UNIT –I

Introduction to Computer Networks

Computer Network –

A computer network is a collection of computers to connect via some physical medium for purpose of resources under some protocols.

Types of Computer Network –

1. **Point to Point Network –**

   Network support one to one communication and must have separate dedicated link between two devices.

2. **Broadcast Network –**

   When Network support one to all communication .

Multicast-Network support one to many(but not all) communication. Broadcast is multicast but multicast is not broadcast .In this one one device is sender and multiple devices are receiver

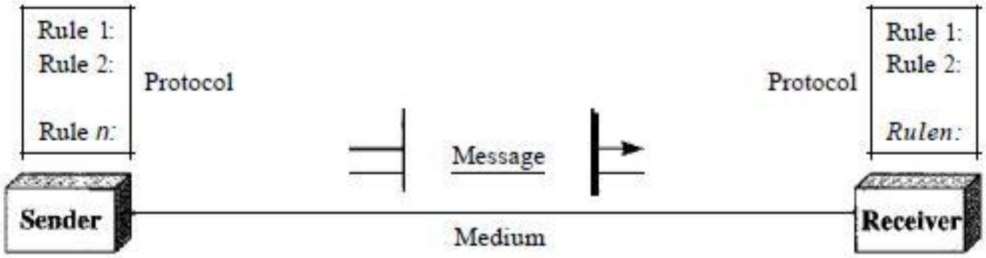
Note- Broadcast is a special case of Multicast .

Data Communication:

When we communicate, we are sharing information. This sharing canbe local or remote. Between individuals, local communication usually occurs face to face, while remote communication takes place over distance.

Components:

A data communications system has five components.



1. Message. The message is the information (data) to be communicated. Popular forms of information include text, numbers, pictures, audio, and video.

2. Sender. The sender is the device that sends the data message. It can be a computer, workstation, telephone handset, video camera, and so on.

3. Receiver. The receiver is the device that receives the message. It can be a computer, workstation, telephone handset, television, and so on.

4. Transmission medium. The transmission medium is the physical path by which a message travels from sender to receiver. Some examples of transmission media include twisted-pair wire, coaxial cable, fiber-optic cable, and radio waves

5. Protocol. A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just

as a person speaking French cannot be understood by a person who speaks only Japanese.

Data Representation:

Information today comes in different forms such as text, numbers, images, audio, and video.

Text:

In data communications, text is represented as a bit pattern, a sequence of bits (0s or 1s). Different sets of bit patterns have been designed to represent text symbols. Each set is called Unicode, which uses 32 bits to represent a symbol or character used in any language in the world used The American Standard Code for Information Interchange (ASCII).

Numbers:

Numbers are also represented by bit patterns. However, a code such as ASCII is not used to represent numbers; the number is directly converted to a binary number .

Images:

Images are also represented by bit patterns. In its simplest form, an image is composed of a matrix of pixels (picture elements), where each pixel is a small dot. The size of the pixel depends on the *resolution.* For example, an image can be divided into 1000 pixels or 10,000 pixels. In the second case, there is a better representation of the image (better resolution), but more memory is needed to store the image. After an image is divided into pixels, each pixel is assigned a bit pattern. The size and the value of the pattern depend on the image.

Audio:

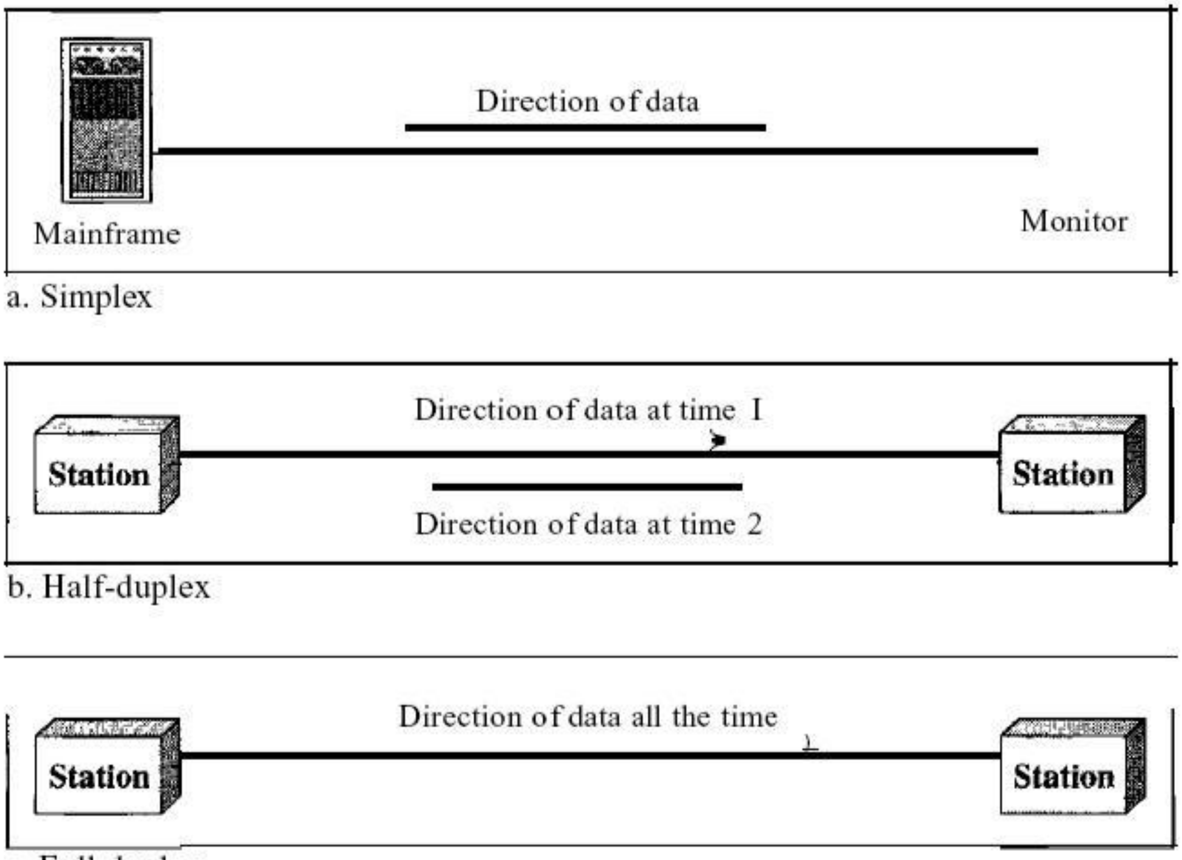
Audio refers to the recording or broadcasting of sound or music. Audio is by nature different from text, numbers, or images. It is continuous, not discrete.

Video:

Video refers to the recording or broadcasting of a picture or movie. Video can either be produced as a continuous entity (e.g., by a TV camera), or it can be a combination of images, each a discrete entity, arranged to convey the idea of motion. Again we can change video to a digital or an analog signal.

Communication Mode / Data Flow

Communication between two devices can be simplex, half-duplex, or full-duplex as shown in Figure


Direction of data
Mainframe
Monitor
Direction of data at time I
Station
Station
Direction of data at time 2
Direction of data all the time
Station
Station

a. Simplex

b. Half-duplex

c. Full·duplex

Simplex:

In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive (see Figure a). Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output. The simplex mode can use the entire capacity of the channel to send data in one direction.

e.g. T.V. and Remote .

Half-Duplex:

In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa The half-duplex mode is like a one-lane road with traffic allowed in both directions.

Walkie-talkies and CB (citizens band) radios are both half-duplex systems.e.g. Railway tracks .

Full-Duplex:

In full-duplex both stations can transmit and receive simultaneously (see Figure c). The full-duplex mode is like a two way street with traffic flowing in both directions at the same time. This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals traveling in both directions. One common example of full-duplex communication is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time.

NETWORKS

A network is a set of devices (often referred to as *nodes)* connected by communication links. A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

Network Criteria

A network must be able to meet a certain number of criteria. The most important of these are performance, reliability, and security.

Performance:

Performance can be measured in many ways, including transit time and response time.Transit time is the amount of time required for a message to travel from one device to another. Response time is the elapsed time between an inquiry and a response. The performance of a network depends on a number of factors, including the number of users, the type of transmission medium, the capabilities of the connected hardware, and the efficiency of the software. Performance is often evaluated by two networking metrics: throughput and delay. We often need more throughput and less delay. However, these two criteria are often contradictory. If we try to send more data to the network, we may increase throughput but we increase the delay because of traffic congestion in the network.

Reliability:

In addition to accuracy of delivery, network reliability is measured by the frequency of failure, the time it takes a link to recover from a failure, and the network's robustness in a catastrophe.

Security:

Network security issues include protecting data from unauthorized access, protecting data from damage and development, and implementing policies and procedures for recovery from breaches and data losses.

Type of Connection

A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another. For visualization purposes, it is simplest to imagine any link as a line drawn between two points. There are two types of connections:

1. point-to-point

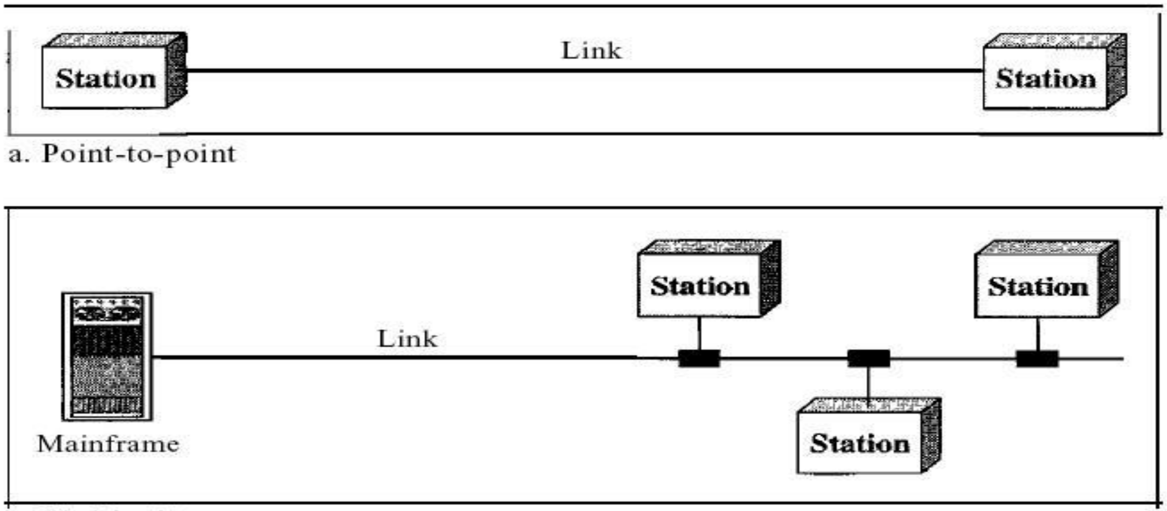
2 .multipoint

Point-to-Point

point-to-point connection provides a dedicated link between two devices. The entirecapacity of the link is reserved for transmission between those two devices. Most point-to-pointconnections use an actual length of wire or cable to connect the two ends, but other options, suchas microwave or satellite links, are also possible. When you change television channels byinfrared remote control, you are establishing a point-to-point connection between the remotecontrol and the television's control system.

Multipoint

A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link. In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a *spatiallyshared* connection. If users must take turns, it is a *timeshared* connection.

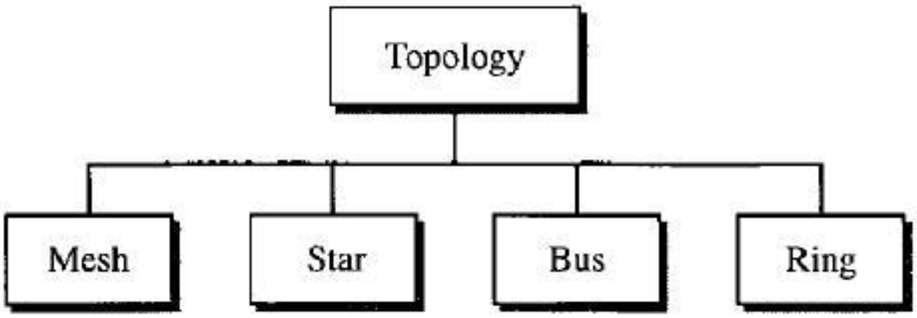


a. Point-to-point

b. Multipoint

Topology

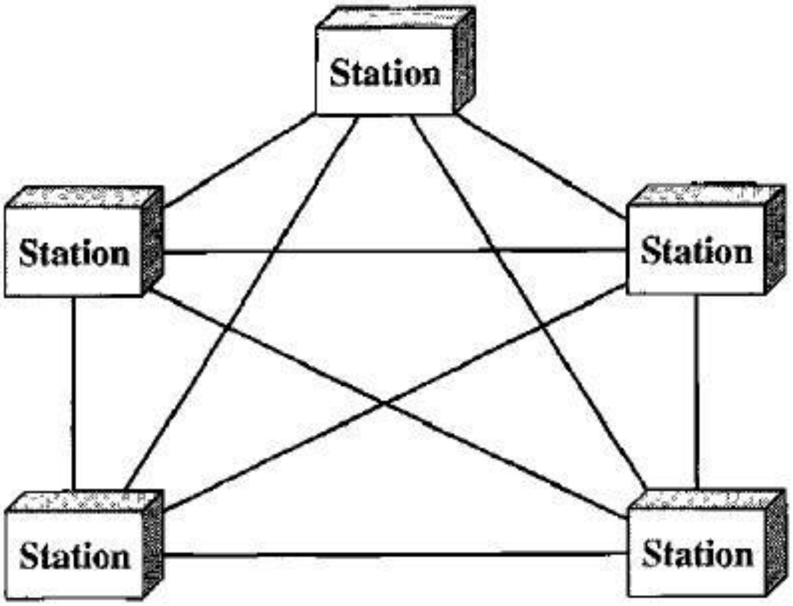
The term ***topology*** refers to the way in which a network is laid out physically. One or more devices connect to a link; two or more links form a topology. The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to one another. There are four basic topologies possible: mesh, star, bus, and ring



Mesh: In a mesh topology, every device has a dedicated point-to-point link to every otherdevice. The term *dedicated* means that the link carries traffic only between the two devices it connects.

To find the number of physical links in a fully connected mesh network with *n* nodes, we first consider that each node must be connected to every other node. Node 1 must be connected to *n* - I nodes, node 2 must be connected to *n* – 1 nodes, and finally node *n* must be connected to *n* - 1 nodes. We need *n(n* - 1) physical links. However, if each physical link allows communication in both directions (duplex mode), we can divide the number of links by 2. In other words, we can say that in a mesh topology, we need *n(n* -1) /2 duplex-mode links.

To accommodate that many links, every device on the network must have *n* – 1 input/output *(VO)* ports to be connected to the other *n* - 1 stations.



Advantages:

1. The use of dedicated links guarantees that each connection can carry its own data load, thus eliminating the traffic problems .
2. A mesh topology is robust. If one link damagedor removed does not effected remaining portion of topology.
3. Easily to identify fault in the network.
4. Less amount of traffic between two devices.

Disadvantages:

1. Disadvantage of a mesh are related to the amount of cabling because every device must be connected to every other device, installation and reconnection are difficult.
2. Second, the sheer bulk of the wiring can be greater than the available space (in walls, ceilings, or floors) can accommodate. Finally, the hardware required to connect each link.

Star Topology:

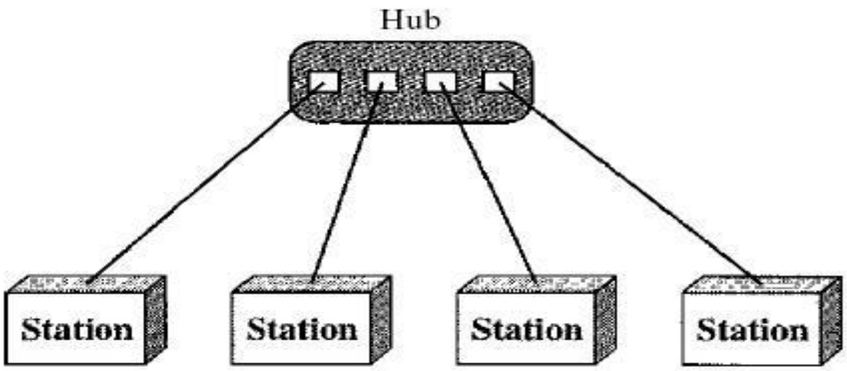
In a star topology, each device has a dedicated point-to-point link only to a central controller, usually called a hub. The devices are not directly linked to one another. Unlike a mesh topology, a star topology does not allow direct traffic between devices. The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device .

Advantages:

1. A star topology is less expensive than a mesh topology. In a star, n device needs only n link and n I/O port to connect it to with Hub.
2. Easier to configure as compare to mesh.
3. Robust- If one link fails, only that link is affected. All other links remain active.
4. Easy fault identification and fault isolation.
5. Addition , shifting and deletion of links involve only one connection.

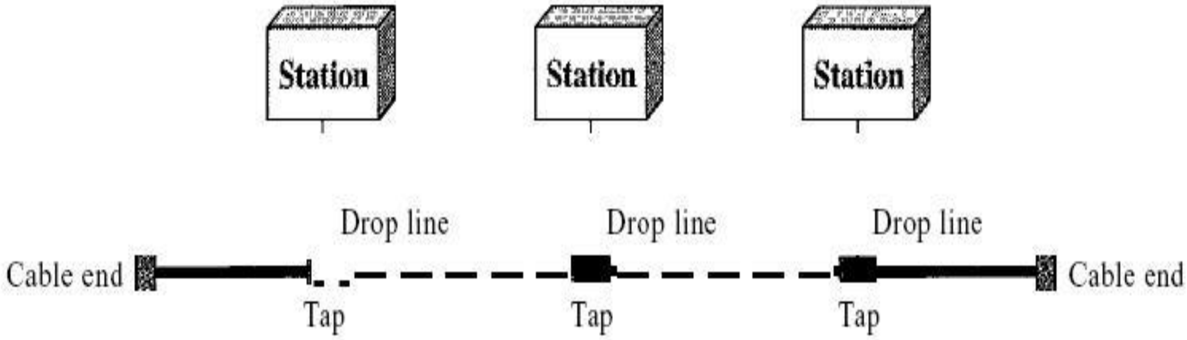
Disadvantages:

1. star topology is dependent on the hub. If the hub goes down, the whole system is dead.
2. Although a star requires far less cable than a mesh, each node must be linked to a central hub. For this reason, often more cabling is required in a star than in some other topologies (such as ring or bus).



Bus Topology:

The preceding examples all describe point-to-point connections. A **bus topology,** on the other hand, is multipoint. One long cable acts as a **backbone** to link all the devices in a network



Nodes are connected to the bus cable by drop lines and taps. A drop line is a connection running between the device and the main cable. A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core. As a signal travels along the backbone, some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it travels farther and farther. For this reason there is a limit on the number of taps a bus can support and on the distance between those taps.

Advantages

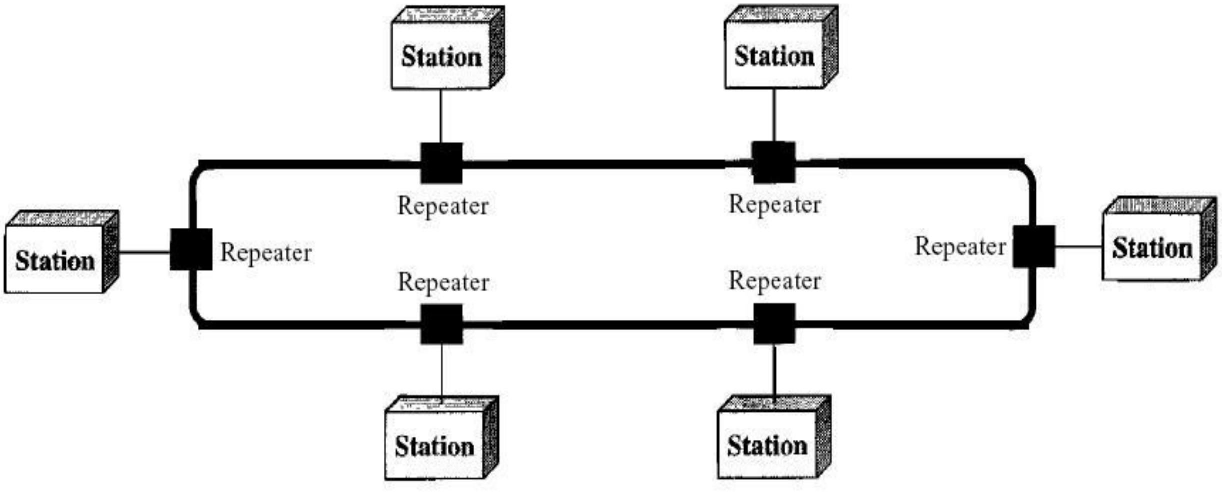
1. Bus topology include ease of installation.
2. Bus uses less cabling than mesh or star topologies since each drop line has to reach
3. Addition , shifting and deletion of links involve only one connection.

Disadvantages

1. Difficult reconfiguration and fault isolation.
2. Difficult to add new devices, require modification or replacement of the backbone.
3. A fault in the backbone halts all transmission, the damaged area reflects signals back in the direction from where the signal originated creating noise in both directions.
4. Number of taps are limited as the signal degrades during travel due to energy transformation of heat.

Ring Topology

In a ring topology, each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Each device in the ring incorporates a repeater. When a device receives a signal intended for another device, its repeater regenerates the bits and passes them along. Generally in a ring, a signal is circulating at all times. If one device does not receive a signal within a specified period, it can issue an alarm. The alarm alerts the network operator to the problem and its location.



Advantage

1 A ring is relatively easy to install and reconfigure. Each device is linked to only its immediate neighbors (either physically or logically).

2. To add or delete a device requires changing only two connections.

3.Fault isolation is simpler.

4. Alarm can help in the location of fault .

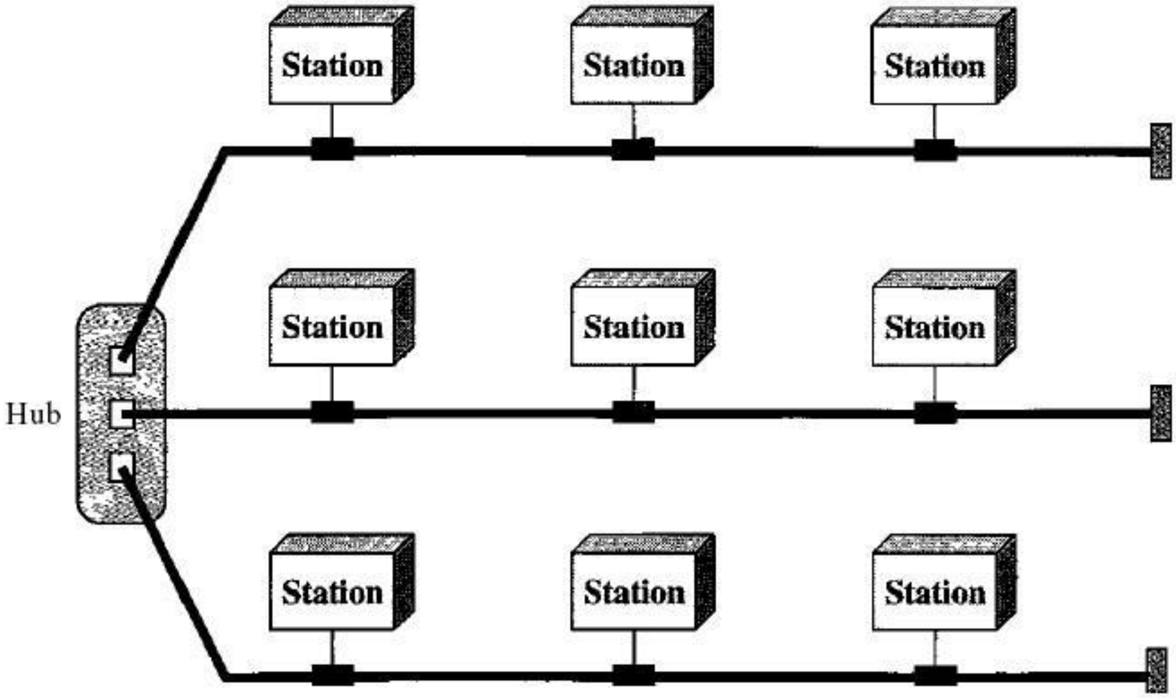
Disadvantage

1.Traffic is unidirectional .

2. In a simple ring, a break in the ring (such as a disabled station) can disable the entire network.

Hybrid Topology

A network can be hybrid. For example, we can have a main star topology with each branch connecting several stations in a bus topology as shown in Figure


Station
Station
Station
Station
Station
Station
Hub
Station
Station
Station

Categories of Networks

Local Area Networks:

Local area networks, generally called LANs, are privately-owned networks within a single building or campus of up to a few kilometres in size. They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information. LANs are distinguished from other kinds of networks by three characteristics:

(1) Their size,

(2) Their transmission technology, and

(3) Their topology.

LANs are restricted in size, which means that the worst-case transmission time is bounded and known in advance. Knowing this bound makes it possible to use certain kinds of designs that would not otherwise be possible. It also simplifies network management. LANs may use a transmission technology consisting of a cable to which all the machines are attached, like the telephone company party lines once used in rural areas. Traditional LANs run at speeds of 10 Mbps to 100 Mbps, have low delay (microseconds or nanoseconds), and make very few errors .

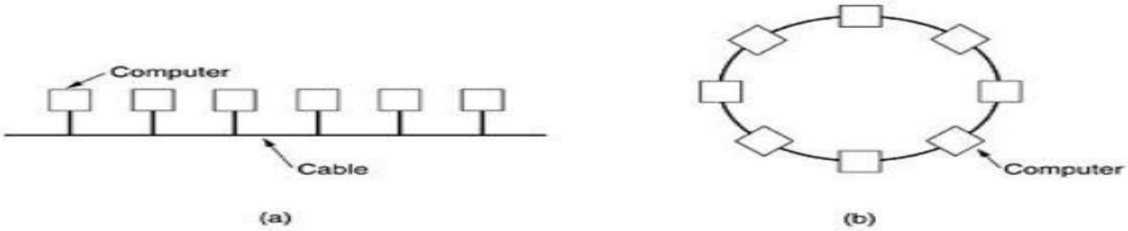


Fig.1: Two broadcast networks . (a) Bus. (b) Ring.

Metropolitan Area Network (MAN):

Metropolitan Area Network:

A metropolitan area network, or MAN, covers a city. The best-known example of a MAN is the cable television network available in many cities. This system grew from earlier community antenna systems used in areas with poor over-the-air television reception.

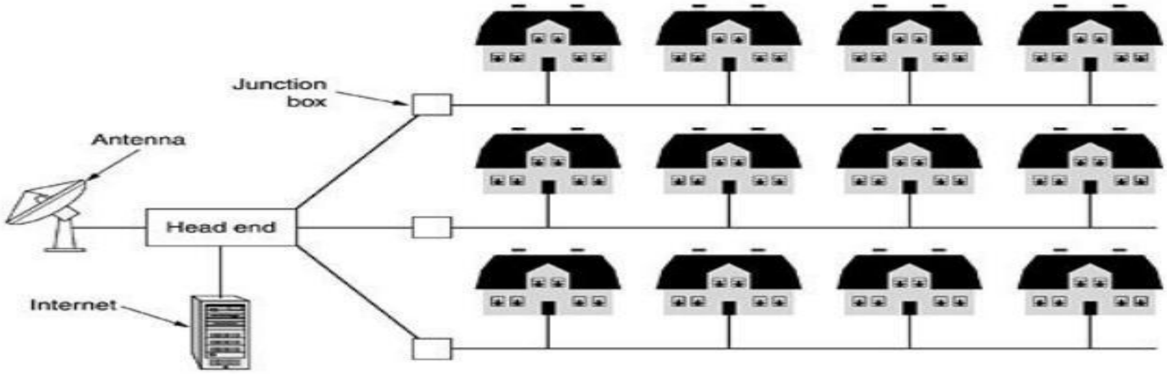


Fig.2: Metropolitan area network based on cable TV.

Wide Area Network (WAN).

Wide Area Network:

A wide area network, or WAN, spans a large geographical area, often a country or continent. It contains a collection of machines intended for running user (i.e., application) programs. These machines are called as hosts. The hosts are connected by a communication subnet, or just subnet for short. The hosts are owned by the customers (e.g., people's personal computers), whereas the communication subnet is typically owned and operated by a telephone company or Internet service provider. The job of the subnet is to carry messages from host to host, just as the telephone system carries words from speaker to listener.

Separation of the pure communication aspects of the network (the subnet) from the application aspects (the hosts), greatly simplifies the complete network design. In most wide area networks, the subnet consists of two distinct components: transmission lines and switching elements. Transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links.

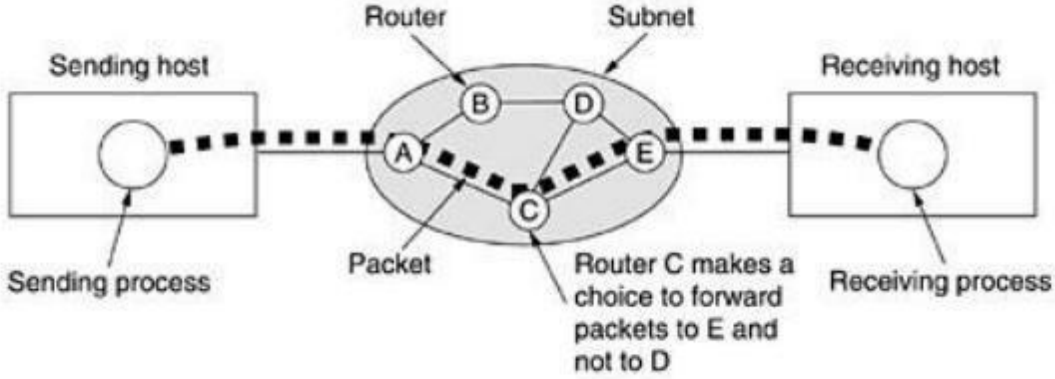
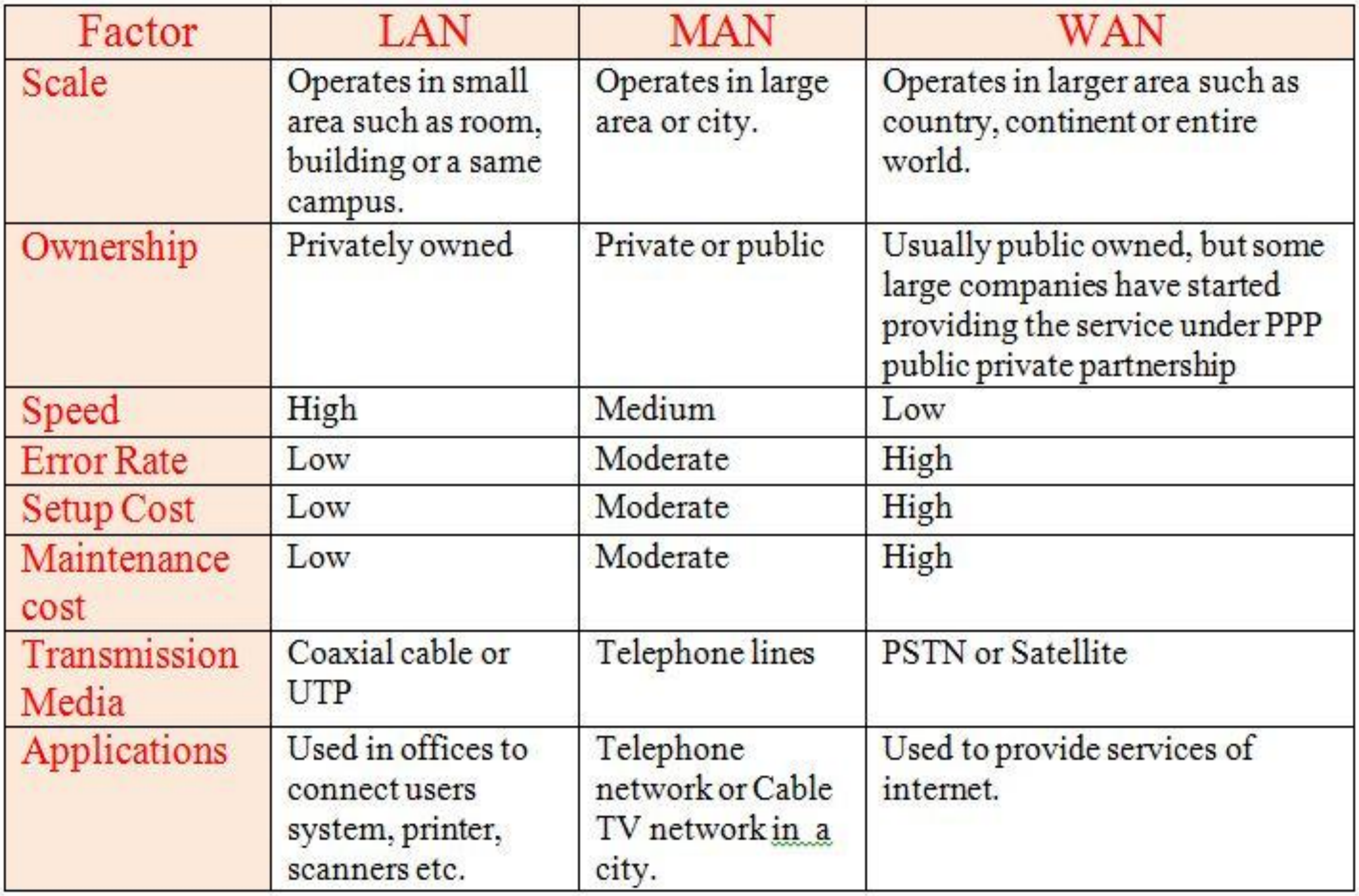


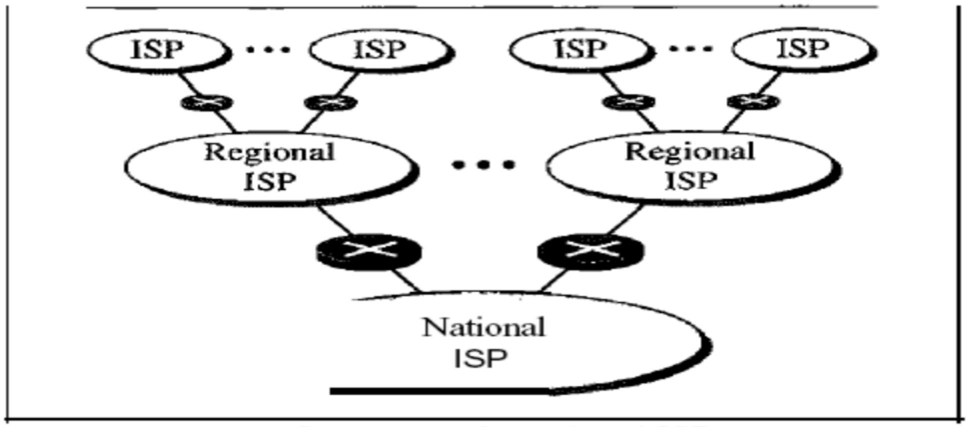
Fig.3.1: A stream of packets from sender to receiver.



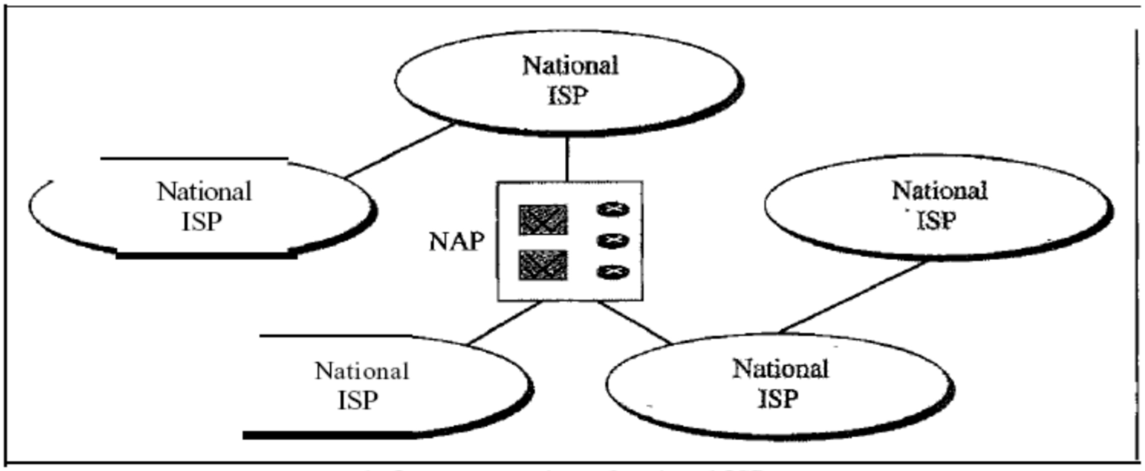
Factor	LAN	MAN	WAN
Scale	Operates in small area such as room, building or a same campus.	Operates in large area or city.	Operates in larger area such as country, continent or entire world.
Ownership	Privately owned	Private or public	Usually public owned, but some large companies have started providing the service under PPP public private partnership
Speed	High	Medium	Low
Error Rate	Low	Moderate	High
Setup Cost	Low	Moderate	High
Maintenance cost	Low	Moderate	High
Transmission Media	Coaxial cable or UTP	Telephone lines	PSTN or Satellite
Applications	Used in offices to connect users system, printer, scanners etc.	Telephone network or Cable TV network in a city.	Used to provide services of internet.

The Internet Today

The Internet has come a long way since the 1960s. The Internet today is not a simple hierarchical structure. It is made up of many wide- and local-area networks joined by connecting devices and switching stations. . Today most end users who want Internet connection use the services of Internet service providers (lSPs). There are international service providers, national service providers, regional service providers, and local service providers. The Internet today is run by private companies, not the government. Figure 1.13 shows a conceptual (not geographic) view of the Internet.



a. Structure of a national ISP



b. Interconnection of national ISPs

International Internet Service Providers:

At the top of the hierarchy are the international service providers that connect nations together.

National Internet Service Providers:

The national Internet service providers are backbone networks created and maintained by specialized companies. There are many national ISPs operating in North America; some of the most well known are SprintLink, PSINet, UUNet Technology, AGIS, and internet Mel. To provide connectivity between the end users, these backbone networks are connected by complex switching stations (normally run by a third party) called network access points (NAPs). These normally operate at a high data rate (up to 600 Mbps).

Regional Internet Service Providers:

Regional internet service providers or regional ISPs are smaller ISPs that are connected to one or more national ISPs. They are at the third level of the hierarchy with a smaller data rate. *Local Internet Service Providers:*

Local Internet service providers provide direct service to the end users. The local ISPs can be connected to regional ISPs or directly to national ISPs. Most end users are connected to the local ISPs. Note that in this sense, a local ISP can be a company that just provides Internet services, a corporation with a network that supplies services to its own employees, or a nonprofit organization, such as a college or a university, that runs its own network. Each of these local ISPs can be connected to a regional or national service provider.

1.4 PROTOCOLS AND STANDARDS

Protocols:

In computer networks, communication occurs between entities in different systems. An entity is anything capable of sending or receiving information.. A protocol is a set of rules that govern data communications. A protocol defines what is communicated, how it is communicated, and when it is communicated. The key elements of a protocol are syntax, semantics, and timing.

Syntax.

The term *syntax* refers to the structure or format of the data, meaning the order in which they are presented.

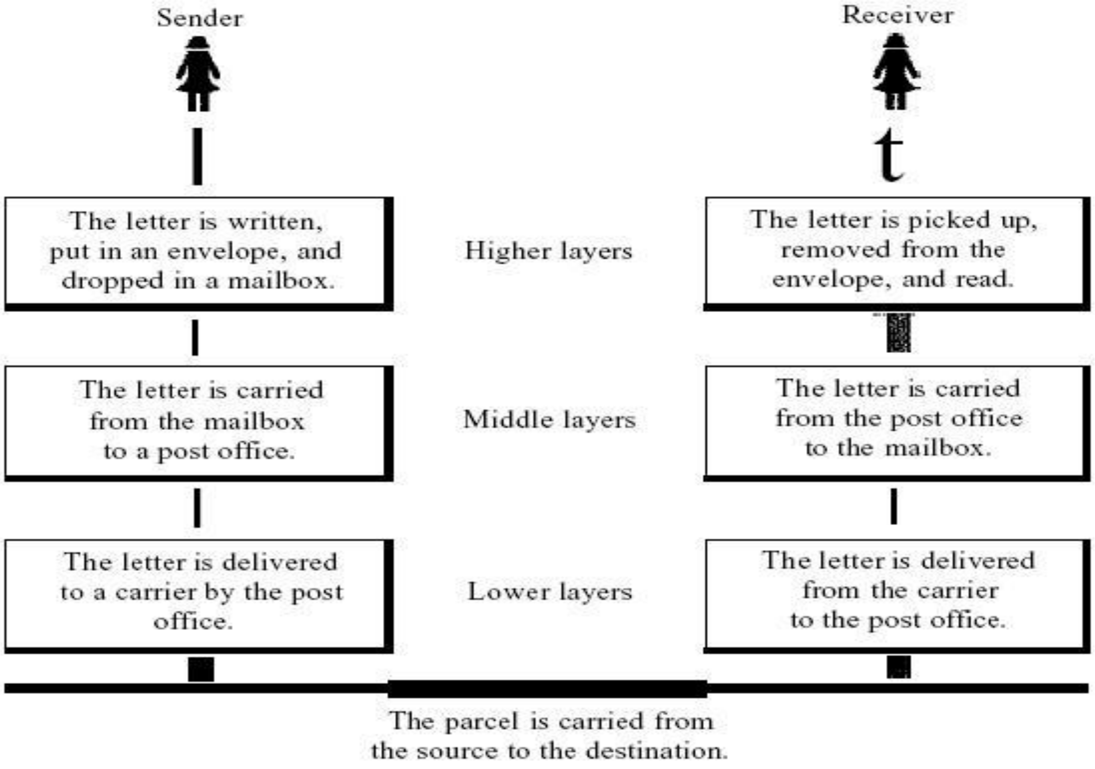
Semantics.

The word *semantics* refers to the meaning of each section of bits. How is a particular pattern to be interpreted, and what action is to be taken based on that interpretation?

Timing. The term *timing* refers to two characteristics: when data should be sent and how fast they can be sent. For example, if a sender produces data at 100 Mbps but the receiver can process data at only 1 Mbps, the transmission will overload the receiver and some data will be lost.

1.5 LAYERED TASKS

We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal maiLThe process of sending a letter to a friend would be complex if there were no services available from the post office. Below Figure shows the steps in this task.


Sender
Receiver
The letter is written, put in an envelope, and dropped in a mailbox.
Higher layers
The letter is picked up, removed from the envelope, and read.
The letter is carried from the mailbox to a post office.
Middle layers
The letter is carried from the post office to the mailbox.
The letter is delivered to a carrier by the post office.
Lower layers
The letter is delivered from the carrier to the post office.
The parcel is carried from the source to the destination.

Sender, Receiver, and Carrier

In Figure we have a sender, a receiver, and a carrier that transports the letter. There is a hierarchy of tasks.

At the Sender Site

Let us first describe, in order, the activities that take place at the sender site.

Higher layer. The sender writes the letter, inserts the letter in an envelope, writes the sender and receiver addresses, and drops the letter in a mailbox.

Middle layer. The letter is picked up by a letter carrier and delivered to the post office.

Lower layer. The letter is sorted at the post office; a carrier transports the letter.

0n the Way: The letter is then on its way to the recipient. On the way to the recipient's local postoffice, the letter may actually go through a central office. In addition, it may be transported by truck, train, airplane, boat, or a combination of these.

At the Receiver Site

Lower layer. The carrier transports the letter to the post office.

Middle layer. The letter is sorted and delivered to the recipient's mailbox.

Higher layer. The receiver picks up the letter, opens the envelope, and reads it.

The OSI Reference Model:

Open Systems Interconnection Basic Reference Model (OSI Reference Model or **OSI Model**) is an abstract description for layered communications.

It was developed as part of the **Open Systems Interconnection** (**OSI**) initiative .

In its most basic form, it divides network architecture into **seven layers** which, from top to bottom, are the Application, Presentation, Session, Transport, Network, Data-Link, and Physical Layers.

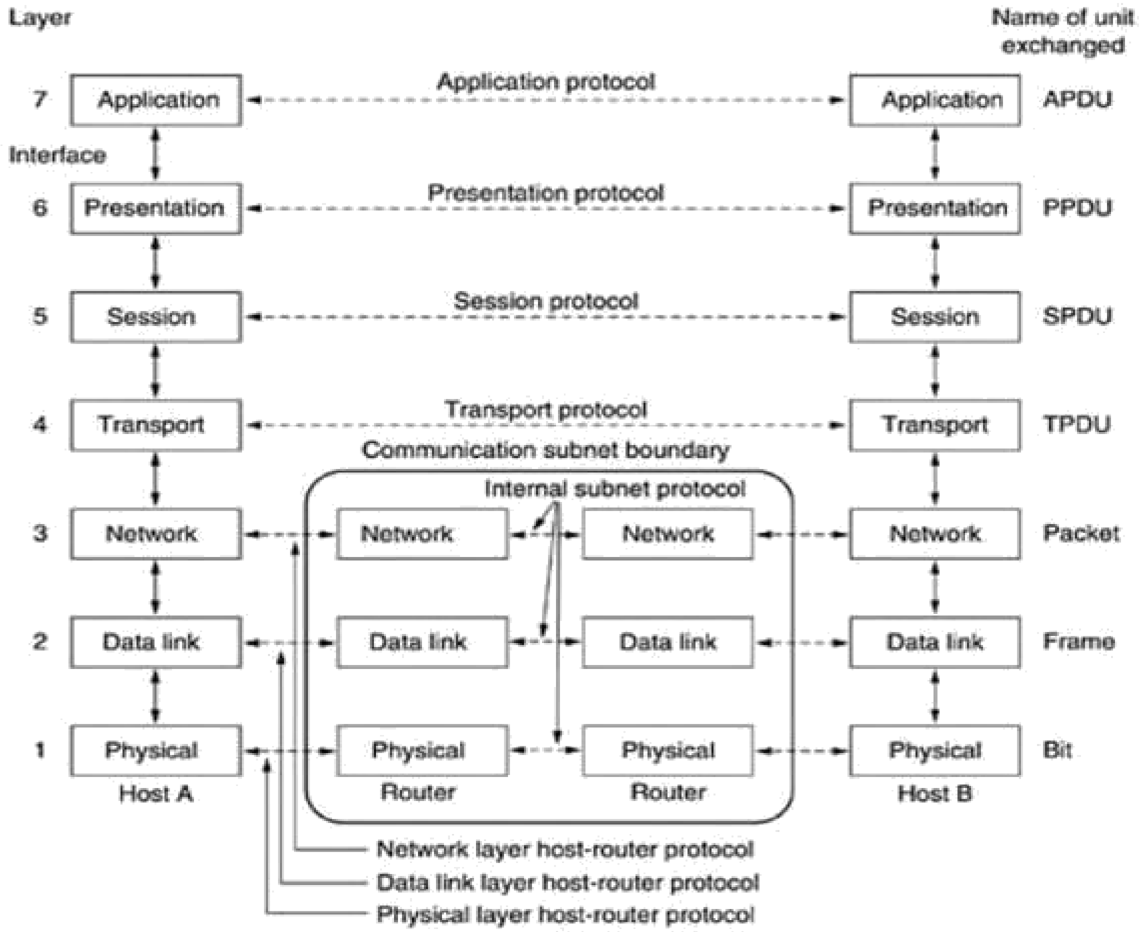


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Fig.4: The OSI reference model

The Physical Layer:

The physical layer is concerned with transmitting raw bits over a communication . This layer deals with mechanical and electrical specifications of the interface and transmission medium.

- Defines the characteristics of the interface between devices and the transmission medium.
- Defines no. of bits sent per second.
- Defines type of encoding i.e. conversion of bits into signals.
- Sender and receiver must be synchronized at bit level .
- Whether the configuration is point-to-point or multipoint.
- Which topology the network exhibits (mesh,star.ring,bus or hybrid)
- Defines direction of medium (simplex, half duplex or full duplex)

The Data Link Layer:

Thedatalinklayer is responsibleform movingframesfromonehop(node) to next hop.

Otherresponsibilitiesofthe datalinklayerinclude the following:

1. **Framing.**Thedatalink layerdividesthe streamofbitsreceivedfrom the network layer into manageabledataunitscalledframes.
2. **Flow control**. Iftherateatwhichthe dataareabsorbedbythe receiveris lessthanthe rateatwhichdataareproducedin thesender,the datalinklayerimposes aflowcontrolmechanismto avoidoverwhelmingthe receiver.
3. **Errorcontrol**. Thedatalink layeraddsreliability to the physicallayerbyadding mechanismsto detectandretransmitdamagedorlostframes. Italsousemechanismto recognize duplicateframes. Errorcontrolisachievedthrough atraileraddedto theendofthe frame.
4. **Accesscontrol.** Whentwo ormoredevicesareconnectedto the samelink, datalink layerprotocolsarenecessaryto determinewhichdevicehascontroloverthelink atanygiventime.

Network Layer

Thenetworklayer is responsible for the source-to-destinationdeliveryofapacket,Possiblyacrossmultiplenetworks(links).

Otherresponsibilitiesof the network layerinclude the following:

1. **Logical addressing**. The physical addressing implemented by the data link layer handles the addressing problem locally. If a packet network boundary, weneed another addressing system to help distinguish the source and destination systems. The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender andreceiver.
2. **Routing**.When independent networks or links are connected to create internetworks(network ofnetworks)oralarge network,the connectingdevices(calledroutersorswitches)routeorswitchthe packetsto their final destination.

Transport Layer

Thetransportlayeris responsiblefor process-to-processdeliveryofthe entiremessage.Aprocessis anapplicationprogramrunningonahost.WhereasthenetworklayerOverseessource-to-destinationdeliveryofindividual packets,it doesnotrecognize anyrelationship betweenthose packets.

Otherresponsibilitiesofthe transport layerinclude the following:

1. **Service-pointaddressing**. Computersoftenrun several programsatthe sametime. Forthis reason, source-to-destinationdeliverymeansdeliverynotonlyfromOnecomputerto the nextbutalsofrom aspecificprocess(running program)ononecomputerto aspecificprocess(runningprogram)onthe otherThetransport

layer headermusttherefore include atype ofaddresscalledaservice-pointaddress(or portaddress).

2. **Segmentationandreassembly**. Amessageis dividedintotransmittable segments,witheachsegmentcontainingasequencenumber.Thesenumbersenablethetransportlayer toreassemblehe messagecorrectlyuponarrivingatthe destinationandto identify andreplacepacketsthatwerelostintransmission.
3. **Connectioncontrol.** Thetransportlayercanbeeitherconnectionlessorconnectionoriented.Aconnectionlesstransport layer treats eachsegmentasanindependentpacketanddeliversitto the transportlayeratthe destinationmachine.Aconnectionorientedtransport layer makesaconnectionwiththe transport layer atthe destination machine first befoedeliveringthe packets.Afterallthe dataaretransferred,the connectionis terminated.
4. **Flowcontrol**. the transport layer is responsible for flowcontrol.However,flow controlatthis layer is performedendto endrather thanacrossasinglelink.
5. **Errorcontrol.**

Errorcontrolatthis layer is performedprocess-toprocessratherthan acrossasinglelink. Thesendingtransport layer makessurethat the entiremessagearrives atthe receiving transport layer without terror

(damage, loss, orduplication).

Session Layer

Thesessionlayeris the networkdialogcontroller.Itestablishesmaintains,andsynchronizes the interaction amongcommunicating

systems.

1. **Dialog Control-**
   Establishes, maintains and terminating dialog between communicating devices.Communication between two devices can be either half duplex or full duplex.
2. **Synchronization**
   Thesessionlayer allowsaprocessto addcheckpoints,or synchronization points,to astreamofdata**.**

Presentation LAYER
Thepresentationlayeris concernedwiththe syntaxandsemanticsofthe informationExchangedbetweentwo systems.

1. **Translation**
   The information mustbechangedto bitstreamsbeforebeingtransmitted. BecausedifferentComputers use different encoding systems, the presentation layer is responsibleforinteroperability between these differentencodingmethods.Thepresentationlayer
   Atthe senderchanges theinformation from its sender-dependentformat into acommonformat.
2. **Encryptio**n
   Encryption and decryption may be necessary for sensitive data
3. **Compression**

Datacompression reduces the numberofbits contained in the information. Datacompressionbecomesparticularlyimportantin the transmissionof multimedia suchas text, audio,andvideo.

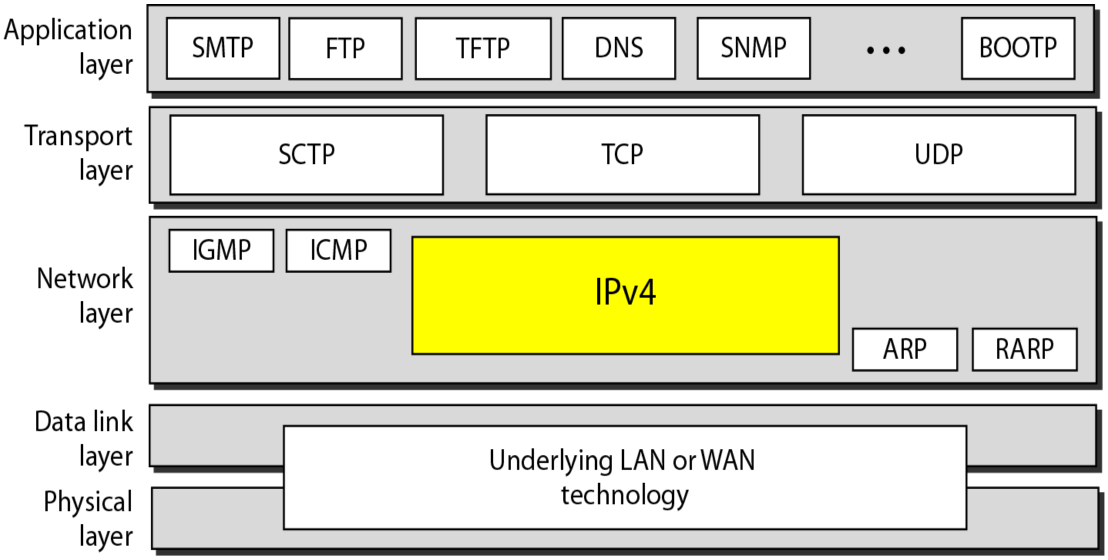
Application Layer

Itprovidesuserinterfaces andsupportfor servicessuchaselectronicmail,Remote file accessandtransfer, shareddatabasemanagement,andothertypes ofdistributedinformationservices.

1. **Network Virtual Terminal**
   Allows user to log on a remote host via terminal emulation software
2. **Mailservices.** Thisapplication provides the basis for e-mail forwarding andstorage.
3. **Directoryservices**. Thisapplication providesdistributeddatabasesources andaccessfor globalinformationaboutvariousobjectsandservices.
4. **File Transfer ,access and Management**

TCP/IP MODEL

Figure *Position of IPv4 in TCP/IP protocol suite*



TCP/IP is a hierarchical protocol means that eachupper-level protocol is supported by one or more lower-level protocols.

<u>Physical and Data link layer</u>

<u>Network Layer</u>

Atthe networklayer (or, internetwork layer), TCP/IPsupports the Internetworking Protocol IP, in turn, usesfour supportingprotocols:ARP, RARP,ICMP, and IGMP.

InternetworkingProtocol(IP)

TheInternetworkingProtocol(IP) is the transmission mechanismusedbythe TCP/IPprotocols. Itis anunreliableandconnectionlessprotocol-abest-effortdeliveryservice.Theterm besteffortmeansthatIPprovidesnoerrorcheckingortracking. IPtransports datain packetscalleddatagrams,eachofwhichis transported separately. Datagrams can travel longdifferentroutesandcanarriveoutofsequenceorbeduplicated.IPdoesnotkeeptrack ofthe routes andhasnofacility forreorderingdatagramsoncethey arriveattheirdestination.

Address Resolution PROTOCOL (ARP)

TheAddressResolution Protocol(ARP)allowsahostto discoverits physicaladdress when it knows its internet address.

Reverse Address Resolution PROTOCOL(RARP)

TheReverseAddressResolutionProtocol(RARP)allowsahostto discoverits Internetaddresswhenitknowsonlyits physicaladdress

Internet Control Message Protocol(ICMP)

ICMP is amechanismusedbyhostsand gateways to sendnotificationofdatagramproblemsbackto the sender. ICMPsendsQuery anderrorreportingmessages.

Internet Group Message Protocol(IGMP)

IGMP is usedto facilitate the simultaneousTransmission ofamessageto agroupofrecipients.

<u>Transport Layer</u>

UDPandTCParetransport level protocolsresponsibleFor deliveryofamessagefromaprocessto anotherprocess.

User Datagram Protocol(UDP)

Itis aprocess-to-processprotocolthat addsonlyportaddresses,checksum Errorcontrol,andlength information to the datafrom the upperlayer.

Transmission Control Protocol(TCP)

TheTransmissionControlProtocol(TCP) providesfull transport-layer servicestoapplications.TCPis areliablestreamtransportprotocol.Theterm stream, in this context, meansconnection oriented:AconnectionmustbeestablishedbetweenbothendsOf atransmissionbeforeeithercantransmitdata.At the sending end of each transmission, TCP divides a stream of datainto smallerUnits calledsegments. Eachsegmentincludes asequencenumberfor reordering afterreceipt,togetherwithanacknowledgmentnumberforthe segmentsreceived

Stream Control Transmission Protocol(SCTP)

TheStreamControlTransmissionProtocol(SCTP) providessupportfor newer Applicationssuchasvoiceoverthe Internet.

<u>Application LAYER</u>

Theapplication layer in TCP/IPis equivalentto the combinedsession,presentation,And applicationlayers in the OSI model.

Addressing

In TCP/IP protocol uses 4 types of address

1. **Physical Address**

   Thephysicaladdress,alsoknownasthelinkaddress,is the addressofanodeasdefinedBy its LANorWANItis included in the frame usedbythe datalink layer.
   Forexample,EthernetUsesa6-byte(48-bit) physicaladdressthat is imprinted onthe networkinterface card(NIC).

   07:01:02:01:2C:4B
   A6-byte(12hexadecimaldigits)physicaladdress

2. **Logical Address**

   Alogicaladdressinthe Internet is currentlya32-bitaddressthatcanuniquelydefineahost connectedto theInternet.Notwo publicly addressed and visible hostsonthe InternetcanhavethesameIPaddress.

   Thephysicaladdresseswillchangefromhoptohop,butthelogicaladdressesusuallyremainthesame.
   e.g. 172.16.0.221

3. **Port Address**

   Inthe TCP/IParchitecture,the label assignedto aProcess is calledaportaddress.AportaddressinTCP/IPis 16bits length.
   e.g. 753

4. **Specific Address**

   Someapplicationshaveuser-friendlyaddressesthataredesignedforthatspecificaddress.
   Examplese-mailaddress(forexample,forouzan@fhda.edu)andtheUniversal ResourceLocator(URL)(forexample,www.mhhe.com)

Connecting Devices

1. **Repeaters**
    - A repeater is a device that operates only in the physical layer.. A repeater receives a signal and, before it becomes too weak or corrupted, regenerates the original bit pattern. The repeater then sends the refreshed signal.
    - A repeater connects segments of a LAN.
    - A repeater forwards every frame; it has no filtering capability.
    - A repeater is a regenerator, not an amplifier.

2. **Hub**

    Hub is a connector it connects the wires coming from different branches.

An active hub is actually a multipart repeater. It is normally used to create connectionsbetween stations in a physical star topology.

3. **Bridges**
    - A bridge operates in both the physical and the data link layer. device. A data link layer device, the bridge can Check the physical(MAC) addresses (source and destination) contained in the frame.
    - A bridge has a table used in filtering decisions.
    - A bridge has filtering capability. It can check the destination address of a frame and decide if the frame should be forwarded or dropped.
    - A bridge does not change the physical(MAC) addresses in a frame.
4. **Routers**
    - A **router** is a device that forwards data packets along networks. A **router** is connected to at least two networks, commonly two LANs or WANs or a LAN and its ISP's network. **Routers are** located at gateways, the places where two or more networks connect.
    - It operate on physical, datalink and network layer .
    - Router is 3 layer device that routes the IP packets based on their logical address

- A router has routing table that is used for making decision about the routes.
- Routing tables are dynamic and updated by using routing protocols.

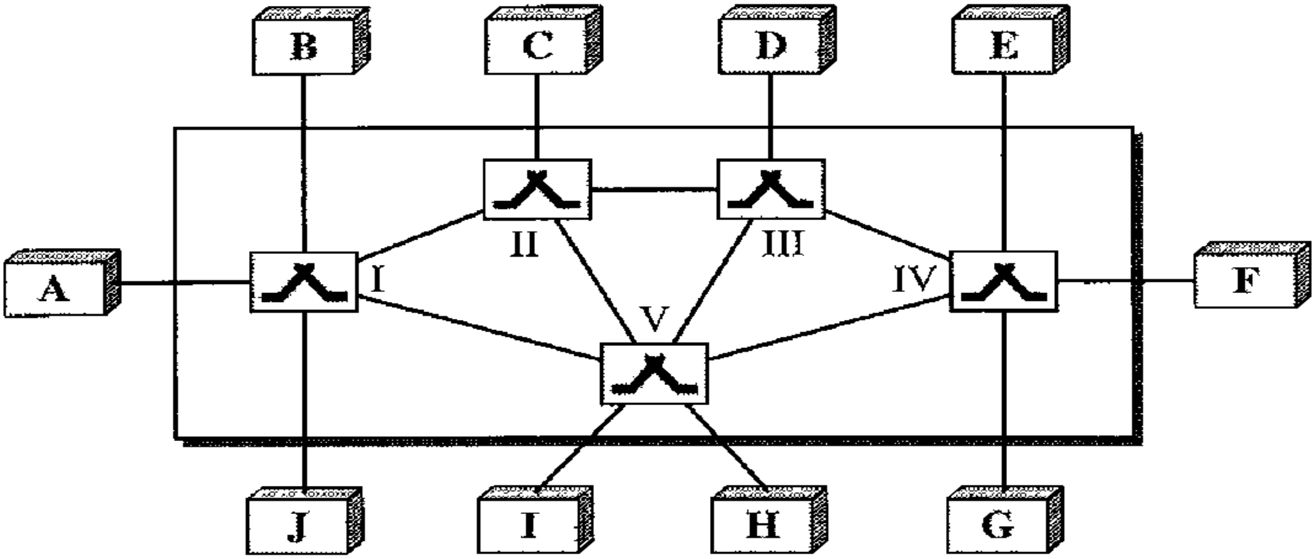
5. Gateway

A gateway is normally a computer that operatesin all five layers of the Internet or seven layers of OSI model. A gateway takes anapplication message, reads it, and interprets it. This means that it can be used as aconnecting device between two internetworks that use different models. For example,a network designed to use the OSI model can be connected to another network usingthe Internet model. The gateway connecting the two systems can take a frame asit arrives from the first system, move it up to the OSI application layer, and remove themessage.

Switching

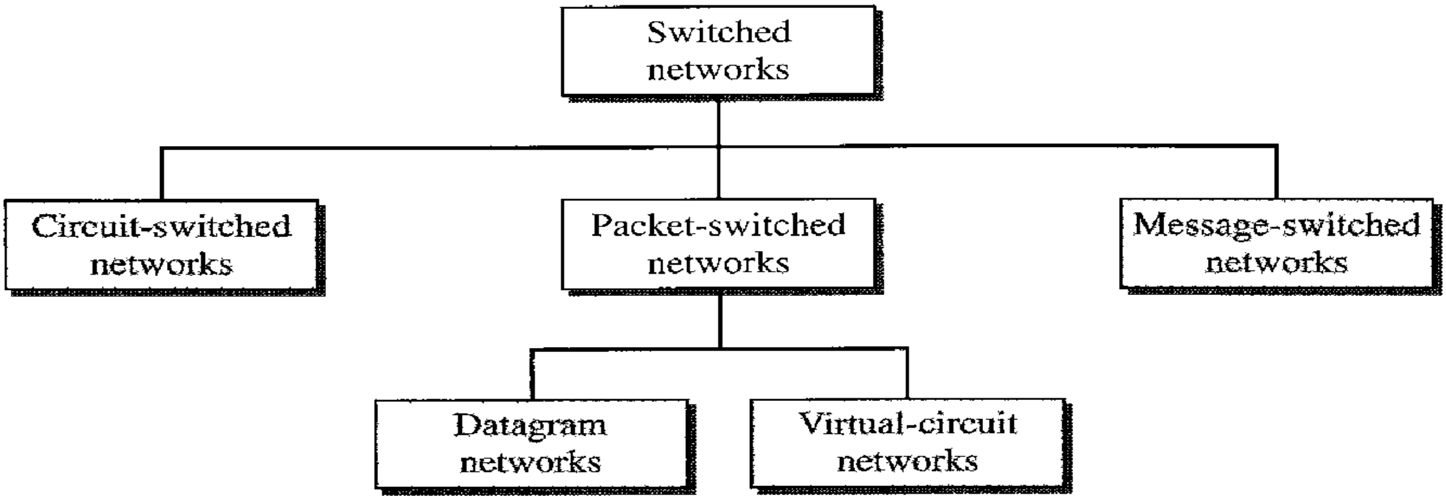
A switched network consists of a series of interlinked nodes, called switches. Switch isa h/w and s/w device capable of creating temporary connection between two or more devices linked to switch but not to each other.

A switch n/w consist of intermediate nodes called switches .on the basis of switching method we can divide a switched network



The end systems (communicating devices) are labeled A, B, C, D, and so on, and theswitches are labeled I, II, III, IV, and V. Each switch is connected to multiple links.

There are 3 types of switching



Circuit Switched Network

- A circuit-switched network is made of a set of switches connected by physical links,in which each link is divided into *n* channels.
- Circuit Switched Network is designed for voice communication**.**

- In circuit switching, the resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer until the teardown phase.

- Circuit Switched Network takes place at physical layer**.**
- The traditional telephone n/w uses circuit switching.

When end system A needsto communicate with end system M, system A needs to request a connection to M thatmust be accepted by all switches as well as by M itself. This is called the setup phase;a circuit (channel) is reserved on each link, and the combination of circuits or channelsdefines the dedicated path. After the dedicated path made of connected circuits (channels)is established, data transfer can take place. After all data have been transferred, thecircuits are tom down

Weakness

1. circuit-switched networks are not as efficient as the other two types of networks because resources are allocated during the entire duration of the connection.These resources are unavailable to other connections
2. Delay is low as there is no wait time.

Packet Switched Network

- In packet-switched network the message is divided into packets of fixed or variable size. The size of the packet is determined by the network and the governing protocol.
- In packet switching, there is no resource allocation for a packet. This means thatthere is no reserved bandwidth on the links, and there is no scheduled processing time for each packet. Resources are allocated on demand.
- The allocation is done on a firstcome,first-served basis. When a switch receives a packet, no matter what is the source or destination, the packet must wait if there are other packets being processed. this lack of reservation may create delay.

Datagram Network

- In a datagram network, each packet is treated independently of all others. Even if a packet is part of a multipacket transmission, the network treats it as though it existed alone. Packets in this approach are referred to as **datagrams.**
- The datagram networks are sometimes referred to as connectionless networks. The term *connectionless* here means that the switch (packet switch) does not keep informationabout the connection state.
- There are no setup or teardown phases. Each packet is treated the same by a switch regardless of its source or destination.
- Datagram switching is normally done at the network layer.
- A switch in a datagram network uses a routing table that is based on the destination address.
- The efficiency of a datagram network is better than that of a circuit-switched network because resources are allocated only when there are packets to be transferred.
- There may be greater delay in a datagram network than in a virtual-circuit network.

Virtual Circuit Network (VCN)

A virtual-circuit network is a cross between a circuit-switched network and a datagramnetwork.it uses some characteristics of both .

- In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).
- A virtual-circuit network is implemented ti the data link layer.
- There are setup ,data transfer and teardown phase.
- Resources can be allocated during the setup phase as circuit switched or on demand as packet switched .
- In virtual-circuit switching, all packets belonging to the same source and destinationtravel the same path; but the packets may arrive at the destination with different delays if resource allocation is on demand.

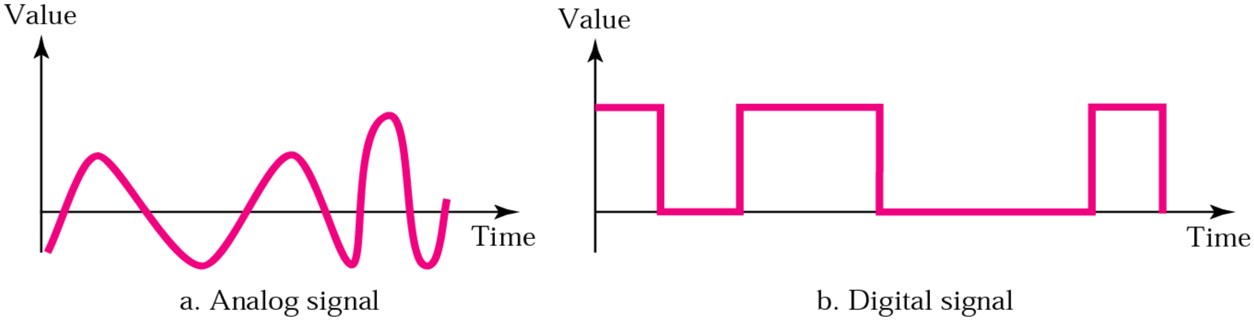
Message Switching Network

- In message switching network no physical path esatabilish in advance b/w sender and receiver .
- In message switching network uses technique of store and forward method
- The intermediate nodes have the responsibility of transferring the entire message to the next node. Hence, each node must have storage capacity. A message will only be delivered if the next hop and the link connecting it are both available

Transmission media

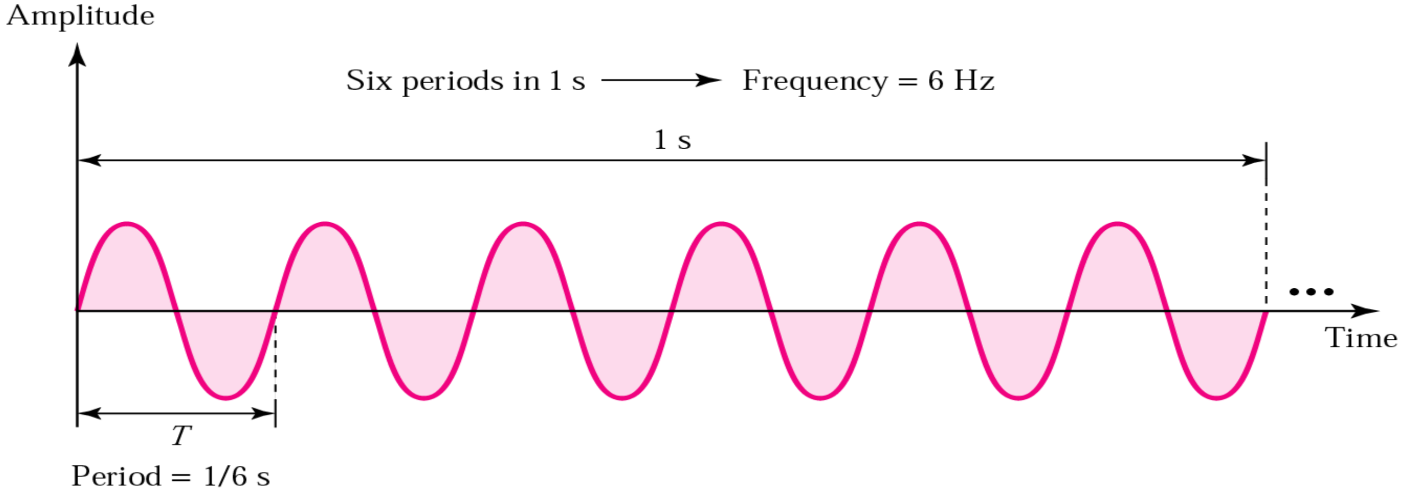
Digital Transmission

Data can be analog or digital. Analog data are continuous and take continuous values.Digital data have discrete states and take discrete values. In data communications, we commonly use periodic analog signals and nonperiodic digital signals.



a. Analog signal b. Digital signal

Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle. Frequency refers to the number of periods in I s. Note that period and frequency are justone characteristic defined in two ways. Period is the inverse of frequency, and frequencyis the inverse of period.



Frequency is the rate of change with respect to time. Change in a short span of time means high frequency. Change over a long span of time means low frequency.

If a signal does not change at all, its frequency is zero.

If a signal changes instantaneously, its frequency is infinite.

- We find the equivalent of 1 ms.We make the following substitutions:
  $100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 100 \times 10^{-3} \times 10^{6} \text{ms} = 10^{5} \text{ms}$
- Now we use the inverse relationship to find the frequency, changing hertz to kilohertz
  $100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$
  $f = 1/10^{-1} \text{ Hz} = 10 \times 10^{-3} \text{ KHz} = 10^{-2} \text{ KHz}$

Bandwidth

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

A digital signal can have more than two levels. In this case, we can send more than 1 bit for each level.

In general if signal has L levels each level needs log L no. of bits .

No. of bits= log L

Bit Rate

The bit rate is the number of bits sent in 1 second expressed in bits persecond (bps).
Q. Assume we need to download text documents at the rate of 100 pages per minute. What is therequired bit rate of the channel?
Solution
A page is an average of 24 lines with 80 characters in each line. If we assume that one characterrequires 8 bits, the bit rate is

100 x 24 x 80 x 8 =1,636,000 bps =1.636 Mbps

Bit Rate = Sampling Rate * No. of bits per Sample

Bit Length

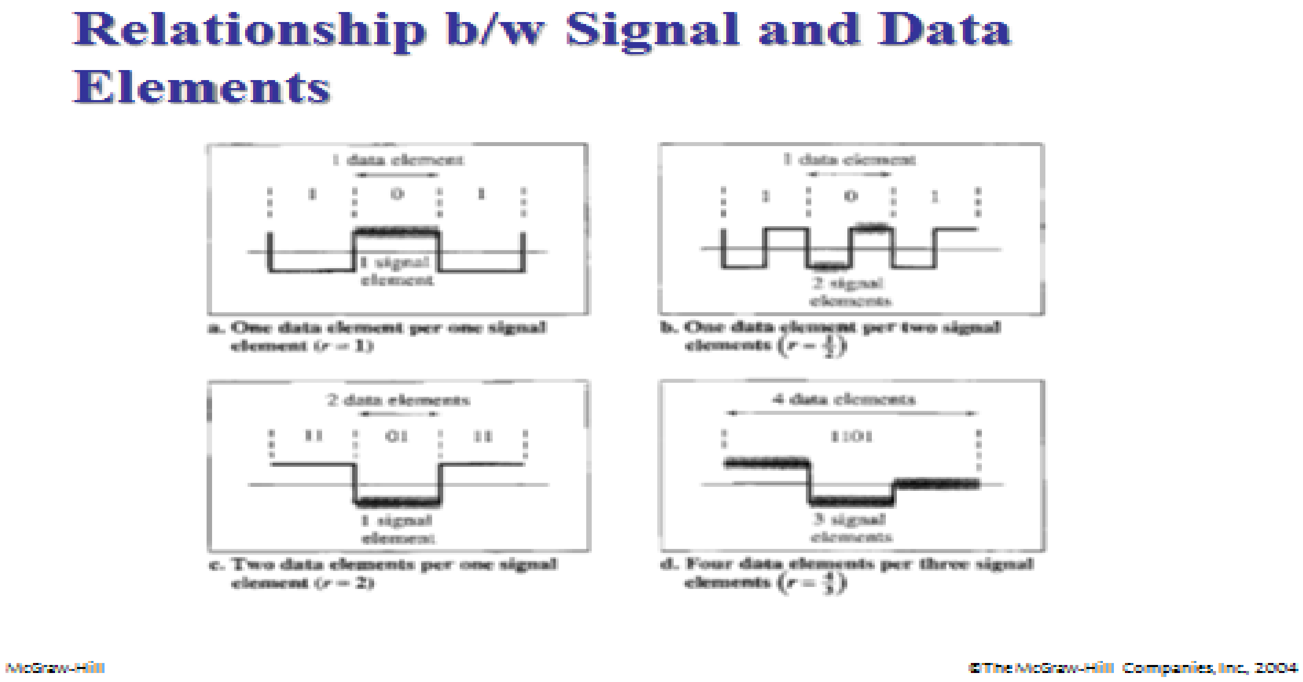
The bit length is the distance one bit occupies on the transmission medium.

Bit length =propagation speed x bit duration

Data RateVs Signal rate

The data rate is the number of bits sent in 1 second expressed in bits persecond (bps).
The signal rate is the number of signals sent in 1 second. The unit is Baud.
The data rate is also known as bit rate
The signal rate is also known as pulse rate or modulation rate or baud rate.

$$S = c \times N \times \frac{1}{r} \qquad \text{baud}$$



Relationship b/w Signal and Data Elements

a. One data element per one signal element ($r = 1$)

b. One data element per two signal elements ($r = \frac{1}{2}$)

c. Two data elements per one signal element ($r = 2$)

d. Four data elements per three signal elements ($r = \frac{4}{3}$)

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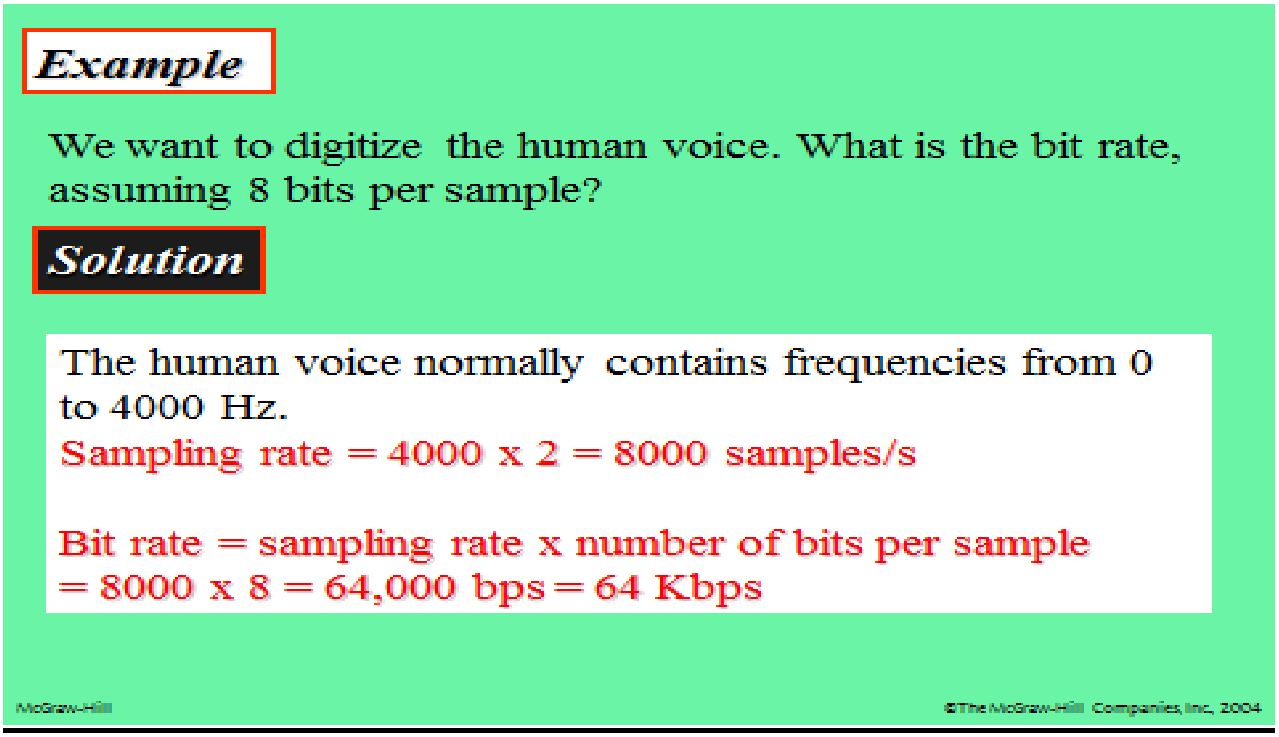

Example

We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Solution

The human voice normally contains frequencies from 0 to 4000 Hz.
Sampling rate = 4000 x 2 = 8000 samples/s

Bit rate = sampling rate x number of bits per sample
= 8000 x 8 = 64,000 bps = 64 Kbps

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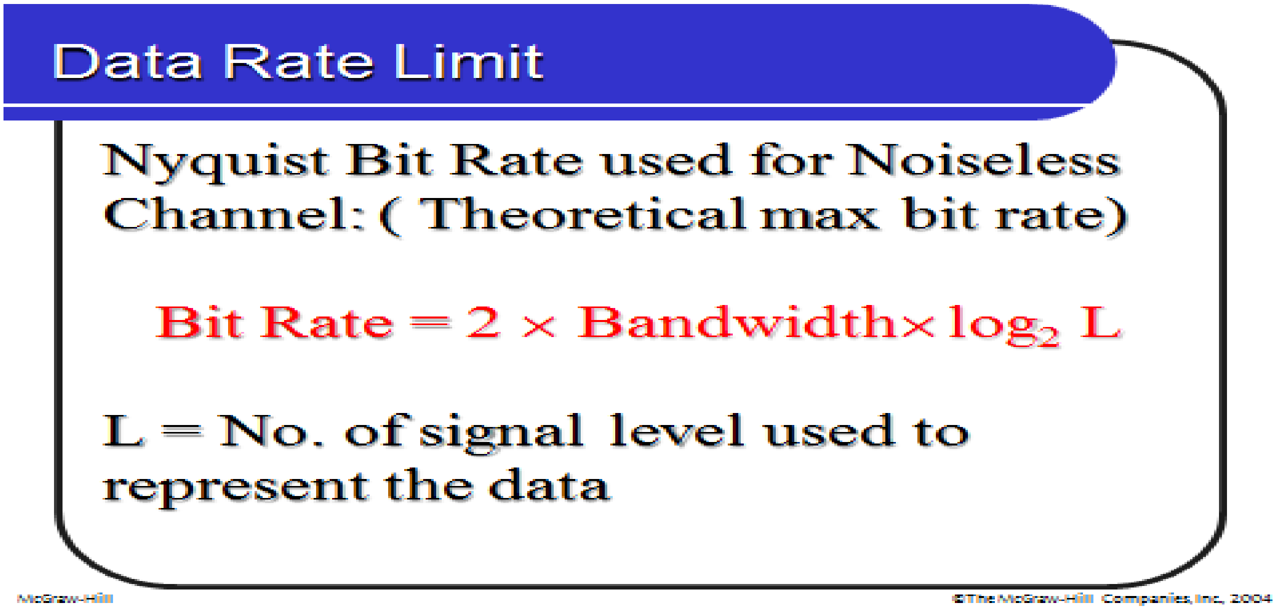
DATA RATE LIMITS

we can send data, inbits per second. over a channel. Data rate depends on three factors:

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise)

Noiseless Channel: Nyquist Bit Rate



Data Rate Limit

Nyquist Bit Rate used for Noiseless Channel: (Theoretical max bit rate)

$$\text{Bit Rate} = 2 \times \text{Bandwidth} \times \log_2 L$$

L = No. of signal level used to represent the data

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For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximumbit rate

BitRate= 2 x bandwidth x 10g2 *L*

In this formula, bandwidth is the bandwidth of the channel, *L* is the number of signallevels used to represent data, and BitRate is the bit rate in bits per second.

Example
Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signallevels.

The maximum bit rate can be calculated as
BitRate =2 x 3000 x log2 2 =6000 bps

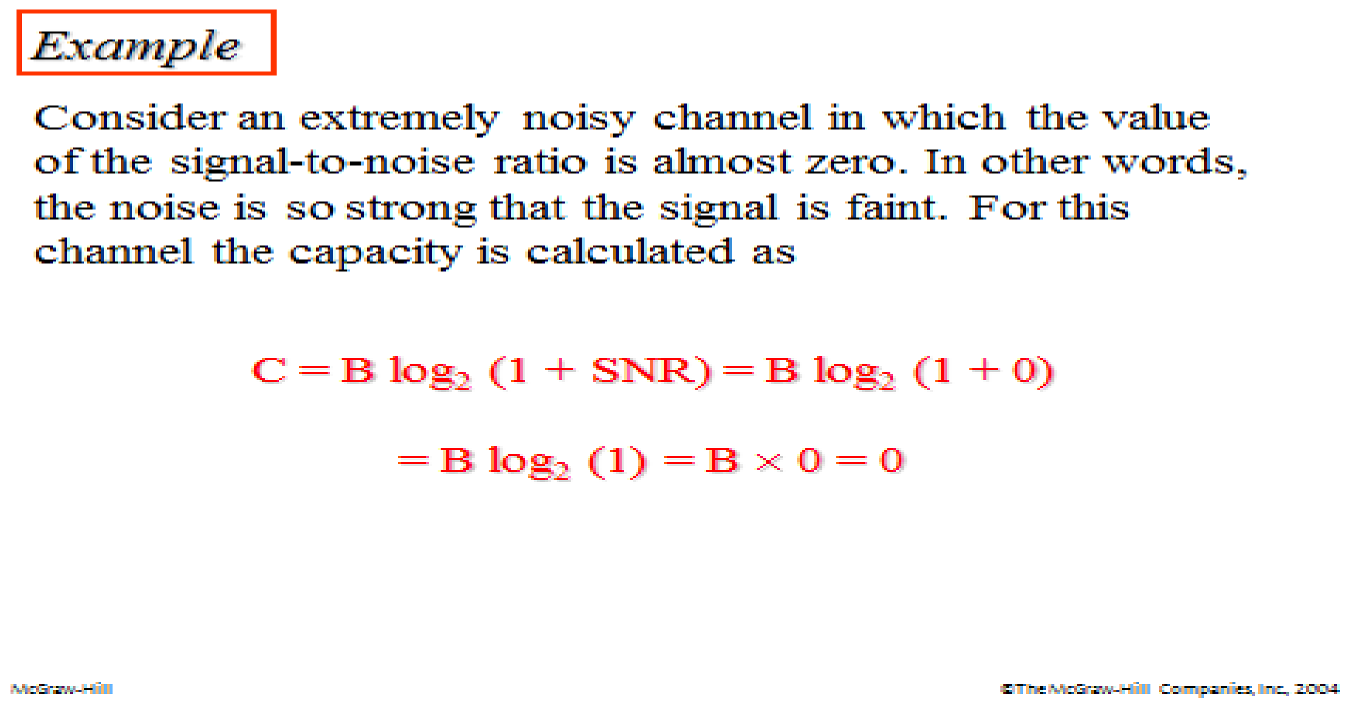
Noisy Channel: Shannon Capacity

we cannot have a noiseless channel; the channel is always noisy. In 1944, Claude Shannon introduced a formula, called the Shannon capacity, to determine thetheoretical highest data rate for a noisy channel:

Capacity =bandwidth X log2 (1 +SNR)

In this formula, bandwidth is the bandwidth of the channel, SNR is the signal-tonoiseratio, and capacity is the capacity of the channel in bits per second.

We have a channel with a 1MHz bandwidth. The SNR for this channel is 63. What are the appropriatebit rate and signal level?
Solution
we use the Shannon formula to find the upper limit.
C =*B* log2 (l + SNR) =106 log2 (1 + 63) =106 10g2 64 =6 Mbps



Example

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity is calculated as

$$C = B \log_2 (1 + SNR) = B \log_2 (1 + 0)$$

$$= B \log_2 (1) = B \times 0 = 0$$

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The Shannon formula gives us 6 Mbps, the upper limit. For better performance we choosesomething lower, 4 Mbps, for example. Then we use the Nyquist formula to find the number ofsignal levels.
4Mbps=2x 1 MHz x *log2 L* ... *L=4*

Note :The Shannon capacity gives us the upper limit;
theNyquist formula tells us how many signal levels we need.

Note:

1. The first, *bandwidth in hertz*, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.

2. The second, *bandwidth in bits per second*, refers to the speed of bit transmissionin a channel or link.

Example

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minutewith each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

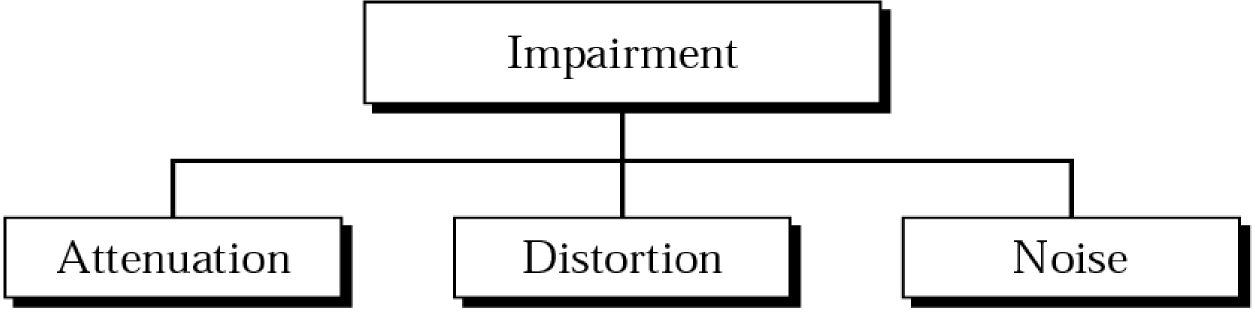
We can calculate the throughput as

Throughput= 12,000 x 10,000 /60=2 Mbps

The throughput is almost one-fifth of the bandwidth in this case.

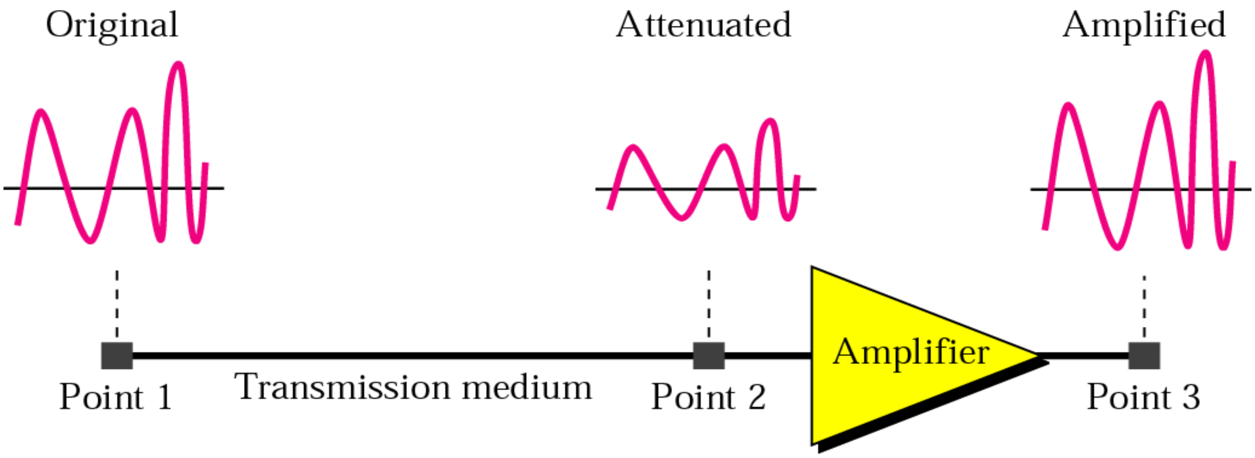
Transmission impairment

Signals travel through transmission media, which are not petfect. The impetfection causessignal impairment. This means that the signal at the beginning of the medium is not thesame as the signal at the end of the medium. What is sent is not what is received. Threecauses of impairment are attenuation, distortion, and noise



Attenuation

Attenuation means a loss of energy. When a signal, simple or composite, travels through a medium, it loses some of its energy in overcoming the resistance of the medium. That is why a wire carrying electric signals gets warm, if not hot, after a while. Some of the electrical energy in the signal is converted to heat. To compensatefor this loss, amplifiers are used to amplify the signal.



The decibel (dB) measures the relative strengths of two signals or one signal at two differentpoints. Note that the decibel is negative if a signal is attenuated and positive if asignal is amplified.

$$\mathbf{dB = 10\log_{10}\frac{\mathit{P}_2}{\mathit{P}_1}}$$

Variables *PI* and *P2* are the powers of a signal at points 1 and 2, respectively

Example 3.26
Suppose a signal travels through a transmission medium and its power is reduced to one-half.
This means that *P2* = 1/2*P1*In this case, the attenuation (loss of power) can be calculated as
P2= 0.5PI
10log P2/P1= = 10 log0.5 = 10(-0.3) = -3 dB
A loss of 3 dB (-3 dB) is equivalent to losing one-half the power.

Q2
The power of a signal is 10 mW and the power of the noise is 1 microW; what are the values of SNRand SNRdB?

Distortion

Distortion means that the signal changes its form or shape. Distortion can occur in acomposite signal made of different frequencies. Each signal component has its ownpropagation speed (see the next section) through a medium and, therefore, its owndelay in arriving at the final destination. Differences in delay may create a difference inphase if the delay is not exactly the same as the period duration. In other words, signalcomponents at the receiver have phases different from what they had at the sender.

Noise

Noise is another cause of impairment. Several types of noise, such as thermal noise, induced noise, crosstalk, and impulse noise, may corrupt the signal. Thermal noise isthe random motion of electrons in a wire which creates an extra signal not originallysent by the transmitter. Induced noise comes from sources such as motors and appliances.

These devices act as a sending antenna, and the transmission medium acts as the receiving antenna. Crosstalk is the effect of one wire on the other. One wire acts as asending antenna and the other as the receiving antenna. Impulse noise is a spike (a signalwith high energy in a very short time) that comes from power lines, lightning.

Latency (Delay)

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source. We cansay that latency is made of four components: propagation time, transmission time,queuing time and processing delay.

Latency =propagation time +transmission time +queuing time + processing delay

Propagation Time

Propagation time measures the time required for a bit to travel from the source to thedestination. The propagation time is calculated by dividing the distance by the propagationspeed.

Propagation time = Distance / Propagation speed

Transmission time

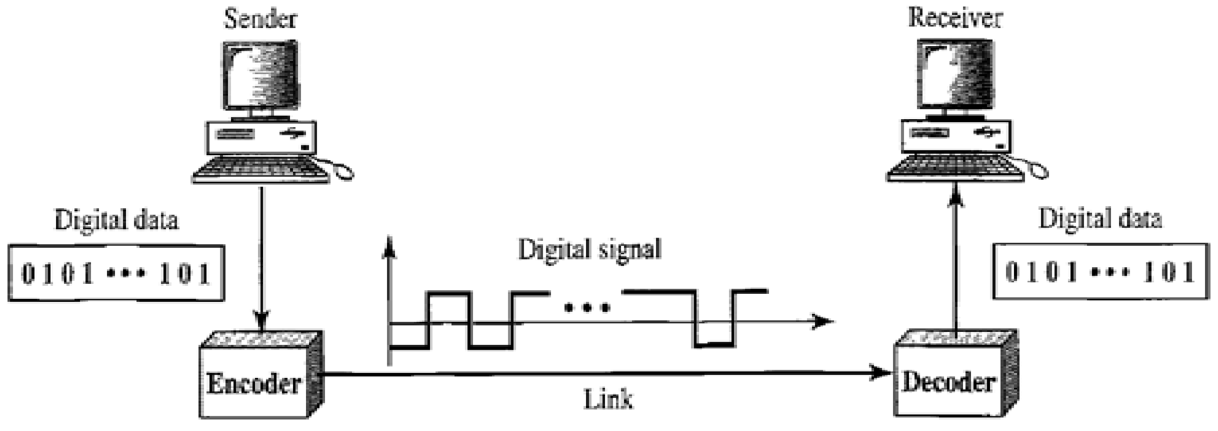
There is a time between the first bit leaving the sender and the last bit arriving at the receiver.

Transmission time = Message / Bandwidth

Jitter

Another performance issue that is related to delay is **jitter.** We can roughly say that jitteris a problem if different packets of data encounter different delays and the applicationusing the data at the receiver site is time-sensitive (audio and video data, for example).**If** the delay for the first packet is 20 ms, for the second is 45 ms, and for the third is40 ms, then the real-time application that uses the packets endures jitter.

Line Coding



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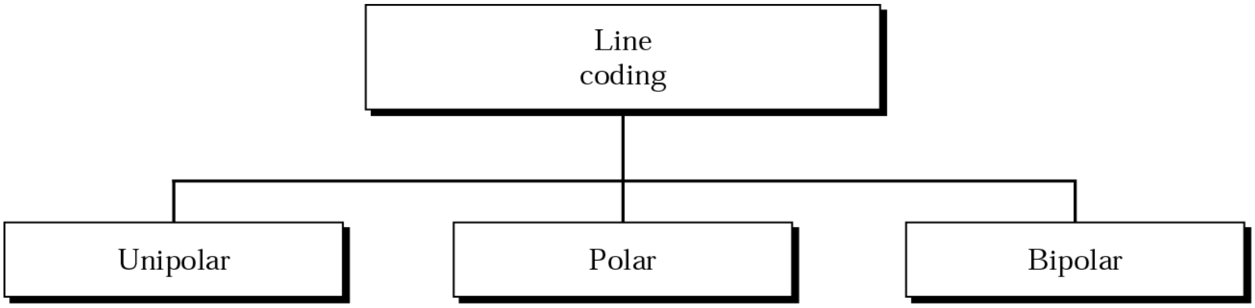
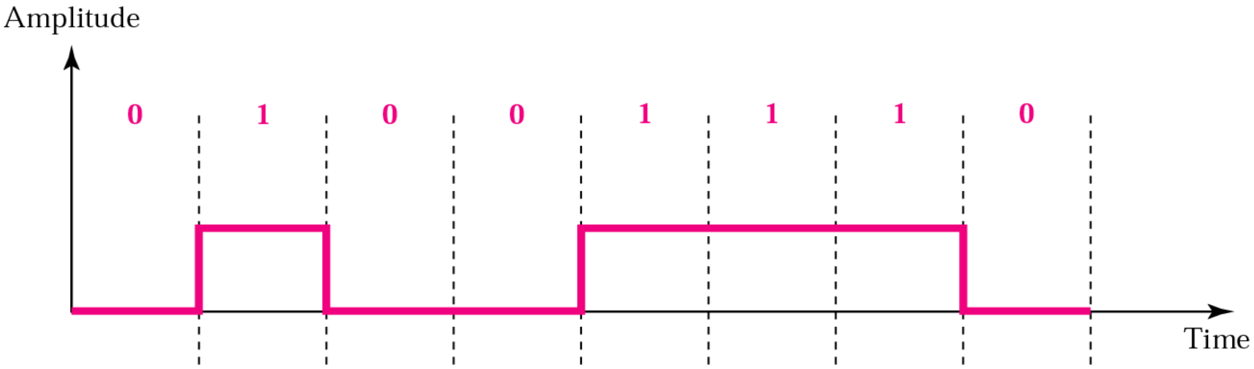
Line coding is the process of converting digital data to digital signals.



Unipolar Scheme

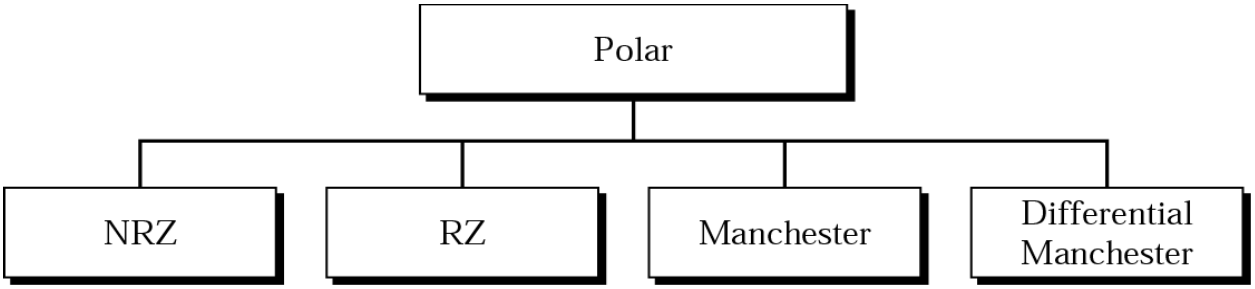
In a unipolar scheme, all the signal levels are on one side of the time axis, either aboveor below.



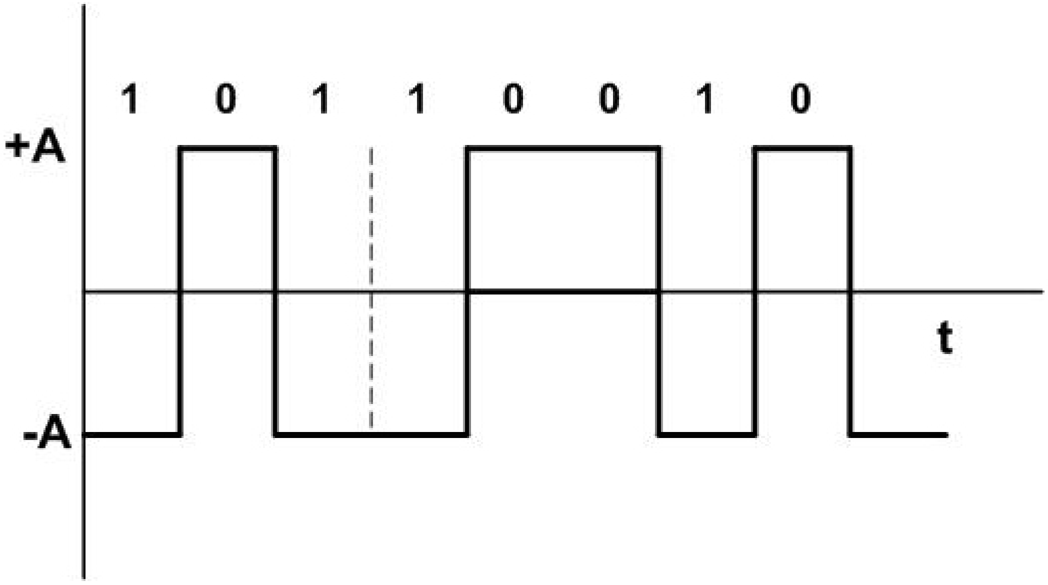
NRZ (Non-Return-to-Zero) Traditionally, a unipolar scheme was designed as a non-return-to-zero (NRZ) scheme in which the positive voltage defines bit I and the zero voltage defines bit O. It is called NRZ because the signal does not return to zero atthe middle of the bit

Polar Schemes

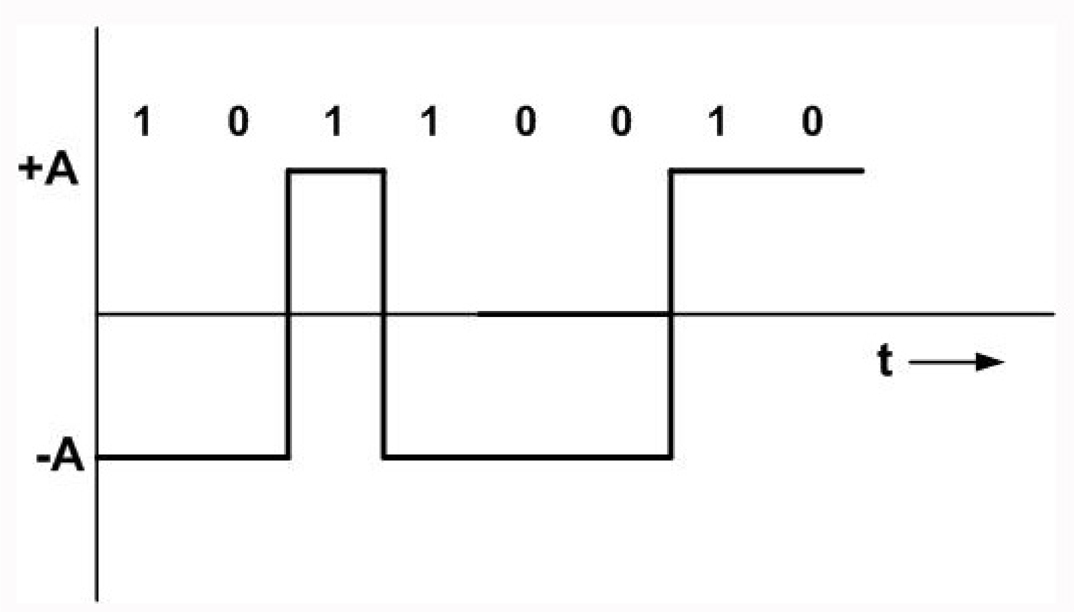
In polar schemes, the voltages are on the both sides of the time axis. For example, thevoltage level for 0 can be positive and the voltage level for I can be negative.



Non-Return-to-Zero (NRZ) In polar NRZ encoding, we use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-Land NRZ-I..
In the first variation, NRZ-L (NRZ-Level), the level of the voltage determines the value of the bit.
In the second variation, NRZ-I (NRZ-Invert), the change or lack of
change in the level of the voltage determines the value of the bit. If there is no change,the bit is 0; if there is a change, the bit is 1.



In NRZ – L , 1 = low level , 0 = high level

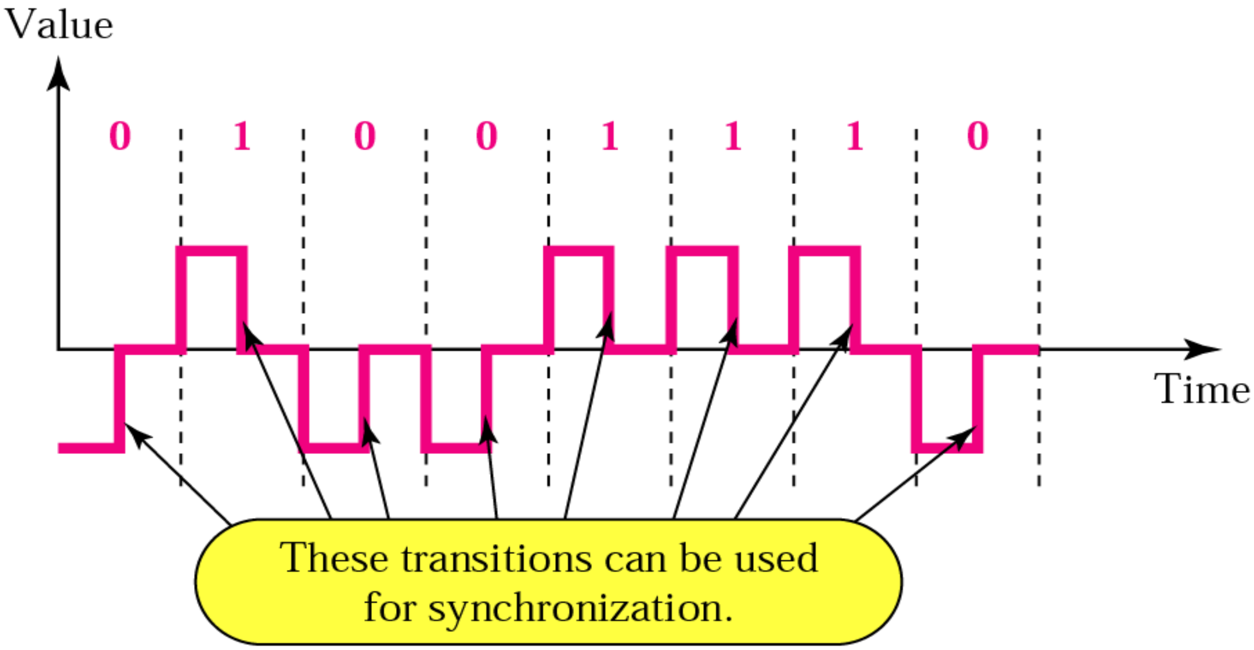


NRZ – I

• For each 1 in the bit sequence, the signal level is inverted.

• A transition from one voltage level to the other represents a 1.

Return to Zero (RZ) The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit hasended and the next bit is starting. One solution is the return-to-zero (RZ) scheme,which uses three values: positive, negative, and zero.

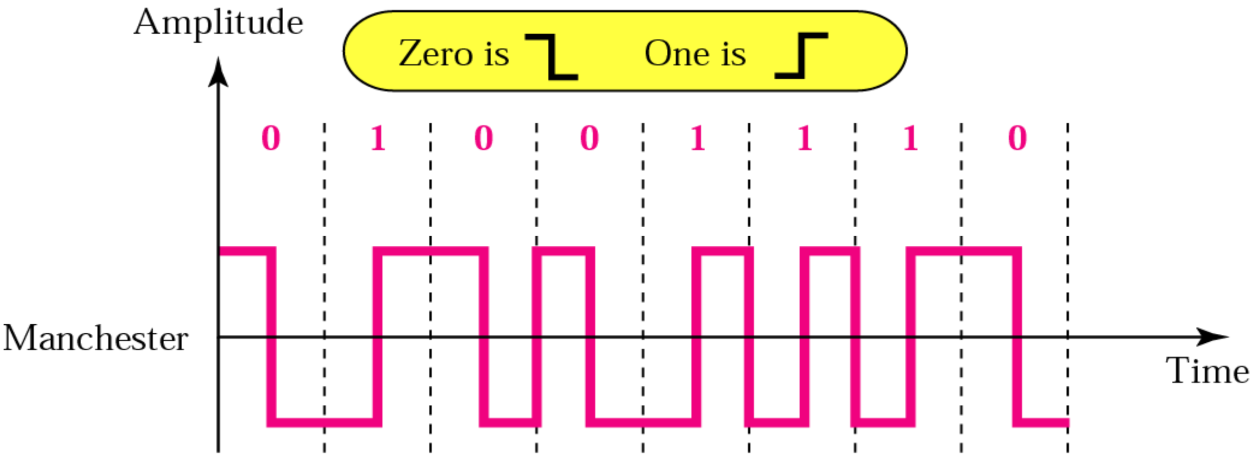


Biphase: Manchester and Differential Manchester The idea of RZ (transition at the middle of the bit) and the idea of NRZ-L are combined into the Manchester scheme.

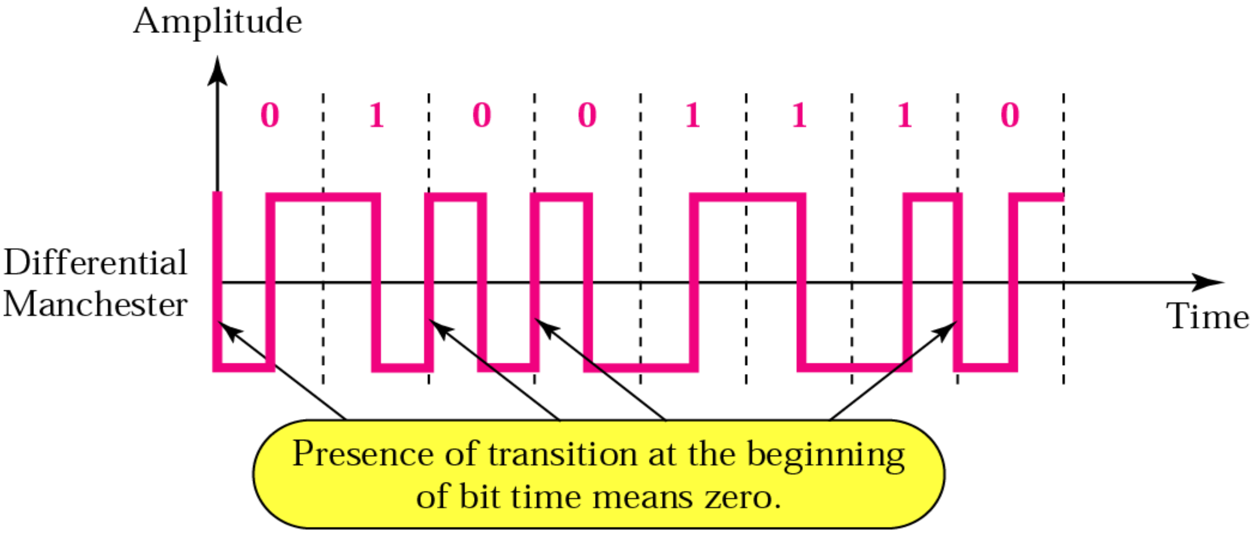
In Manchester encoding, the duration of the bit is divided into two halves. The voltageremains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides synchronization.

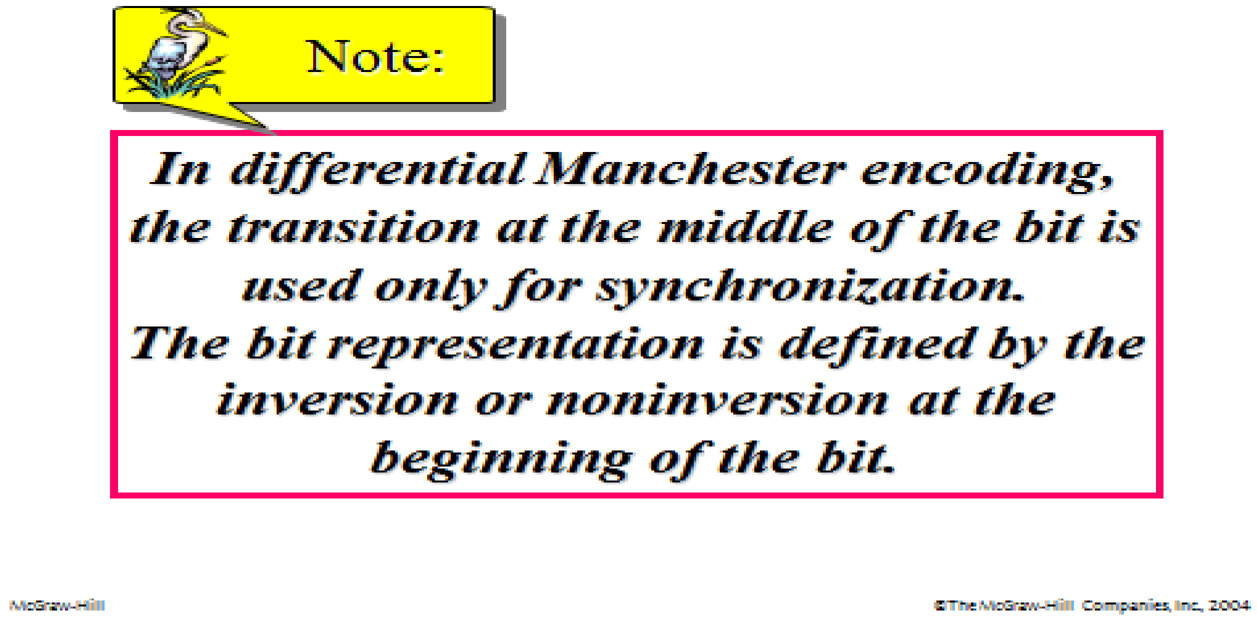
Differential Manchester,on the other hand, combines the ideas of RZ and NRZ-I. There is always a transition atthe middle of the bit, but the bit values are determined at the beginning of the bit. If thenext bit is 0, there is a transition; if the next bit is 1, there is none

Manchester



Differential Manchester


Amplitude
0
1
0
0
1
1
1
0
Differential Manchester
Time
Presence of transition at the beginning of bit time means zero.



Note:

In differential Manchester encoding, the transition at the middle of the bit is used only for synchronization.
The bit representation is defined by the inversion or noninversion at the beginning of the bit.

McGraw-Hill

Note: In Manchester and differential Manchester encoding, the transition at the middle of the bit is used for synchronization.