# Data Communication (Unit-I)

**Objective:**

It introduces basics of Data Communication, computer network layers, communication protocols and also explains about characteristics of signals, modulation techniques.

Contents:

- Introduction to Data Communication
- Standards of Data Communication
- Layered Network Architecture
- Open System Interconnection(OSI) and Transmission Control Protocol(TCP)
- Data Communication Circuit
- Data transmission modes
- Serial and Parallel Communication
- Communication Networks
- Basics of Signals
- Noise and Signal to Noise Ratio
- Modulation
- Bit rate, Information Capacity and Baud
- M-ary Encoding

1. Introduction to Data Communication:

Data communication: It is defined as exchanging or sharing data between the systems or devices through transmission medium. Transmission media can be wired or wireless. So data is central component in communication, it is defined as raw facts without context. For example temperature during the day is represented as data such as 20, 25,28,30,34,38,25,22.

Information:
If these temperature values displayed as degree centigrade with respect to hours is known as information or average of temperature or maximum temperature is also known as information. So information is defined as data with context or processed data.

Data types (Representation): Data can be classified as following types.

2) Temporal data
3) Spatial data
4) Combination of temporal and spatial data

Alphanumeric data: It consists of text, numbers or symbols. For example: Name: JAVA & Version: JDK 1.6

Temporal data: It is the data that varies over time. A temporal data denotes the evolution of an object characteristic over a period of time.Example: student attendance over a month, audio, speech signal.

Spatial data: It consists of geographic images and spatial context. Example: Satellite images bring daily weather reports

Combination of temporal and spatial data: it consists of both images and time, example is Video refers to the recording or broadcasting of pictures over a time.

**1.1 - Components of Communication Systems**

Data communication is the transfer of data from one device to another via some form of transmission medium. A data communications system has five components, namely, Data, Sender, Receiver, Transmission medium, and Protocol.

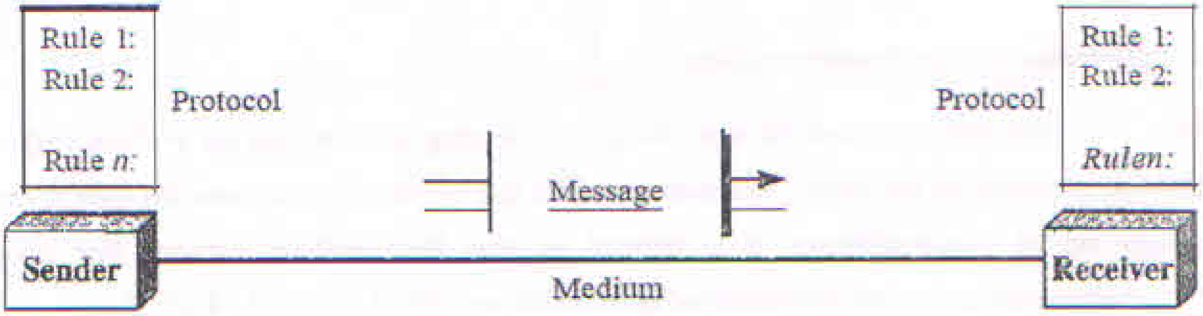



Fig: 1.1 Components

1. Message: It 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: 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 path by which Data transfers from sender to receiver. Some examples of transmission medium include guided medium (wired) twisted-pair wire, coaxial cable, and fiber-optic cable or unguided medium (wireless)

5. Protocol: A protocol is a set of rules that governs data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just as a sender send the data but receiver does not understand what it is.

Applications:

1) Telecommunication
2) Internet and Intranet applications

**Standards Organizations:**

Standards are the guidelines and procedures that help the manufactures, vendors, government agencies and other service providers to ensure quality, productivity and reduced cost.

Communication standards: The guideline and procedures are used to improve the major issues facing the data communication industry, such as software, programming language, electrical, cable interface, transmission media and format compatibility. Thus an orderly transfer the data between the systems.

**Classification of standards:**

a) Standards are classified based on aspect (or subject matter) into two types.
1) Product standard
2) Performance standard
b) Standards are classified based on Recognition (or stake) into two types.
    1) De facto standard :( by fact or by convention) standards are not approved by an organized body, but new devices are developed using those standards for introducing new product or technology.
    2) De jure (by law or by regulation): standards are approved by recognized body.

c) Based on availability to manufactures classified into two types

   1) Closed standards: standards are owned by company and it can develop the systems using those standards. Others cannot do.

      Ex: Apple computer

   2) Open standards: standards can use any company and produce the systems. But royalty must be paid to original company.

**Standards organizations:**

Standards are developed through cooperation of government representatives, manufactures, on profit organizations and users.

International standards organizations(ISO):It was founded in 1946, international organization for standardization on various areas such as Engineering,Science,Health and other areas.ISO is voluntary and nontreaty organization whose members is mainly comprised mainly of government agencies throughout the world.

The main functions of ISO is produce the guidelines and procedures for industry and users and it also coordinates the other organizations.

Members of ISO (Data communication) consist of following organizations.

1) International Telecommunication Union-Telecommunication Sector(ITU-T)
2) Institute of Electrical and Electronics Engineering(IEEE)
3) American National Standard Institute(ANSI)

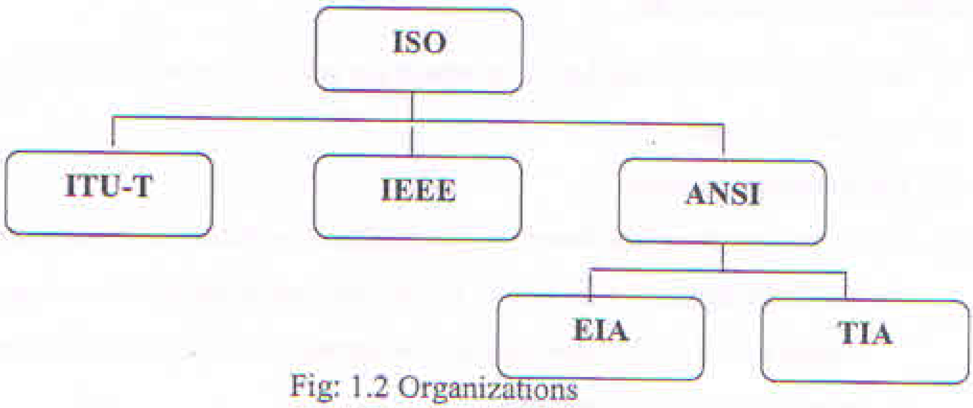



Fig: 1.2 Organizations

1) International Telecommunication Union-Telecommunication Sector(ITU-T):Members of ITU-T is comprised of government authorities and representatives from many countries.ITU develops the standards for telephone and data communication and provides three set of configurations.

a)V-series: for medium interfacing and data transmission over the telephone network.

b)X-series: for medium interfacing and data transmission over the public digital network

a)Q-series: for medium interfacing and data transmission over the ISDN and B-ISDN

ITU has 14 groups to study various topics or issues. Some of the issues are

- Network & service operation
- Tariff & accounting
- Network maintenance
- Protection against EM waves
- Language & sfotwrae aspects for communication
- Television and sound transmission
- Multimedia services

Institute of Electrical and Electronics Engineers (IEEE): It is the largest professional organization and members comprise of Electronics, Electrical, Computers and Communication Engineers. So it develops the standards in the field of Electrical Engineering, Electronics and Communication.

American National Standard Institute (ANSI):

It is the official agency for the United States and its members consists of professional bodies, industry association and other organizations.ANSI activities are undertaken with welfare of the united states and its citizens.

Electronics Industry Association (EIA): Aligned with ANSI, it is nonprofit organization develops the guidelines for the developing electronics manufacture industry and its safety.

Telecommunication Industry Association (TIA): It is the leading association in telecommunication and information technology. It provides manufactures communication, information technology products and services.

Internet Architecture Board (IAB): It develops the standards for internet relevant issues.

1) Translate the architecture protocols and procedures used by the internet.
2) Maintenance internet standards
3) Coordinate internet societies
4) Provide guidelines in technical and policy matters

Internet Engineering Task Force (IETF): Members from network designers, operators, vendors and researchers concerned with evaluation of internet architecture and smooth operation of Internet.

Internet Research Task Force (IRTF): International organization promotes research to evaluation of future internet in the area of internet protocols, applications, architectures and technology.

**Layered Network Architecture:**

Network: Set of communication devices connected by medium. Network architectures define the standards and techniques for designing and building communication systems for computers and other devices. To reduce the design complexity, most of the networks are organized as a series of layers or levels, each one build upon one below it. The basic idea of a layered architecture is to divide the design into small pieces. Each layer adds to the services provided by the lower layers in such manner that the highest layer is provided a full set of services to manage communications and run the applications. The benefits of the layered models are modularity and clear interfaces, i.e. open architecture and comparability between the different providers' components.

The basic elements of a layered model are services, protocols and interfaces. A service is a set of actions that a layer offers to another (higher) layer. Protocol is a set of rules that a layer uses to exchange information with a peer entity. These rules concern both the contents and the order of the messages used. Between the layers service interfaces are defined. The messages from one layer to another are sent through those interfaces.

Why Layered architecture?

1. To make the design process easy by breaking unmanageable tasks into several smaller and manageable tasks (by divide-and-conquer approach).

2. Modularity and clear interfaces, so as to provide comparability between the different providers' components.

3. Ensure independence of layers, so that implementation of each layer can be changed or modified without affecting other layers.

4. Each layer can be analyzed and tested independently of all other layers.

Concepet of network layer generally we use in several applications. for example software project implementation is done by dividing into modules and postal service as shown in figure 1.3.

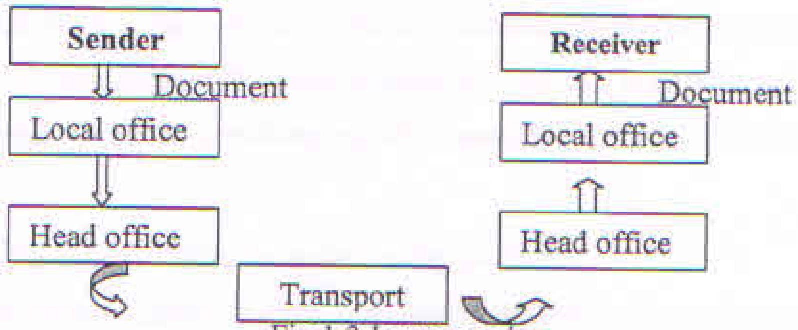



Fig.1.3 Layer service

Peer to Peer communication:

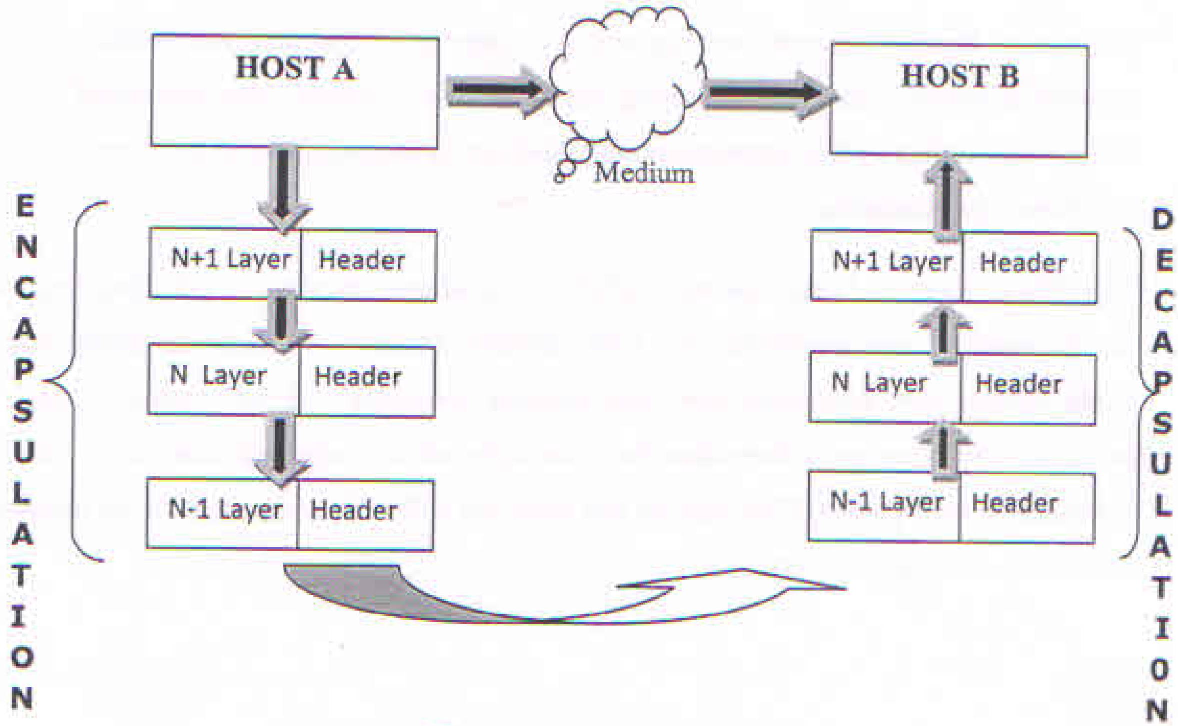



Fig.1.4 Layered network

In an n-layer architecture, layer n on one machine carries on conversation with the layer n on other machine. Three-layer architecture is shown in Fig. 1.4, the entities comprising the corresponding layers on different machines are called peers. In other words, it is the peers that communicate using protocols. In reality, no data is transferred from layer n on one machine to layer n of another machine. Instead, each layer passes data and control information to the layer immediately below it, until the lowest layer is reached. Below layer-1 is the physical layer through which actual communication occurs. The peer process abstraction is crucial to all network design. Using it, the un-manageable tasks of designing the complete network can be broken into several smaller, manageable, design problems, namely design of individual layers.

Thus from above example it is clearly understood that layer architecture simplifies the network design. It is easy to debug network applications in a layered architecture network. There are two layered Models namely OSI Model and TCP/IP Model.

**Open System Interconnection (OSI):**

In 1970s every computer vendor had developed its own proprietary layered network architecture, so computers from different vendors could not be networked together for communicating the data. Open Systems Interconnection (OSI) was an international effort by the International standardization Organization (ISO) to enable multivendor computer interconnection.

The Open System Interconnection (OSI) is reference model, it provides framework for development of new protocols.. The OSI reference model is a conceptual model composed of seven layers, each specifying particular network functions. The OSI model divides the tasks involved with moving information between networked computers into seven smaller, more manageable task groups. This enables the solutions offered by one layer to be updated without adversely affecting the other.

Layers of OSI as follows.

1. Physical Layer
2. Data Link Layer
3. Network Layer
4. Transport Layer
5. Session Layer
6. Presentation Layer
7. Application Layer

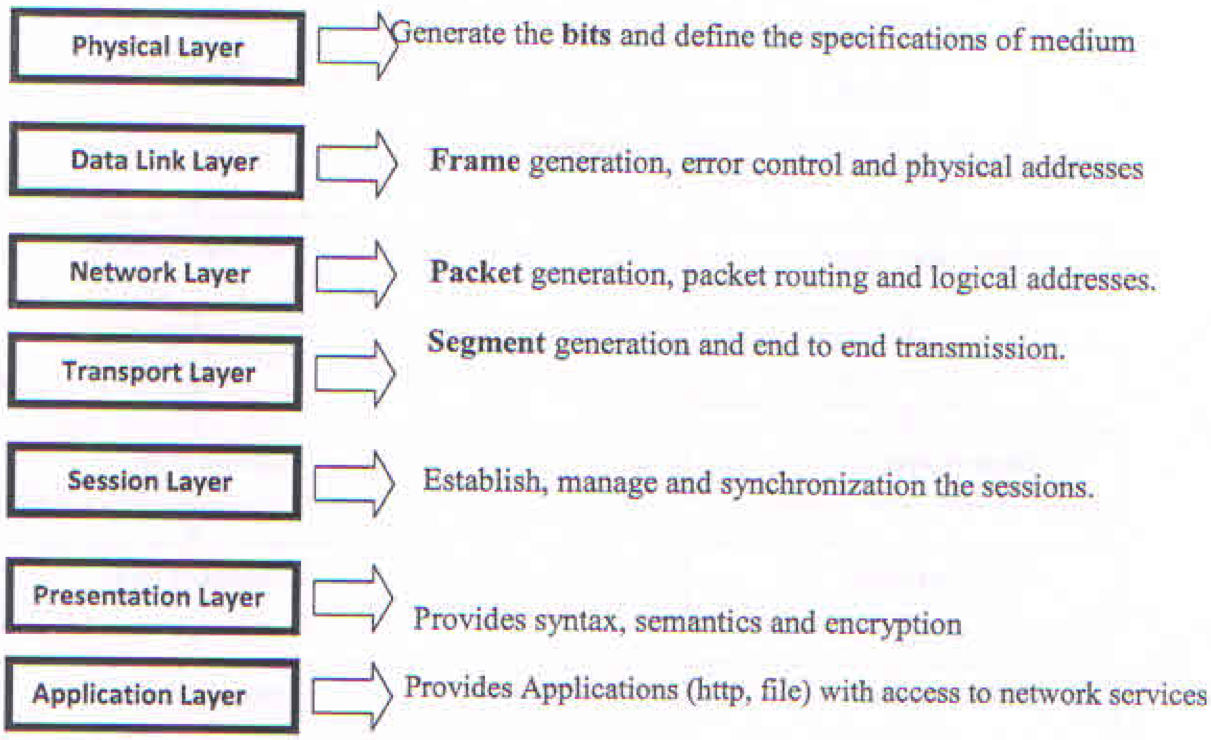



Fig.1.5 OSI functions

**OSI Model and Communication between Systems:**

Information being transferred from a software application in one computer system to a software application in another must pass through the OSI layers. For example, if a software application in System A has data to transmit to a software application in System B, the application program in System A will pass its information to the application layer (Upper layer) of System A. The application layer then passes the data along with header (trailer added only at data link layer) to the presentation layer (Layer 6), which relays the data to the session layer (Layer 5), and so on down to the physical layer (Layer 1). At the physical layer, the information is placed on the physical network medium and is sent across the medium to System B. The physical layer of System B removes the information from the physical medium, and then its physical layer passes the information up to the data link layer (Layer 2), which passes it to the network layer (Layer 3), and so on, until it reaches the application layer (Layer 7) of System B. Finally, the application layer of System B passes the information to the recipient application program to complete the communication process.

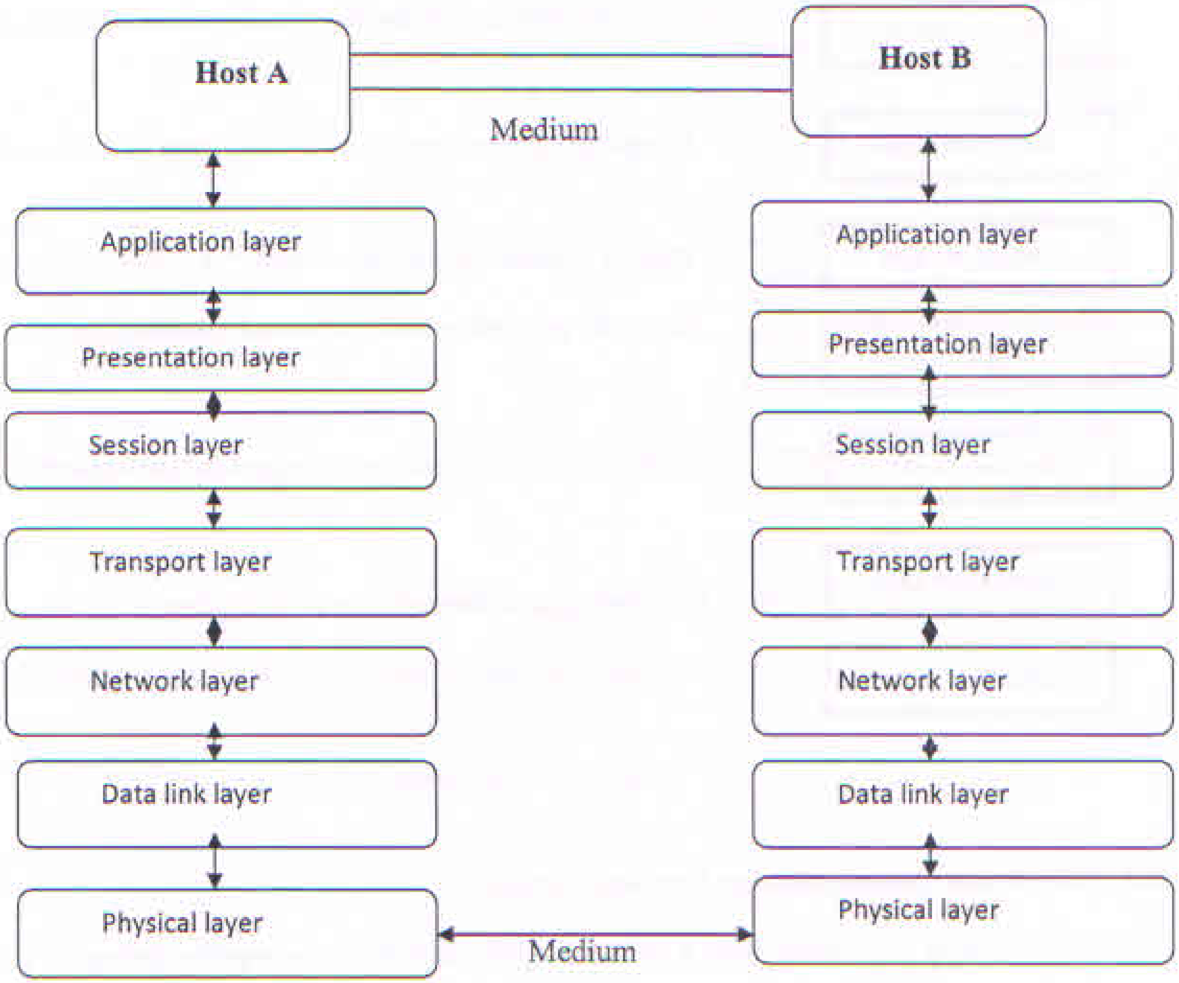



Fig.1.6 OSI Architecture

**Functions of OSI layers:**

Physical layer:

The physical layer is concerned with transmission of raw bits over a communication channel. It specifies the mechanical, electrical and procedural network interface specifications and the physical transmission of bit streams over a transmission medium connecting two pieces of communication equipment. The various functions of physical layer.

1) Bit generation: physical layer data consists of stream of bits.
2) Data rate: physical layer decides number of bits sent each second.
3) It defines the type of medium and interface between system and medium.
4) Concerned with line configuration, physical topology and transmission mode.

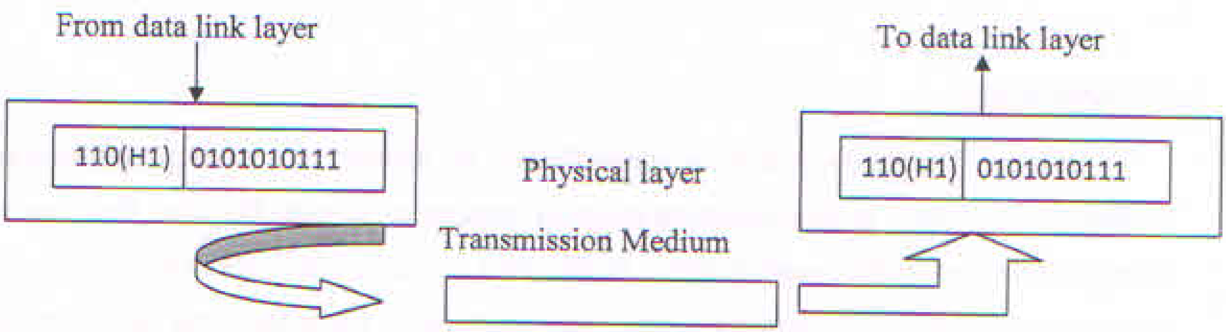



Fig.1.7 Physical layer

Data link layer: The responsibilities of the data link layer include framing, physical addressing, flow control, error control, and access control. The data link layer divides the stream of bits received from the network layer into manageable data units called frames. If frames are to be distributed to different systems on the network, the data link layer adds a header and a trailer to the frame to define the sender and receiver of the frame.

Functions:

1) Frame generation
2) Error control & flow control
3) Medium access control
4) Provide services to upper layer and lower layer.

Network layer:

A packet is a combination of a header and data. The network layer is responsible for the delivery of individual packets from the source to the destination. The data from the transport layer moves down to the network layer. At this layer, a header H3 is added to the packet, and then descends to Data Link layer. Upon reaching its destination, the header attached to it at the corresponding sending layer is removed, and then the data unit ascends to the Transport layer.

Functions:

1) Packet generation
2) Packet routing
3) Packet life time
4) Logic link control

Transport layer:

The transport layer is responsible for the delivery of a message from one process to another. A process is an application program running on a host. The data from the session layer moves down to the transport layer. At this layer, a header H4 is added to the segments and then segments descend to Network layer. Upon reaching its destination, the header attached to the segments is removed, and then the data unit ascends to the Transport layer.

The transport layer header must include a type of address called a service-point address or port address, for delivering specific processes between computers. The network layer gets each packet to the correct computer and the transport layer gets the entire message to the correct process on that computer. Data is divided into transmittable segments, with each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination and to identify and replace packets that were lost in transmission. The transport layer can be either connectionless or connection-oriented. A connectionless transport layer treats each segment as an independent packet and delivers it to the transport layer at the destination machine. A connection-oriented transport layer makes a connection with the transport layer at the destination machine first before delivering the packets.

Functions:

1) Segment generation
2) Flow control
3) Connection establishment

Session layer:

This layer allows users on different machines to establish session between them. .The responsibilities of the session layer include dialog control, and synchronization. The session layer allows two systems to enter into a dialog. It allows the communication between two processes to take place in either half-duplex or full-duplex.

Some of the session related services are:

1) Dialog control
2) Synchronization or check points
3) Token management

Presentation layer:

The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems. Syntax refers to the order in which data is presented. Semantics helps in interpreting a particular pattern and the action to be taken based on that interpretation. The data from the application layer moves down to the presentation layer. At this layer, a header H6 is added at the beginning of the data unit and then descended to session layer. Upon reaching its destination, the header H6, attached to the data unit, is removed, and then the data ascends to the application layer.

Functions:

1) Syntax and semantics
2) Encryption and decryption
3) Compression

Application layer:

The application layer is responsible for providing services to the user. The application layer enables the user, whether human or software, to access the network, by providing distributed information services. The data is created by the sender with the help of user interfaces and other support services. At this layer, a header H7 is added at the beginning of the message and then descended to presentation layer. Upon reaching its destination, the header H7, attached to the message, is removed, and then the data is received by the end-user.

Functions of Application layer:

1) File transfer (FTP): Connect to a remote machine and send or fetch an arbitrary file. FTP deals with authentication, listing a directory contents, ASCII or binary files, etc.

2) Remote login (telnet): A remote terminal protocol that allows a user at one site to establish a TCP connection to another site, and then pass keystrokes from the local host to the remote host.

3) Mail (SMTP): Allow a mail delivery agent on a local machine to connect to a mail delivery agent on a remote machine and deliver mail.

4) Web (HTTP): Base protocol for communication on the World Wide Web.

(Hint: **PHYSICAL DATA** NOT TRANSFERED SO **PROVIDE APPROVAL**)

**TCP / IP Protocol Suite:**

When TCP/IP is compared to OSI, it can be said that the host-to-network layer is equivalent to the combination of the physical and data link layers. The internet layer is equivalent to the network layer, with transport layer in TCP/IP taking care of part of the duties of the session layer. TCP/IP's application layer is equivalent to the combined session, presentation, and application layers in the OSI model.

The first four layers provide physical standards, network interfaces, internetworking, and transport functions that correspond to the first four layers of the OSI model. The three topmost layers in the OSI model, however, are represented in TCP/IP by a single layer called the application layer.

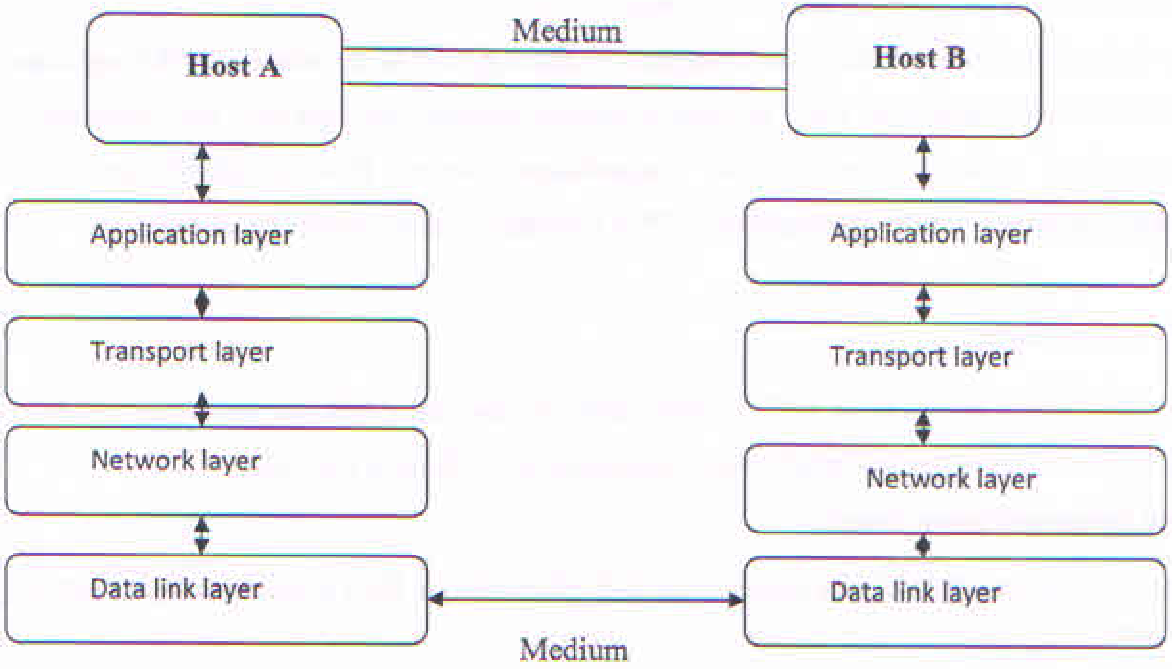


Fig.1.8 TCP/IP Architecture

Functions of layers:

Data Link Layer:

At the physical and data link layers, TCP/IP does not define any specific protocol. It supports all the standard and proprietary protocols. A network in a TC/IP internetwork can be a local-area network or a wide-area network.

Network Layer:

At the network layer (or, more accurately, the internetwork layer), TCP/IP supportsthe Internetworking Protocol. IP, in turn, uses four supporting protocols: The Address Resolution Protocol (ARP) is used to associate a logical address with a physical address.

Reverse Address Resolution Protocol: The Reverse Address Resolution Protocol (RARP) allows a host to discover its Internet address when it knows only its physical address

Transport Layer:

Traditionally the transport layer was represented in TCP/IP by two protocols: TCP and UDP. IP is a host-to-host protocol, meaning that it can deliver a packet from one physical device to another. UDP and TCP are transport level protocols responsible for delivery of a message from a process (running program) to another process.

User Datagram Protocol: The User Datagram Protocol (UDP) is the simpler of the two standard TCPIIP transport protocols. It is a process-to-process protocol that adds only port addresses

Transmission Control Protocol. The Transmission Control Protocol (TCP) provides full transport-layer services to applications. TCP is a reliable stream transport protocol

Application Layer:

The application layer in TCP/IP is equivalent to the combined session, presentation and application layers in the OSI model Many protocols are defined at this layer

**Data communication circuit:**

Circuit, it consists of five basic components and other devices. So it is combination of following devices.

1. Source
2. Transmitter
3. Medium
4. Receiver
5. Destination

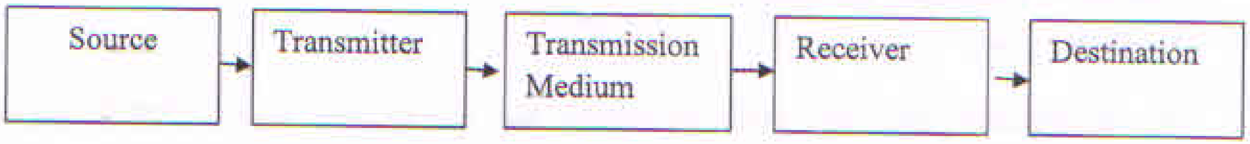



Fig.1.7 Data communication circuit

Figure 1.7 shows simplified block diagram of a two station data communication circuit.Source: The information source generates data and could be main frame computer, personal computer, workstation or any digital equipment. The source equipment provides a means for human to enter the data into the system.

Transmitter: it carries the modulating signal by means of modulation process.so modulated wave send through transmission medium.

Transmission Medium: The transmission medium is the path by which Data transfers from sender to receiver. Some examples of transmission medium include guided medium (wired) twisted-pair wire, coaxial cable, and fiber-optic cable or unguided medium (wireless).

Receiver: it receives the modulated signal and removes the carrier signal. The resultant signal is given to destination.

Destination: It receives the signal and it can be main frame computer, personal computer, workstation or any digital equipment.

**Types Transmission Modes or Data Flow:** data Communication between two devices can be classified into following types:

1) Simplex
2) Half Duplex
3) Full Duplex
4) full-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 1.8).

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.

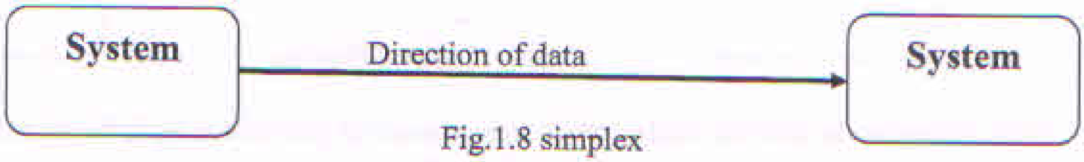



Fig.1.8 simplex

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 in figure 1.9 The half-duplex mode is like a one-lane road with traffic allowed in both directions. When cars are travelling in one direction, cars going the other way must wait. In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time. Walkie-talkies and CB (citizens band) radios are both half-duplex systems. The half-duplex mode is used in cases where there is no need for communication in both directions at the same time; the entire capacity of the channel can be utilized for each direction.

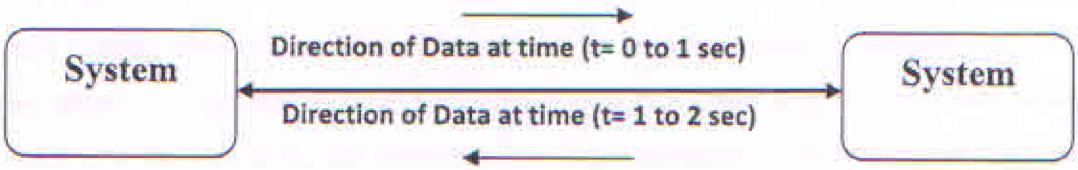



Fig.1.9 Half Duplex

Full-Duplex: In full-duplex (also called duplex), both stations can transmit and receive simultaneously (see Figure 1.10).The full-duplex mode is like a two way street with traffic flowing in both directions at the same time. In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction. 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 travelling 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. The full-duplex mode is used when communication in both directions is required all the time. The capacity of the channel, however, must be divided between the two directions.


Fig.1.10 Full Duplex

Full-Full-Duplex: In full/full duplex mode transmission is possible in both the directions at the same time but not between the same two stations. For example system (1) can send data to one system (2) and receive data from another system (3) at a same time.

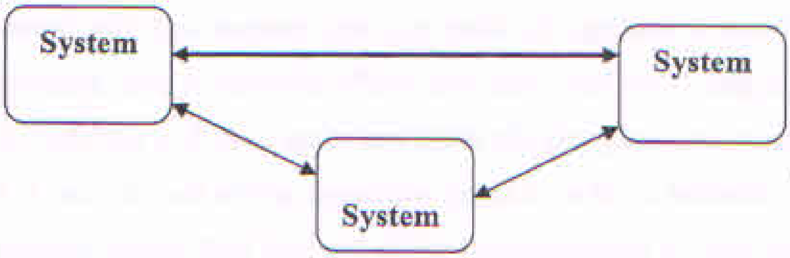



Fig.1.11Full/Full Duplex

**Serial and Parallel Communication:**

Serial Communication: It is the process of transfer the data sequentially from one system to another. In serial transmission one bit follows another, so we need only one communication channel rather than n to transmit data between two communicating devices (see Figure 1.12).The advantage of serial over parallel transmission is that with only one communication channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of n. So used for long distance communication.

Since communication within devices is parallel, conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line and the receiver (serial-to-parallel).Serial transmission occurs in one of three ways: asynchronous, synchronous, and isochronous.

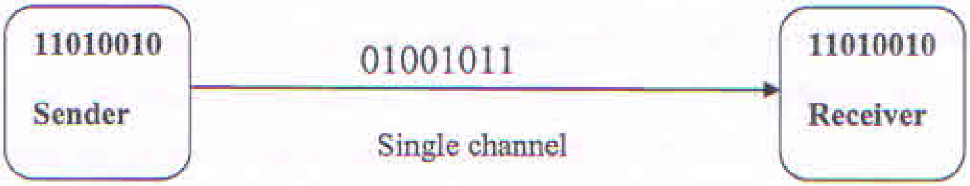



Fig.1.12 serial communication

Parallel Transmission:

Binary data, consisting of Is and Os, may be organized into groups of n bits each. Computers produce and consume data in groups of bits much as we conceive of and use spoken language in the form of words rather than letters. By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission. The mechanism for parallel transmission is a conceptually simple one: Use n wires to send *n* bits at one time. That way each bit has its own wire, and all n bits of one group can be transmitted with each clock tick from one device to another.

Figure 1.13 shows how parallel transmission works for $n$ =8. Typically, the eight wires are bundled in a cable with a connector at each end. The advantage of parallel transmission is speed. All else being equal, parallel transmission can increase the transfer speed by a factor of *n* over serial transmission. But there is a significant disadvantage: cost. Parallel transmission requires *n* communication lines (wires in the example) just to transmit the data stream. Because this is expensive, parallel transmission is usually limited to short distances.

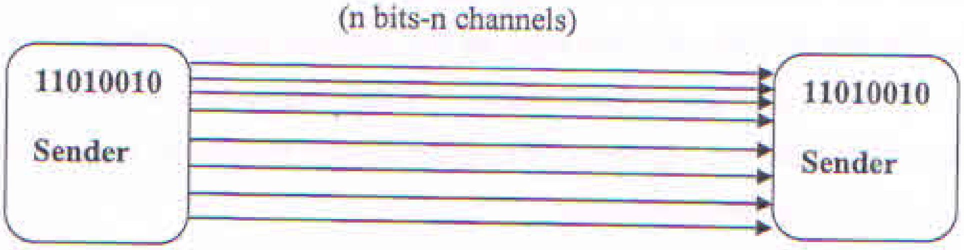



Fig.1.13 parallel communication

**Networks:**

Types of connections:

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. For communication to occur, two devices must be connected in some way to the same link at the same time. There are two possible types of connections:

1. Point-to-Point(Peer to Peer) Connection:
2. Multipoint Connection:

Point-to-Point connection: A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices. Most point-to-point connections use an actual length of wire or cable to connect the two ends, but other options, such as microwave or satellite links, are also possible (see Figure 1.14). When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.

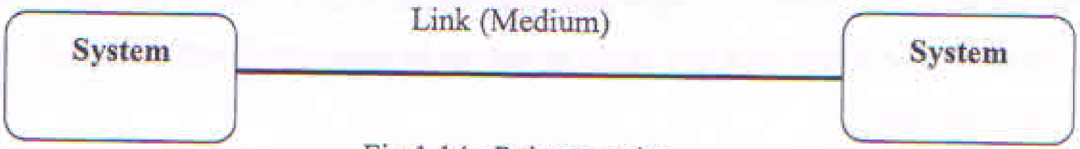



Fig.1.14 Point to point

Multipoint Connection: A multipoint (also called multidrop) connection is one in which more than two specific devices share a single link (see Figure 1.15).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 spatially shared connection. If users must take turns, it is a timeshared connection.

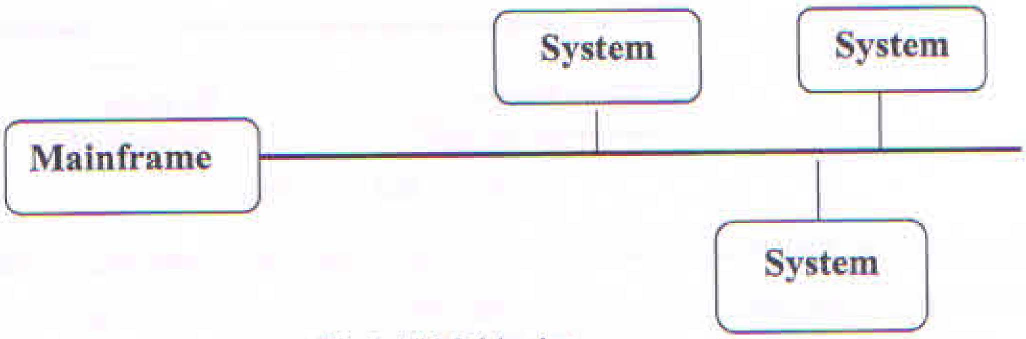



Fig.1.15 Multipoint

**Network Topology**:

The term physical topology refers to the way in which a network is laid out physically. 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 five basic topologies they are bus, star, ring, mesh and hybrid.

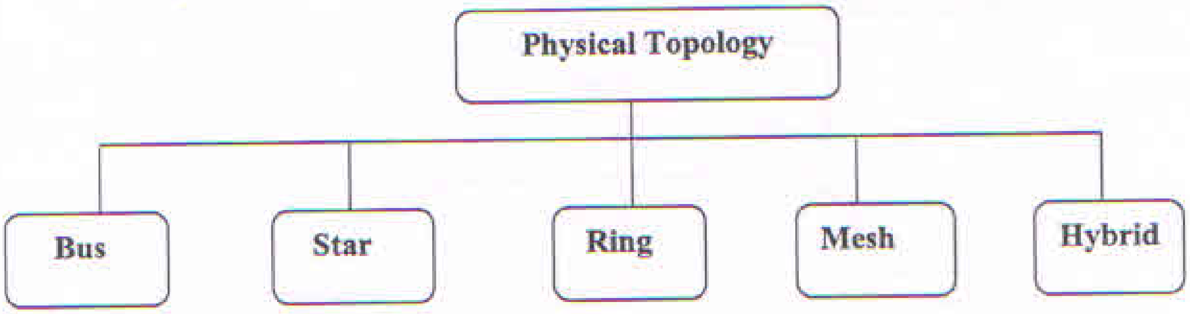



Fig.1.16 Topology

Bus: 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. Advantages of a bus topology include ease of installation. Backbone cable can be laid along the most efficient path, then connected to the nodes by drop lines of various lengths. In this way, a bus uses less cabling than mesh or star topologies. Disadvantages include difficult reconnection and fault isolation. In addition, a fault or break in the bus cable stops all transmission

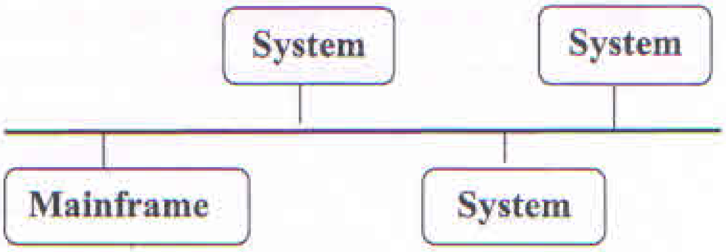



Fig.1.17 Bus Topology

Star: 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. 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 (see Figure 1.18). A star topology is less expensive than a mesh topology. In a star, each device needs only one link and one I/O port to connect it to any number of others. Other advantages include robustness. If one link fails, only that link is affected. All other links remain active. One big disadvantage of a star topology is the dependency of the whole topology on one single point, the hub. If the hub goes down, the whole system is dead.

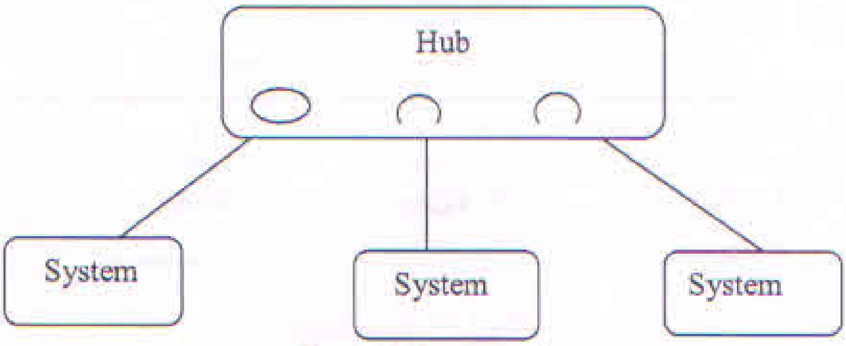



Fig.1.18 Star Topology

Ring: 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. A ring is relatively easy to install and reconfigure. To add or delete a device requires changing only two connections. In addition, fault isolation is simplified.

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.

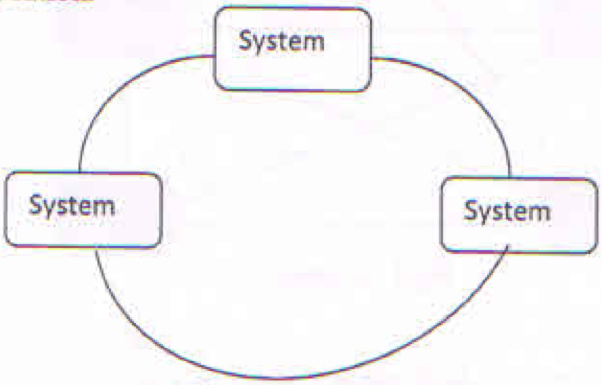



Fig.1.19 Ring

Mesh: Mesh In a mesh topology, every device has a dedicated point-to-point link to every other device. 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.

A mesh offers several advantages over other network topologies. First, the use of dedicated links guarantees that each connection can carry its own data load, thus eliminating the traffic problems that can occur when links must be shared by multiple devices. Second, a mesh topology is robust. If one link becomes unusable, it does not incapacitate the entire system. The main disadvantages of a mesh are related to the amount of cabling and the number of I/O ports required.

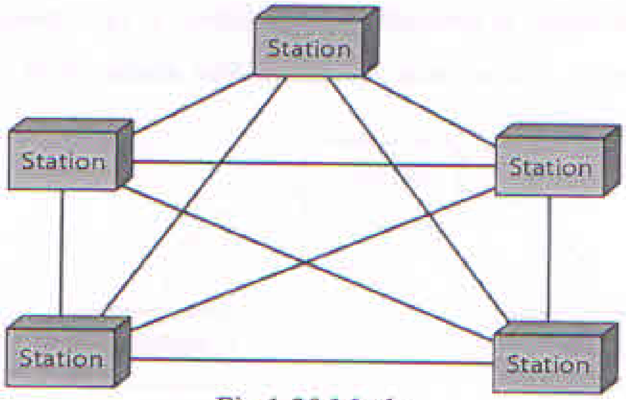



Fig.1.20 Mesh

Hybrid: A network can be hybrid. Hybrid networks use a combination of any two or more topologies in such a way that the resulting network does not exhibit one of the standard topologies like bus, star, ring, etc. For example, there can be a star topology with each branch connecting several stations in a bus topology. If a station in the network fails, it will not affect the rest of the network. While hybrid networks have found popularity in high-performance computing applications, some systems have used genetic algorithms to design custom Networks that have the fewest possible hops in between different stations.

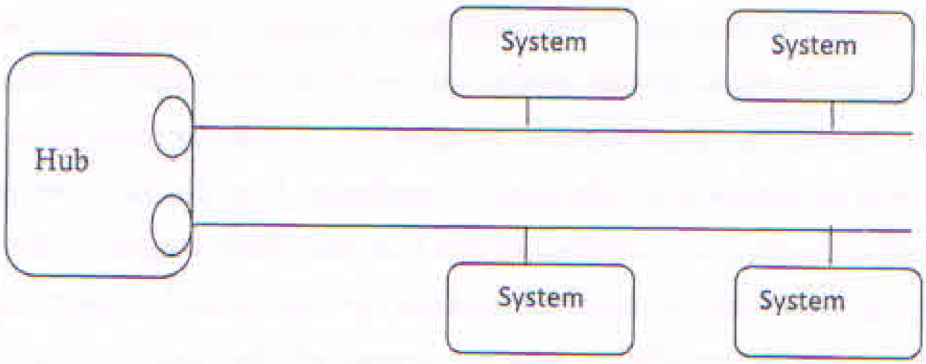



Fig.1.21 Hybrid Topology

Types of networks: Based on scale or metric or size

1. Personal Area Network (PAN)

2. Local Area Network (LAN)

3. Wide Area Network (WAN)

4. Metropolitan Area Network (MAN)

Personal area network: it is wire or wireless network in which computers and other devices are communicated over the distance of less than or equal to 1m. A common example is a wireless network that connects a computer with its peripherals.

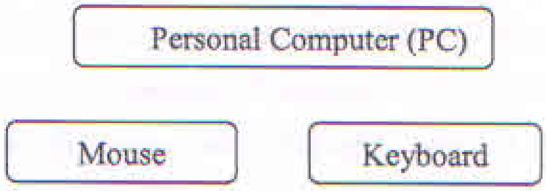



Fig.1.22 Bluetooth PAN Configuration

Local Area Network (LAN): A local area network, consists of a computer network at a single site, typically an individual office building (<=1km). A local area network (LAN) is usually privately owned and links the devices in a single office, building, or campus (see Figure 1.10). Depending on the needs of an organization and the type of technology used, a LAN can be as simple as two PCs and a printer in someone's home office; or it can extend throughout a company and include audio and video peripherals.

LANs are designed to allow resources to be shared between personal computers or workstations. The resources to be shared can include hardware (e.g., a printer), software (e.g., an application program), or data. A common example of a LAN, found in many business environments, links a workgroup of task-related computers, for example, engineering workstations or accounting PCs.

Wireless LAN: There is a standard for wireless LAN is called IEEE 802.11, popularly known as wifi.It runs speed anywhere from 11 to few hundred Mbps.

Wired LAN: It is also called IEEE 802.3, popularly known as Ethernet. It runs at speed of 100Mbps to few Gbps.

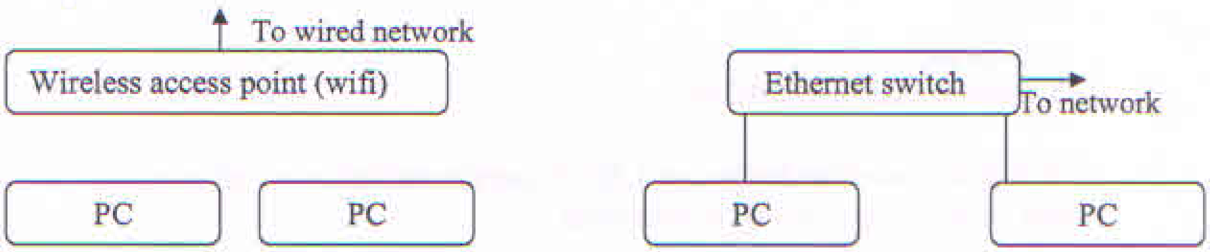



Fig.1.23 wireless LAN and wired LAN

Metropolitan Area Network (MAN):

A metropolitan area network, or MAN, consists of a computer network across an entire city, college campus or small region (<10km).A metropolitan area network (MAN) is a network with a size between a LAN and a WAN. It normally covers the area inside a town or a city. It is designed for customers who need a high-speed connectivity, normally to the Internet, and have endpoints spread over a city or part of city. A good example of a MAN is the part of the telephone company network that can provide a high-speed DSL line to the customer. Another example is the cable TV network that originally was designed for cable TV

Wide Area Network (WAN): A wide area network, or WAN (>10km), occupies a very large area, such as an entire country or the entire world. A WAN can contain multiple smaller networks, such as LANs or MANs. The Internet is the best-known example of a public WAN. A WAN can be as complex as the backbones that connect the Internet or as simple as a dial-up line that connects a home computer to the Internet. The point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an Internet service provider (ISP). This type of WAN is often used to provide Internet access.

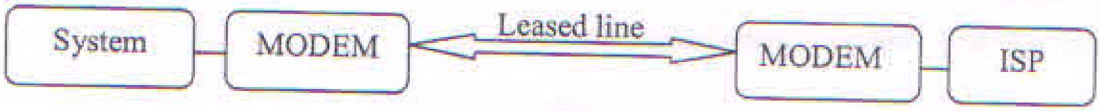



Fig.1.24 point to point WAN

**Network Devices:** Networks can be interconnected using following devices.

1. Hub
2. Switch
3. Router
4. Repeater
5. Network Interface card (NIC).

Hub: It is connection device used LAN. It contains multiple ports, when packet arrives at port and same will be delivered to other ports.

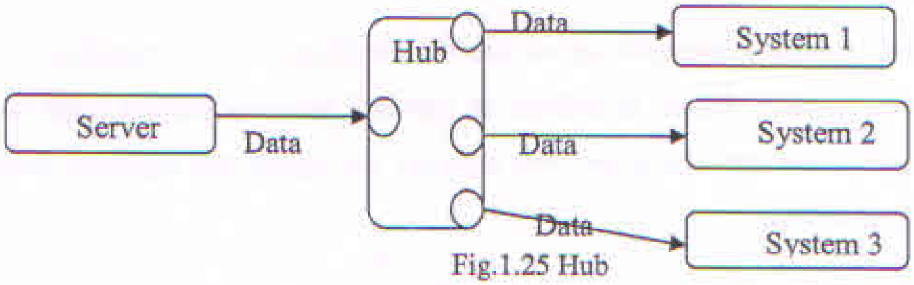



Fig.1.25 Hub

Switch: it is a device that connects devices together on a computer network, by using packet switching to receive, process and forward data to the destination device.

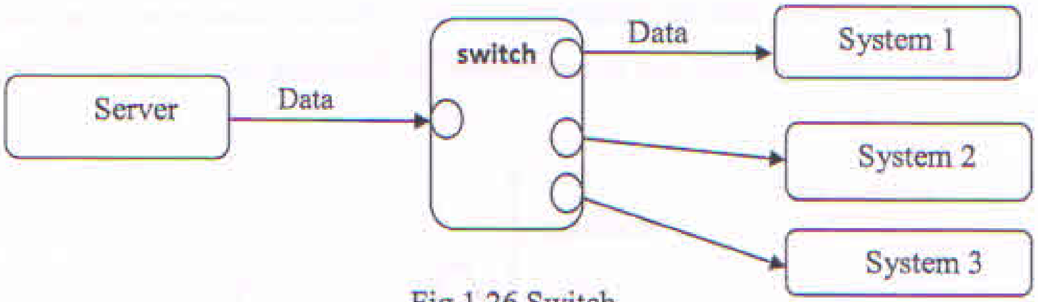



Fig.1.26 Switch

Router: 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.

Repeater: A repeater is a network device that is used to regenerate or replicate signals that are weakened or distorted by transmission over long distances and through areas with high levels of electromagnetic interference (EMI). The purpose of a repeater is to extend the LAN segment beyond its physical limits.

Network Interface card (NIC): A network interface controller (NIC, also known as a network interface card, network adapter, LAN adapter or physical network interface) is a computer hardware component that connects a computer to a computer network. NIC has 6 byte MAC addresses.48 bit number first part manufacture and second part unique NIC number.(or LAN addresses

**Signal analysis:**

Data produced by source transmits across trsmitted medium. So it is transformed in the form of electromagnetic signals. Signal is defined as physical quantity various with one independent parameter. It gives the status of object over a period. the signals that represent them can be either analog or digital in form.

Analog signal: it refers to magnitude is continuous over a period.

For example, an analog clock that has hour, minute, and second hands gives information in a continuous form; the movements of the hands are continuous. Analog data, such as the sounds made by a human voice, take on continuous values. When someone speaks, an analog wave is created in the air. Analog signal can be represented by following mathematical equation

$S(t) = A \sin(wt)$

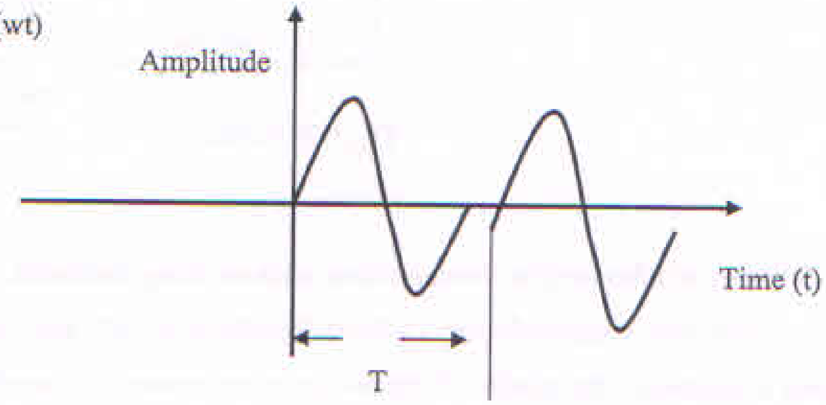



Fig.1.27 Analog signal

Digital signal: Both magnitude and time are discretised. Digital data take on discrete values. For example, data are stored in computer memory in the form of 0's and 1's.

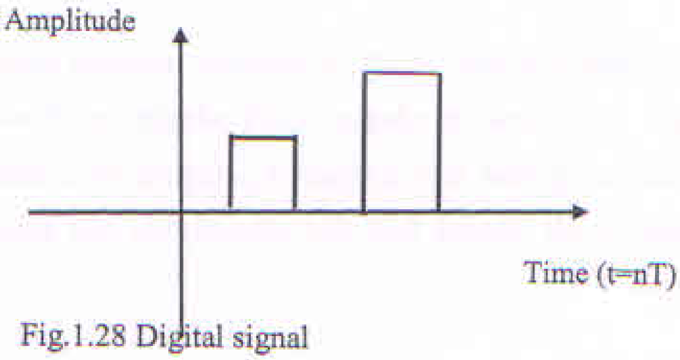



Fig.1.28 Digital signal

**PERIODIC ANALOG SIGNALS:**

Periodic analog signals can be classified as simple or composite. A simple periodic analog signal, a sine wave, cannot be decomposed into simpler signals. A composite periodic analog signal is composed of multiple sine waves. Sine Wave The sine wave is the most fundamental form of a periodic analog signal. When we visualize it as a simple oscillating curve, its change over the course of a cycle is smooth and consistent, a continuous, wave can be represented by following parameters.

1. Amplitude
2. Period
3. Frequency
4. Phase
5. Wavelength

A sinusoidal signal can be represented as $S(t)=A\sin(2\pi ft+\varphi)$

Where A=maximum amplitude

f=frequency=1/T

t=time

φ=phase

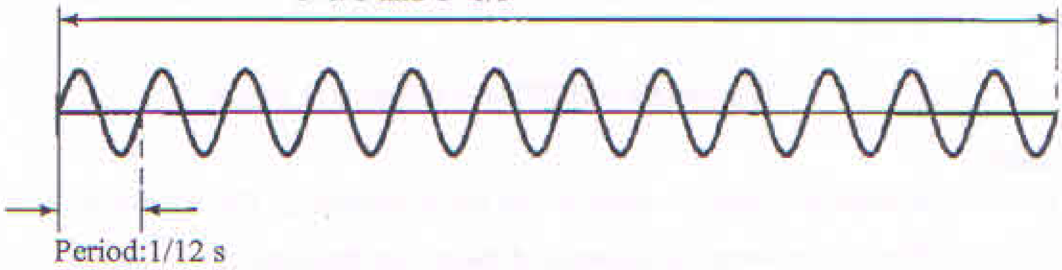
Amplitude: it is the displacement from reference axis. Maximum displacement is known as peak amplitude of signal.

Period and Frequency:

Period refers to the amount of time, in seconds, a signal needs to complete one cycle.

Frequency refers to the number of periods in 1 s. Note that period and frequency are just one characteristic defined in two ways. Period is the inverse of frequency, and frequency is the inverse of period, as the following formulas show.

$f=1/T$ and $T=1/f$



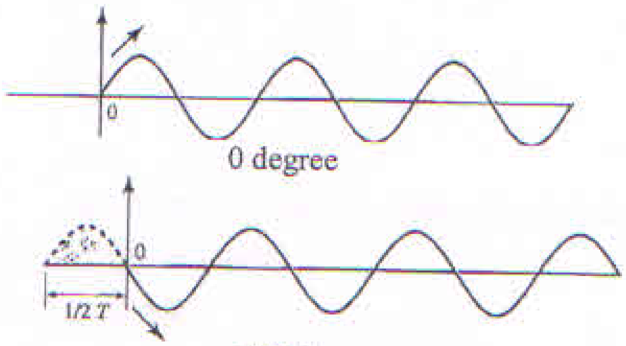

A signal with a frequency of 12 Hz

Example: The power we use at home has a frequency of 60 Hz . The period of this sine wave can be determined as follows:

$$T=1/f=1/60 = 0.0166\ s = 0.0166 \times 10^3\ ms$$

Phase:

The term phase describes the position of the waveform relative to time O. If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of the first cycle. Phase is measured in degrees or radians




Wavelength:

Wavelength is another characteristic of a signal travelling through a transmission medium. Wavelength binds the period or the frequency of a simple sine wave to the propagation speed of the medium Wavelength can be calculated if one is given the propagation speed (the speed of light) and the period of the signal.

Wavelength =propagation speed ×period= propagation speed/frequency

The propagation speed of electromagnetic signals depends on the medium and on the frequency of the signal. For example, in a vacuum, light is propagated with a speed of 3 x 108 m/s. That speed is lower in air and even lower in cable.

Example: determine the wavelength of signal for a given frequency (f) 1 kHz and its velocity 200 m/sec.

$$\text{Wavelength} = 200/1000 = 0.1\text{meter or } 10^5 \mu m$$

Bandwidth:

It is band of frequencies system or channel can allow through it. The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

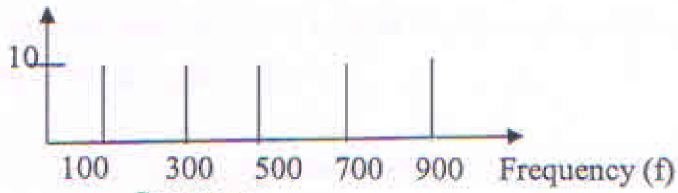
For example, if a composite signal contains frequencies between 1000 and 5000Hz, its bandwidth is 5000 - 1000, or 4000 Hz.

Example: If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700 and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have maximum amplitude of 10 V.

Solution

Let fmax be the highest frequency, fmin is the lowest frequency, and B the bandwidth. Then

Bandwidth=B =fmax-fmin = 900 - 100 =800 Hz




Spectrum

**Noise or Iinterference:** It is undesired signal that leads to change the original data or signal of interest.


Electrical noise: can be defined as undesirable electrical energy signals, which distort or interfere with an original (or desired) signal. Noise could be transient (temporary) or constant.

Types of electrical noise:

1. Manmade Noise
2. Thermal Noise
3. Correlation Noise
4. Transient Noise

Manmade noise: Electrical noise produced by mankind. Sources are electrical engines, motors,industries and leakage from high voltage lines.

Thermal Noise: It is the undesired signal produced due to random motion of electronics at higher operating temperature. Its magnitude can be expressed as thermal noise power.

Thermal Noise Power: Thermal noise power density (N0) is defined as thermal noise power per 1Hz bandwidth. It is proportional to absolute temperature (T).

$$N0 \propto T$$

$$\text{Thermal noise power density} = N0\ (\text{watts/Hz}) = KT \text{ ---------- } (1)$$

K=Boltzmann constant=$1.38\times10^{-23}$ J/K

Equation (1) can be written as thermal noise power= N1=KBT watts

Above noise power also expressed in decibels (deci=10, which is useful for representing very big ratio or values to moderate ratio or value) so multiply both sides by 10log10

$$N1 = 10\log10KBT \text{ decibels}$$

Correlation noise: it is produced either harmonic distortion or intermodulation distortion.

Harmonic distortion produces multiple of fundamental frequency of signal. If signal frequency is f then system produces signal which is multiple of fundamental frequency f


Intermodulation distortion: Intermodulation (IM) or intermodulation distortion (IMD) is the amplitude modulation of signals containing two or more different frequencies, caused by nonlinearities in a system.


Impulse noise: it is high magnitude noise with in short duration which changes the signal of interest.

**Signal to Noise Ratio (SNR):** It is defined as ratio of signal power to noise power. Significance of this value gives the noise content in a channel or system. SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise). A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

Signal to Noise Ratio (SNR) = Signal power (Ps)/Noise Power (Pn)

SNR gives unitless and it also expressed in decibels so multiply both sides by 10log10 now above equation can be written as

SNR (db) =10log10 (Ps/Pn)

Example:
The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and SNRdb?

Solution:

$$SNR = 10 \times 10^{-3} / 1 \times 10^{-6} = 10,000$$

$$SNR = 10 \log10\ 10{,}000 = 10 \log10\ 10^{4} = 40 \text{ decibels}$$

Modulation: It is the process of change in carrier signal is proportional to data (modulating signal). It is classified into two types based on type of modulating signal as shown in figure 1.29

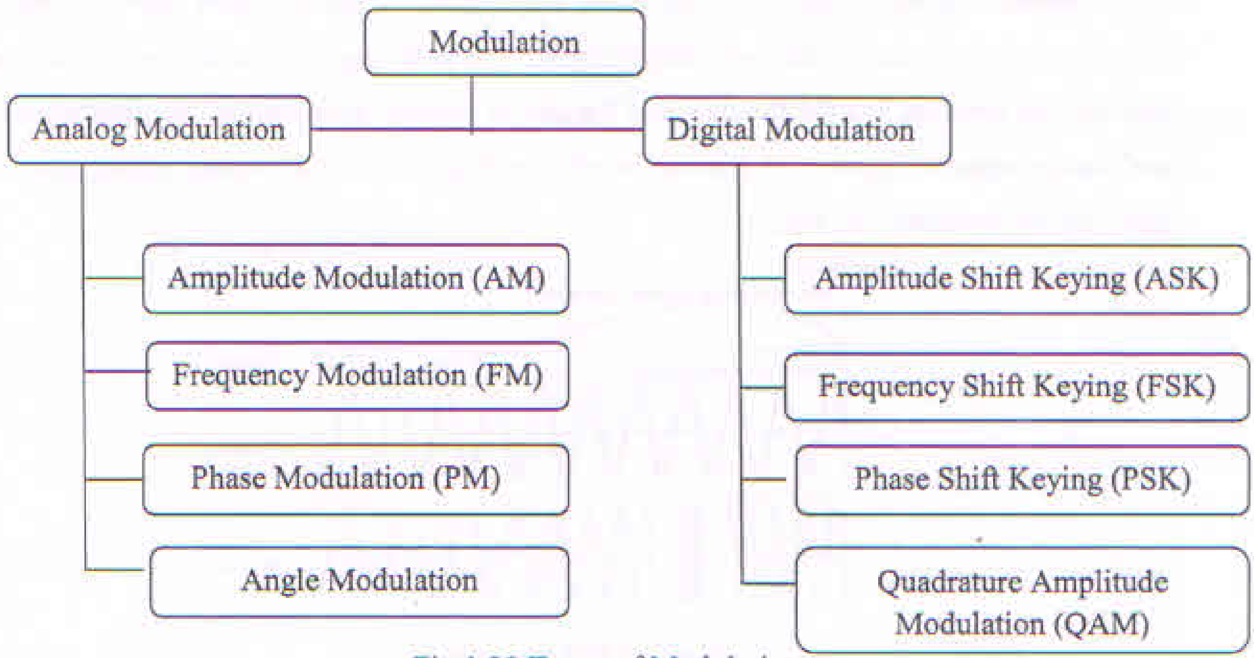



Fig.1.29 Types of Modulation

Analog Modulation: It is the process of change in carrier signal is proportional to analog data (modulating signal).

| Change in Carrier signal (Amplitude, frequency, phase) $\alpha$ Magnitude of modulating signal |
|---|

Amplitude Modulation (AM):

In AM transmission, the carrier signal is modulated so that its amplitude varies with the changing amplitudes of the modulating signal. The frequency and phase of the carrier remain the same; carrier wave amplitude changes proportional to data (modulating signal) as shown in figure 1.30

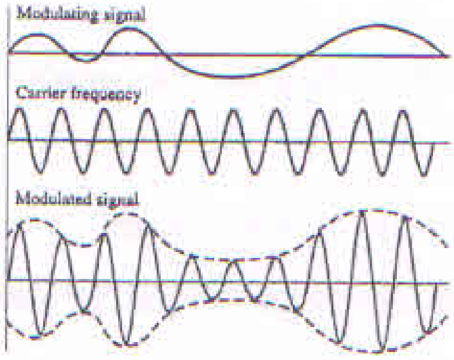



Fig.1.30 AM Modulation

Frequency Modulation:

In FM transmission, the frequency of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and phase of the carrier signal remain constant, but the frequency of the carrier changes proportional to amplitude of data (modulating signal). Figure 1.31 shows the relationships of the modulating signal, the carrier signal, and the resultant FM signal.

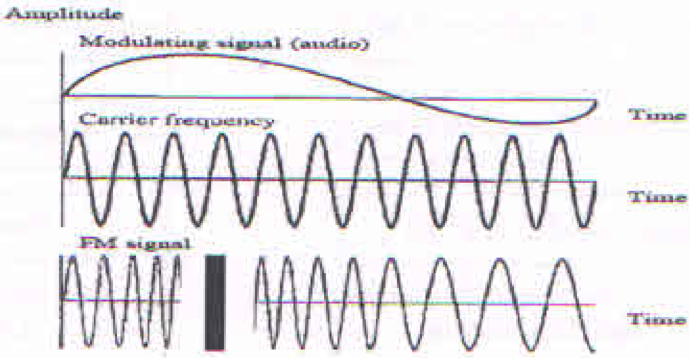



Fig.1.31 FM Modulation

Phase modulation:

In PM transmission, the phase of the carrier signal is modulated to follow the changing voltage level (amplitude) of the modulating signal. The peak amplitude and frequency of the carrier signal remain constant, but as the amplitude of the information signal changes, the phase of the carrier changes correspondingly.

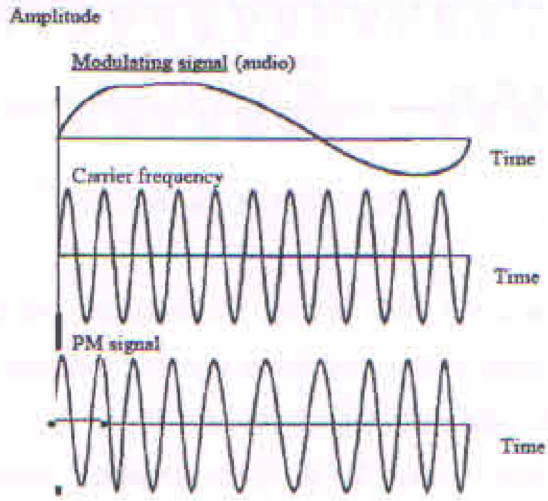



Fig.1.32 Phase Modulation

Angle modulation:

It is combination of frequency and phase modulation. In which carrier frequency and phase proportional to amplitude of data (modulating signal).

**Digital Modulation:**

Amplitude Shift Keying:

In amplitude shift keying, the amplitude of the carrier signal is varied to create signal elements. Both frequency and phase remain constant while the amplitude changes. Binary ASK Although we can have several levels (kinds) of signal elements, each with a different amplitude, ASK is normally implemented using only two levels. This is referred to as binary amplitude shift keying or on-off keying (OOK). The peak amplitude of one signal level is 0; the other is the same as the amplitude of the carrier frequency.

Figure 1.33 gives conceptual views of binary ASK. When the amplitude of the signal is 1, the amplitude of the carrier frequency is held; when the amplitude of the signal is 0, the amplitude of the carrier frequency is zero.

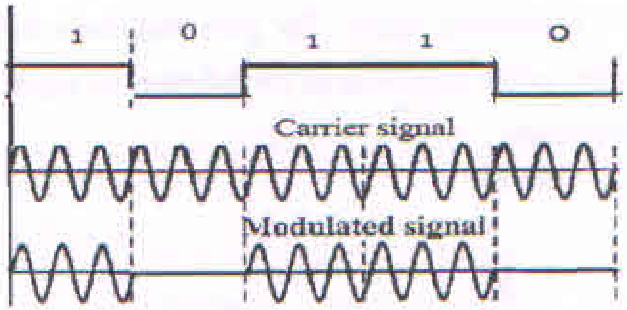



Fig.1.33 ASK modulation

Frequency Shift Keying:

In frequency shift keying, the frequency of the carrier signal is varied to represent data. The frequency of the modulated signal is constant for the duration of one signal element, but changes for the next signal element if the data element changes. Both peak amplitude and phase remain constant for all signal elements. When the amplitude of is zero, the oscillator keeps its regular frequency; when the amplitude is positive, the frequency is increased.

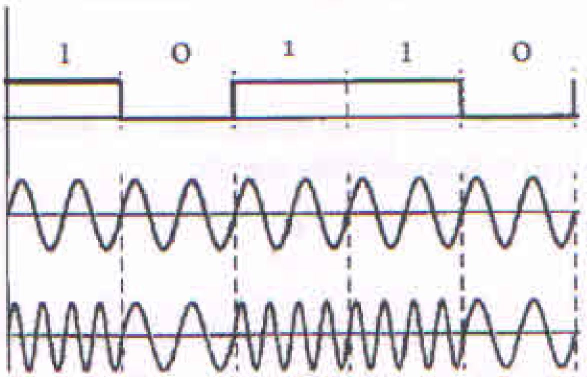



Fig.1.34 FSK Modulation

Phase Shift Keying:

In phase shift keying, the phase of the carrier is varied to represent two or more different signal elements. Both peak amplitude and frequency remain constant as the phase changes. Today, PSK is more common than ASK or FSK. However, Binary PSK (BPSK) The simplest PSK is binary PSK, in which we have only two signal elements, one with a phase of 0°, and the other with a phase of 180°.The signal is multiplied by the carrier frequency;

the 1 bit (positive voltage) is represented by a phase starting at 0°; the a bit (negative voltage) is represented by a phase starting at 180°.

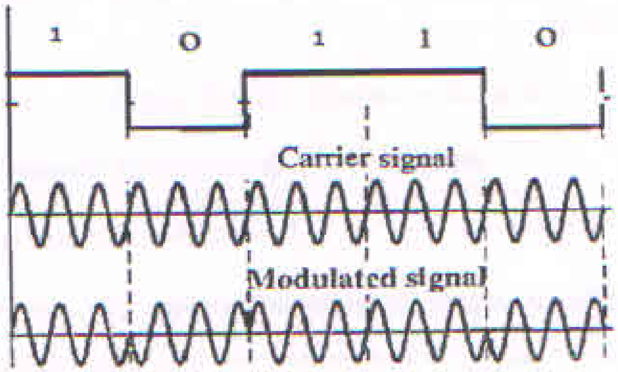



Fig.1.35 PSK Modulation

Quaternary PSK (QPSK):

The simplicity of BPSK enticed designers to use 2 bits at a time in each signal element, The two composite signals created by each multiplier are sine waves with the same frequency, but different phases. When they are added, the result is another sine wave, with one of four possible phases: *45°*, *-45°*, *135°*, and *-135°*.

Quadrature Amplitude Modulation: Quadrature amplitude modulation is a combination of ASK and PSK.

**Bit Rate**: It is defined as number of bits per unit time. Generally expressed in bits per second.

**Information capacity:** it is defined as ability of channel to transfer information per unit time. It is the data rate so expressed in bits per second. Many theories have been developed for determining the information capacity.

1. Hartley law for information theory: Information capacity directly proportional to bandwidth and transmission time.

Information capacity ∞ (Bandwidth) (Time)

$I = K1 \times B \times t$ bps

K1=proportional constant depends on modulation and noise

2. Shannon Information theory: Shannon develops information capacity for noise channel. It depends on both bandwidth(B) and signal to noise ratio(SNR).

Information capacity (I) = B×log2 (1+S/N) bps

3. Nyquist information capacity: Information capacity depends on bandwidth (B) and number of levels for encoding the data.

Information capacity (I) = B×log2M bps

Where B=Minimum nyquist bandwidth

M=Number of discrete levels

**Baud**: Baud is the number of signal elements per second, after modulation. Baud refers to the rate of change of a signal on the transmission medium after encoding and modulation have occurred. Hence, baud is a unit of transmission rate, modulation rate, or symbol rate and, therefore, the terms symbols per second and baud are often used interchangeably.

Baud = Bit Rate/N

N=number of bits to encode each level (N=log2M)

**M-ary Encoding:** M-ary is a term derived from the word binary. M simply represents a digit that corresponds to the number of conditions, levels, or combinations possible for a given number of binary variables. For example, a digital signal with four possible conditions (voltage levels, frequencies, phases, and so on) is an M-ary system where M = 4. If there are eight possible conditions, M= 8 and so forth. The number of bits necessary to produce a given number of conditions is expressed mathematically as

N=log2M

Where N = Number of bits necessary
M = Number of conditions, levels, or combinations possible with N bits

above Equation can be simplified and rearranged to express the number of conditions possible with N bits as For example, with one bit, only $2^1 = 2$ conditions are possible. With two bits, $2^2 =$ 4 conditions are possible, with three bits, $2^3 = 8$ conditions are possible, and so on.

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2) Data Communication & Networking, Behrouz A Forouzan.