications links.

4. Easy to connect a new workstation to the net.

5. Speeds of PBX-based networks are limited

7.6 Client/Server Computing

An important current development in organizational computing is ***downsizing***- moving from platforms based on mainframes and minicomputers to a microcomputing environment. These architectures are based on the client/server model.

Characteristics of client/server computing:

1. The processing of a given application is split up among a number of clients - serving individual users - and one or more servers - providing access to databases and doing most of the computing.

2. Main objective of a client is to provide a graphical user interface to a user

3. Main objective of a server is to provide shared services to clients

4. In client/server computing, individual applications are actually written to run on several computer platforms to take advantage of their capabilities

5. Client/server computing is difficult to implement

Most frequently used models of client/server computing are:

1. Two-Tier Architecture

2. Three-Tier Architecture

Characteristics of Two-Tier Architecture: [Figure 7.13a]

1. Client performs presentation services. It displays the GUI and runs the program that determines what happens when the user selects a menu option.

2. Server manages the accesses to the database

3. Clients send remote procedure calls to activate specific applications logic on a server

Characteristics of Three-Tier Architecture: [Figure 7.13b]

1. An application server runs most of the application logic, with the user workstation responsible for the display at the front end and the database server providing database servers at the back end. Objective is to distribute application so as to reduce the overall hardware costs while minimizing the network traffic

Issues of client/server computing:

1. Is attractive in terms of their acquisition price as related to their performance

2. Is moving computing control out of the data centers and into the end-user areas

3. Software is complex, and is expensive to maintain

4. Generate significant traffic on the firm's backbone network that connects clients and servers

5. Can be performed in LAN and WAN environments

7.7 Wide Area Networks

Wide area networks are the fundamental infrastructure of organizational computing. These long-distance telecommunications networks employ a variety of equipment so that the expensive links may be used effectively. The offerings of common carriers and of providers of value-added services may be combined with private networks to create an overall organizational network.

Telecommunications Equipment for Wide Area Networks [Figure 7.15][Slide 7-9]

WANs include equipment that controls message transfer and makes it possible to share the links among a number of transfers.

Host Computer

A WAN has a powerful host computer. The host runs a system program, called a telecommunications monitor, which processes incoming messages, passing them to the appropriate application programs, and accepts outgoing messages from the applications in order to transmit them into the network.

Front-End Processor

Relieves the host computer of most of the tasks involved in network control. Under the control of its own software, the front-end processor accepts messages coming from the network and routes outgoing messages to their destinations. It performs the necessary code conversions, encrypts and decrypts secure messages, and performs error checking so that the host deals with Aclean@ messages.

Cluster Controller

Manages several terminals, connecting them to a single telecommunications link, and performs communication tasks for them, such as screen formatting, code conversion, and error checking. A cluster controller may also allow the terminals to share a high-speed printer and may handle electronic mail among the cluster terminals.

Multiplexor

Combines the data that terminals send to it over local low-speed links into a single stream. This stream is then transmitted over a high-speed telecommunications channel and is split by another multiplexor on the opposite end of the channel.

Concentrator

Combines transmission from several slower terminals that operate in a burst mode into a single transmission stream that requires a link of lower speed than the sum of the speeds of all the terminals combined. A concentrator stores messages from terminals and forwards them when warranted.

Switches

Establishes connections between nodes that need to communicate.

Access Terminals

Include a variety of dumb terminals, with no processing capacity and intelligent terminals with processing capacity, such as personal computers.

Where do Facilities for Wide Area Networks Come From?

Some network facilities are owned by user organizations, others can be leased by them, or simply used on a pay-as-you-go basis. Among the typical facilities owned by user firms are workstations, host computers, and front-end processors. The essential providers of telecommunications links and services are common carriers and the vendors of enhanced services on value-added networks. These include:

1. Common carriers

2. Providers of value-added networks

3. Private lines and private networks

Common Carriers

Are companies licensed by a country's government to provide telecommunications services to the public. The vast majority of common carriers provide telephone service. These carriers offer the use of a wide-area telecommunications infrastructure, that is, facilities for the transmission of voice and data messages.

Common carriers offer a service called ***virtual private network*** where a user firm can purchase guaranteed access to facilities with specified capabilities, such as transmission speed and access points.

Providers of Value-Added Networks

Value-added vendors lease facilities from the common carriers and provide telecommunications services to their own customers. These vendors add value to the basic infrastructure furnished by the common carrier. The ***value-added networks*** (VAN) provided by the vendors furnish services over and above those provided by common carriers.

Private Lines and Private Networks

Instead of using a service that has to be shared with others, a firm may lease its own private lines or entire networks from carriers. This can have economic advantages as compared with VAN use, as well as provide faster and more secure communications.

7.8 The Internet and Electronic Commerce

The Internet has changed the face of individual and organizational computing. Driven by the possibilities offered by the Internet and the Web, electronic commerce is expanding its reach.

Present and Future of the Internet

The ***Internet*** is the global network of computer networks without a centralized control that has become the contemporary Ainformation highway.@

Characteristics of the Internet:

1. It is run in a decentralized fashion by a number of voluntary organizations, the principal of which is the Internet Society.

2. It is a medium of communication, a source of information, and a developing means of electronic commerce.

3. A major obstacle to its development has become the limited capacity of the links interconnecting the networks.

Facilities for Communication and Information Access

The Internet provides several essential facilities that organizations can use for internal as well as interorganizational information sharing and communication.

The principal categories of Internet use include:

1. **Communication**

Electronic mail (E-mail) facilitates quick exchange of information and ideas, and is the Internet facility in widest use. E-mail can be used for one-to-one communications or to participate in larger communications forums (newsgroups).

2. **Information Access:**

The Internet provides access to the largest organized (loosely) repository of information on earth: the collection of electronic documents stored on sites all over the world. The main problem is finding the information. To help with this problem Web search engines have been developed. Examples include Gopher sites, using indexes such as Veronica, or via a WAIS (Wide Area Information Service) keyword search.

The World Wide Web

The World Wide Web (or simply, the Web) is an information service available over the Internet, providing access to distributed