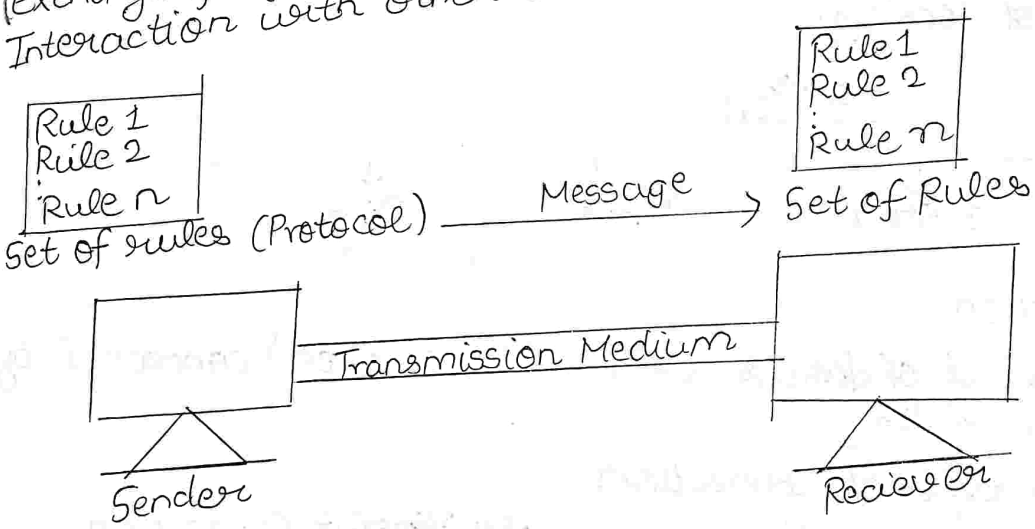
Unit 1 → Data Communication Fundamentals.

Data Communication (In order to achieve data communication, communicating devices must be part of communicating system made up of combination of hardware & software.)
(It refers to exchange of data between two or more devices via some form of transmission medium.)

Computer Network
(It is a telecommunication network which allows computer to exchange data. The best known computer network is Internet.)

Component/Elements of Data Communication
- Data
- Sender
- Reciever
- Transmission Medium
- Protocol.

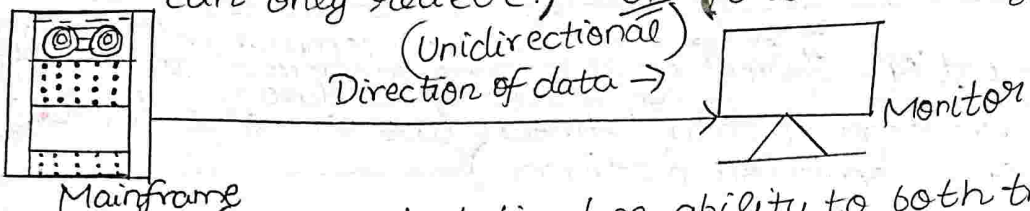
Application of Data Communication
- (Video conferences)
- (Instant messaging)
- (Information sharing by using Web or Internet)
- Resource sharing such as printers & storage devices
- (Exchange of information by means of e-mails & FTP)
- Interaction with other users using dynamic web pages.
- (Parallel computing)



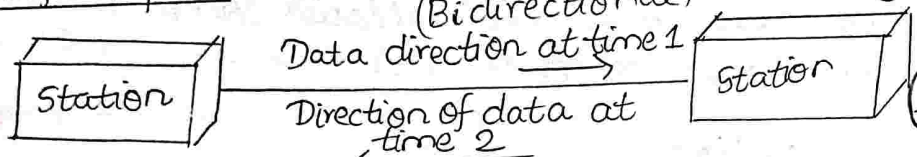
Data Representation
Data can be represented in various form like:
- Text
- ASCII values
- Digits
- Pictures
- Audio
- Video

Modes of Data Communication
(It is direction of data flow from sender to reciever & vice versa)
(There are 3 modes of Data Communication:
i) Simplex Mode ii) Half Duplex Mode iii) Full duplex Mode)

i) Simplex → (Here communication is undirectional.)
(Only one of 2 devices on a link can transmit & other can only recieve.) Ex (Person listenting to radio)

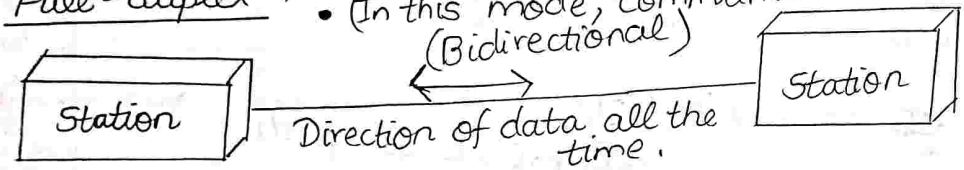


ii) Half-Duplex → (Here, each station has ability to both transmit & recieve but not at same time.) → (when one device is sending & other can only recieve. and vice versa.)



(Ex Walkie-Talkies.)

iii) Full-duplex → (In full duplex, both station can recieve & transmit.)
(In this mode, communication is bidirectional.)

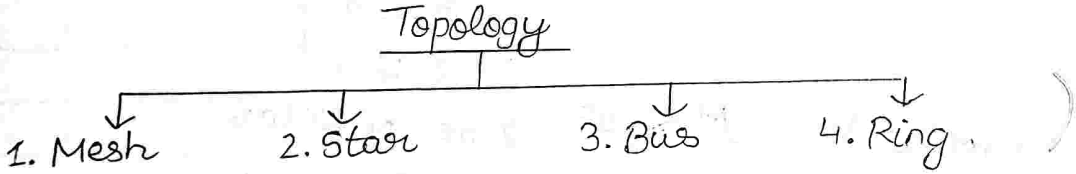


(Ex → Telephone Network)

Network Topology

(Physical structure of network clarifying how devices are connected to each other through communication links.)

(Classification of topology:

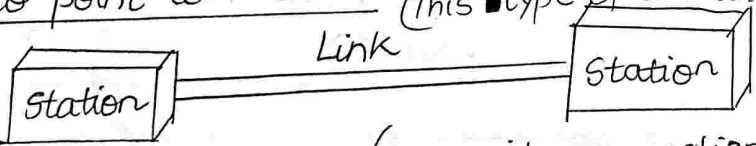


Line Configuration

(A network is a set of devices (ofted called nodes) connected by communication links.)

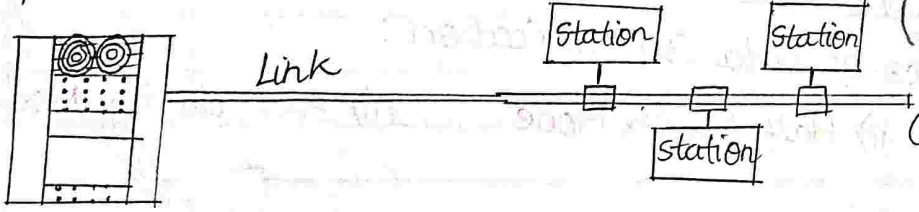
(They are two types of connection
- Point to point connection
- Multipoint Connection)

Point to point connection → (It provides dedicate link between 2 devices for data transmission.) (This type of connection is also called as unicasting.)



(Ex Television with a remote controller)

Multipoint connection → (It provides connection to more than two specific devices that share a single link.)



(Ex → Cable TV, Broadcast service)

(Shared Link)

Effective Data Communication ?

It depends upon 3 fundamental characteristics of data communication system:

→ **Delivery**: Data must be delivered to correct destination by the communication system & must be recieved by desired reciever.

→ **Accuracy**: System must deliver data accuracy without any alternation.

→ **Timeliness**: System must deliver data in a prescribed time domain.

Elements of data communication.

Major elements of data communication system are as follows:

i) **Message** → It is info or data to be communicated. It may be in the form of text, numbers, pictures, sound, video, etc.

ii) **Sender** → It is device which sends the data. It can be computers, telephone, workstations, etc.

iii) **Reciever** → It is device which recieves the message. It can also be computer, telephone, workstations, etc.

iv) **Transmission medium** → It is physical path by which message travels from sender to reciever. Ex → Coaxial & fibre optic cable, microwaves, IR waves, twisted pair cable.

v) **Protocol**: It is set of rules that governs data communication. It establishes argeement between communicating devices. Protocols are beign embedded with communicating software.

Data Representation

Data may be presented in different types:

1) **Text** → It is represented in bit pattern, a sequence of bits.

2) **ASCII** → ANSI developed a code known as ASCII which uses 7 bits for each symbol.

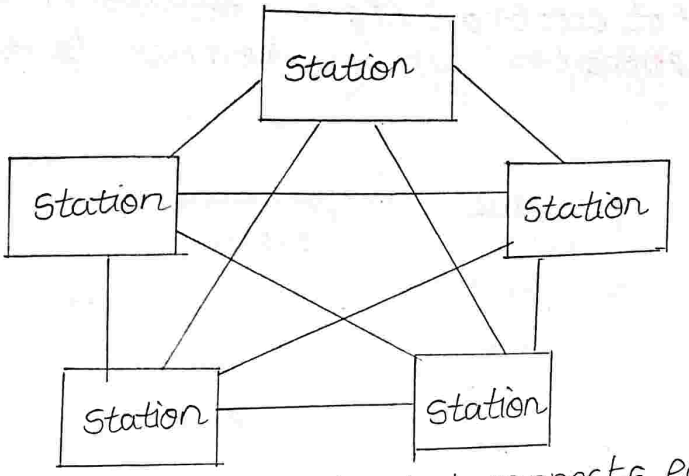
3) **Numbers** → It is also represented by bit pattern, the number is directly converted to binary number.

4) **Images** → It is represented by bit-patters. An image is composed of pixels.

5) **Audio** → It is medium for representation of sound.

6) **Video** → It can be produced either as a continous entity or it can be combination of images, arranged to convey idea of motion.

1) Mesh Topology

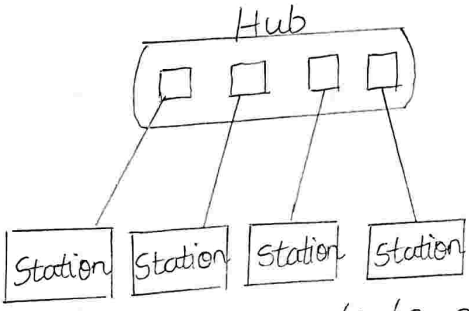


No of connections
$= n(n-1)/2$

For $n=5$,
$= 5(5-1)/2 = \underline{10}$

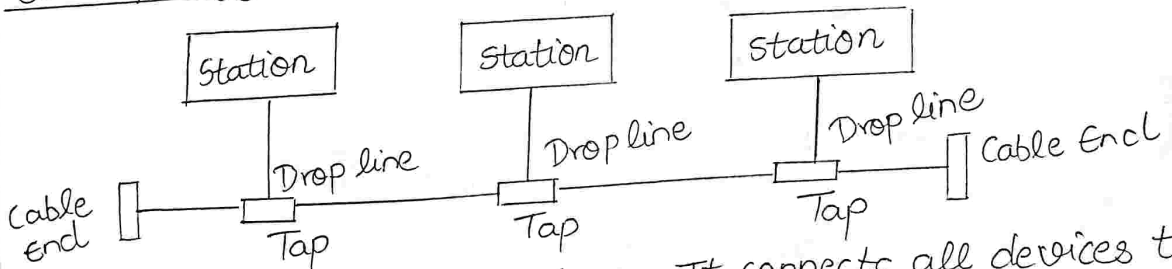
A dedicated point to point link that connects each device on network to another device on network, only carrying data between two devices or more devices.

2) Star Topology



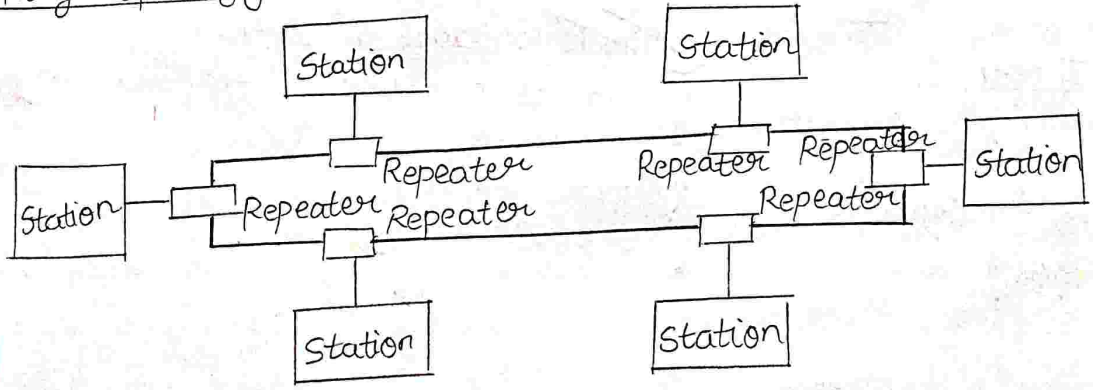
It connects each device in network to a central hub. Devices can only communicate with each other indirectly through central hub.

3) Bus Topology



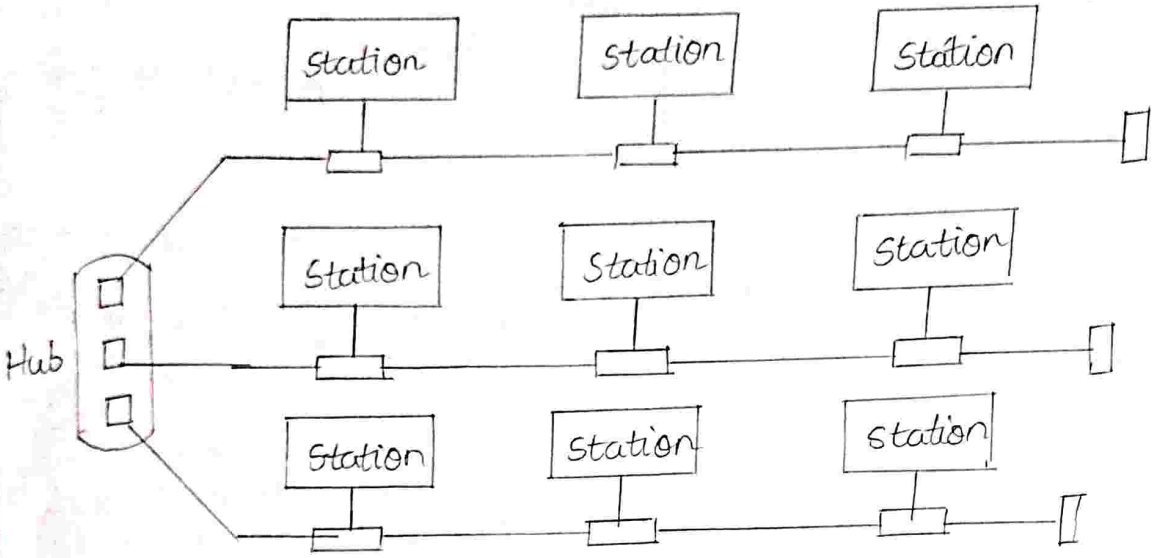
Also known as backbone topology. It connects all devices to main cable via drop lines. Advantage of using this topology lies in its simplicity as less cables are required & makes installation easy.

4) Ring Topology



A point to point link that connects a devices to two or more devices located on either side of it creating ring of devices through which data is forwarded via repeater until it reaches its target devic

5) Hybrid Topology

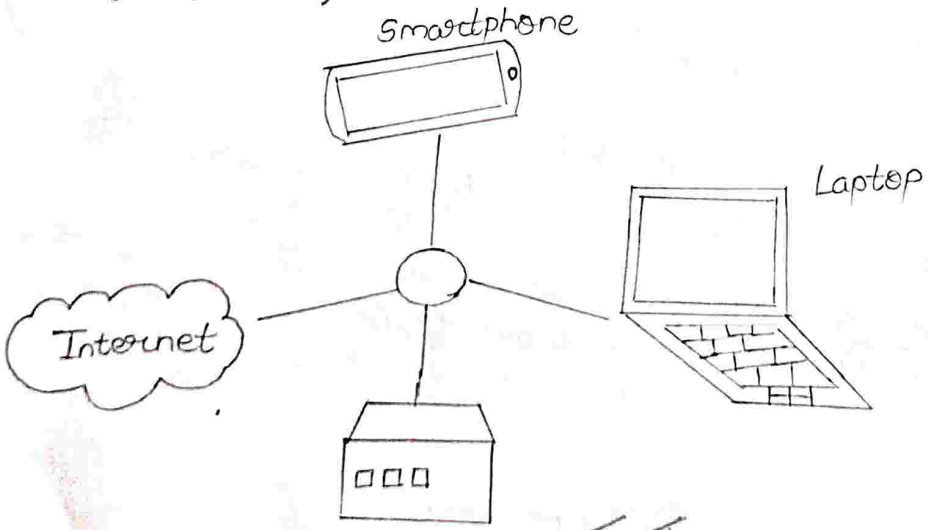


Any combination of two or more topology is known as hybrid technology It is commonly found in individual departments have personalized topology adapted to their needs & network usage.

- When 2 or more network are connected, they become an internetwork or network.

Internet → Internet is collaboration of more than hundreds of thousands of interconnected networks.

The origin of internet devised from concept of Advanced Research Project Agency Network (ARPANET). ARPANET was developed by United States Department of Defence.



Advantages of Internet

- Social Networking
- Entertainment
- Education & technology
- Online services

Disadvantages of Internet

- Threat to personal information
- Spamming
- Cyber Crime
- Virus Attacks

Categories of Topology:

1) Mesh Topology

Advantages:
- Use of dedicated link gaurontees that each connection can carry its own data thus eliminating traffic problems.
- (Mesh topology is robust.)
- (Privacy or security)
- (Fault indentification & fault isolation is easy)

Disadvantages:
- (Installation & reconnections are comparitively difficult)
- Due to shear bulk of wiring, (hardware required to connect each link can be expensive.)

2) Star Topology

Advantages:
- (Less expensive than mesh topology)
- (Robust i.e. if one link fails then other links remains active)
- (Fault Identification / Isolation is easy.)

Disadvantages:
- (More cabling is required in a star than in other topologies)
- (If hub goes down, entire system collapses.)

3) Bus Topology * (Backbone Topology)

Advantages:
- (Ease of installation)
- (Uses less cabling than mesh & star.)

Disadvantages:
- (Reconnection & fault isolation is difficult.)
- (Fault or break in bus cable stops all transmission.)

4) Ring Topology

Advantages:
- (Ring is easy to install & reconfigure.)
- (Fault isolation is simplified.)

Disadvantages:
- (A break in ring can disable entire network)
- (This weakness can be idealised by using dual ring or by closing off the break.)

5) Hybrid Topology

Advantages:

(Allows coexistence by integrating different networks to work together)

Disadvantage:

(costly & needs support to maintain the network)

Services of Internet.

There are international service providers, national, local, regional service providers. Some of the basic services provided by the Internet:

1) (E-Mail (Electronic mail): Method of sending message, notes, letters from one person to another or even many peope at same time via internet.) We can also send file, graphics, images, etc. Biggest advantage of email is that it is cheap and faster. Once the mail is recieved & read, it can be forwarded or/and reply.

2) (FTP (File Transfer Protoct) → It is an internet utility software used to upload & download files.) It enables access to directory/folders on remote computers & allows software, data & text files to be transferred between diff kind of computer. FTP works on the basis of same principle of client/server.

3) (Telnet (Remote Computing) → A telecommunication utility software, which uses available telecommunication facility & allows you to become user on remote computer. Once you gain access to remote computer, you can use it for intented purpose.

4) (WWW (World Wide Web) → It is a hypertext based information retrieval tool. One can easily jump/surf the web by jumping from one document to another using links in those documents.) (Documents can be in many format such as text, graphics, animation, sound or video or combination of all, such documents are called webpages & the links are hyperlinks.)

(The tool used to view webpages on internet is known as Internet Browser)

Network Criteria

(The most important criteria that a network must be able to meet are:)

1) (Performance → It can be measured in two ways. i.e. by its transit time & response time.)

- (Transit Time → Amount of time required for message to travel from one device to other.)
- (Response Time → Elapsed time between an inquiry (by reciever) & response (by sender))

* Performance can also be measured by throughput & delay.
- Throughput → It is the maxm amount of data that can pass through the network.
- Delay → Delay is difference in estimated time & network response time.

ii) Reliability → It is measured by frequency of failure i.e. time taken a link to recover from failure & unexcepted network's robustness.

iii) Security → Network security issues include protecting the data from unauthorized access, data loss by implementing network procedures & policies.

Categories of Networks:

1) LAN → They are privately owned networks & defined within a small physical area such as in single office, building or campus. (It is limited to few kilometres & network management is simple)
- LAN uses transmission technology consisting of single cable to which all machines are attached.
- (LAN's are mostly used to allow resources to be shared among personal computer or workstation.)

2) MAN → It is designed to extend over an entire city / It might be group of nearby corporate offices or a city either be public or private
- MAN may be a single networks such as cable television network or may be by means of connecting no. of LAN's into large network so that resources can be shared from LAN to LAN as well as device to device
- (MAN can support both data & voice signals and might even be related to local cable television network.)

3) WAN → It provides a long distance transmission of data, voice, image & video information over a large geographical area, that may comprime a country, continent or even the whole world.
- Wide Area Links are usually provided by inter exchange carrier at a monthly cost for leased line.
- Links are relatively slow & error prone
- Usually in combinations, (WAN can be expandecl to span an unlimited no. of miles.)

Protocol

(A set of rules or conventions that governs all aspects of data communication. The key elements are.
i) Syntax → (It refers to structure/format of data, the order which they are presented.)
ii) Semantics → (It refers to meanings of each section of bits. How is particular patter to be intepreted & action to be taken.)
iii) Timing → (It refers to time & speed of sending a data.))

Standards

(Guidelines provided to manufactors, vendors, government agencies and other service providers to ensure kind of interconnectivity required for national & international communications.)
(Two categories: (These standards are not been approved by an organized body but have been adopted by widespread use of them.)
i) De jure
ii) De facto
↳ (These standars are legislated by an official recognized body))

Fundamentals of Network.

Definition: (Network)
- (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 recieving data generated by other nodes on network.)

Network Criteria (←)

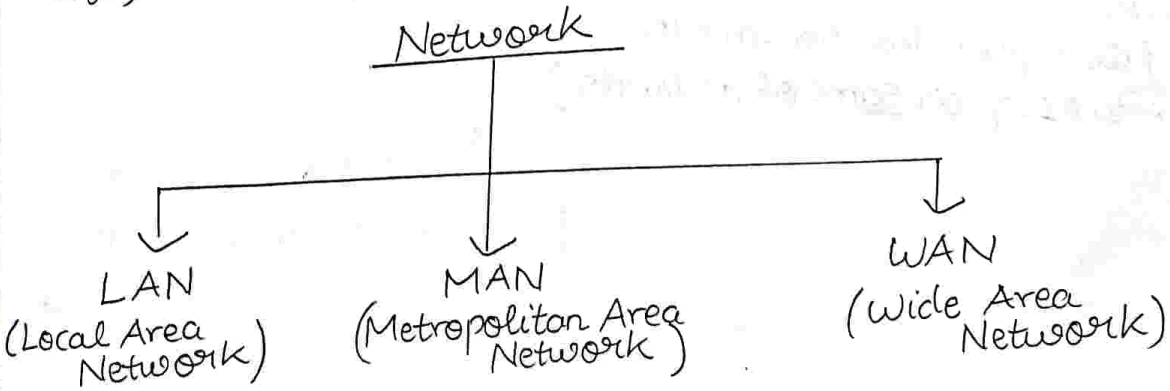
→ Performance
- Transit time
- Response time
- No. of users
- Transmission medium

→ Reliability
- Frequency of failure
- Time taken to recover from failure.

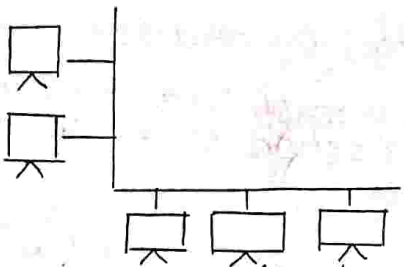
→ Security
- Protecting data from un-authorized access.
- Protecting data from damage.

Categories of Network

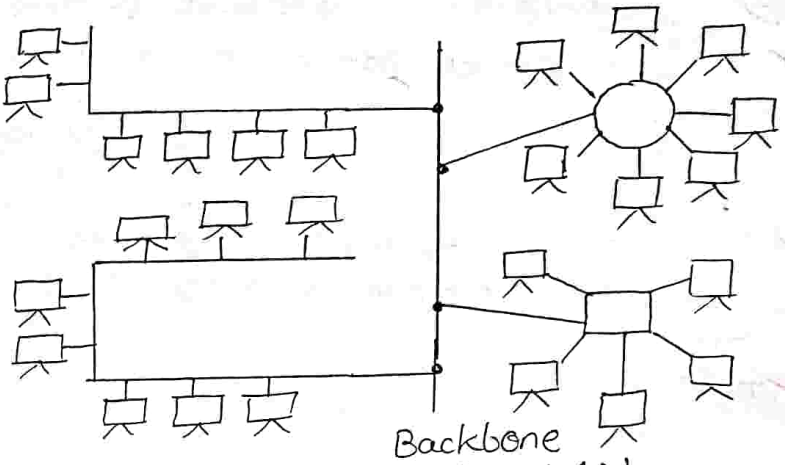
There are 3 primary categories.
- size, ownership, distance it cover, physical architecture.



1) LAN



a. Single Building Lan (LAN)



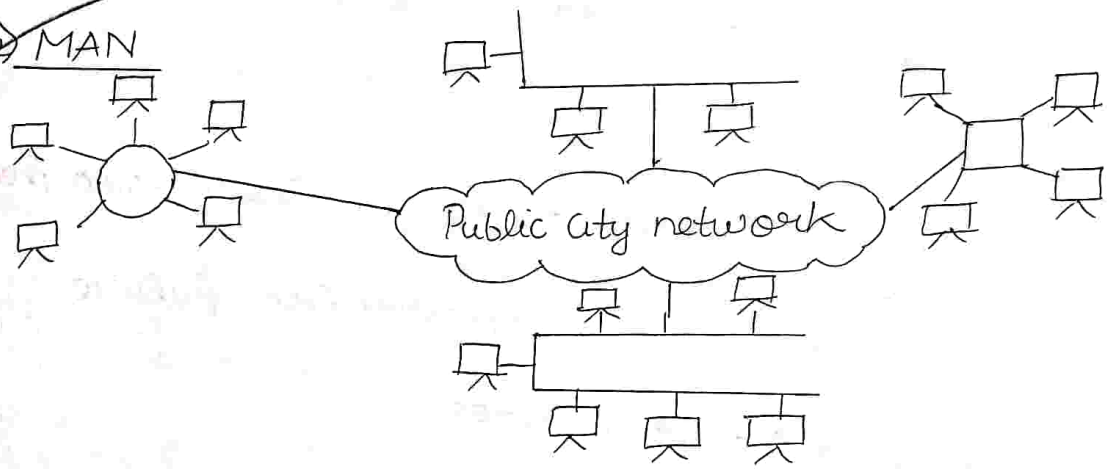
b. Multiple Building LAN

Advantages & Disadvantages:

Advantages:
- Higher data rate/speed
- Reduced cost
- Easy to transfer & manage data
- Data security
- Single internet connection

Disadvantages:
- High initial cost of installation.
- Requires constant LAN administration

2) MAN



Advantages & Disadvantages:

Advantages:
- Fast communication using high speed carriers
- Excellent support for an extensive size network
- Support for full duplex data transmission
- Includes an entire city or some of its parts.

Disadvantages:
- More cabling is required
- Tough to provide system security.

3) WAN

Advantages & Disadvantages :

Advantages :
- Large geographical area
- Easy longer distance communication

Disadvantages :
- Higher initial set up cost
- Difficult to maintain
- More errors & issues
- More time to resolve issues
- Lower security

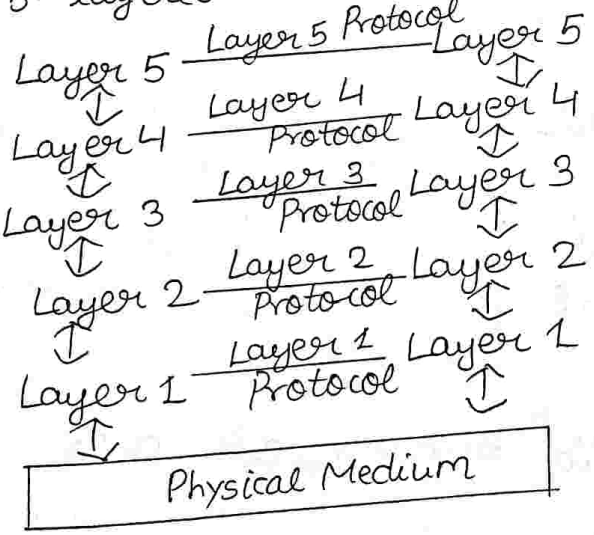
Network Model.

Computer network models are responsible for establishing a connection among sender & reciever and transmitting the data in a smooth manner respectively.

There are two computer network models i.e. OSI Model & TCP/IP Model on which whole data communication process relies

Layered Architecture.

5- layered architecture.



Requirements :
- Divide & Conquer Approach
- Modularity
- Easy to Modify
- Easy to test & debug

OSI Reference Model.

Introduction:

Open System Interconnection, first introduced in the year 1970's

- An ISO Standard Covering all aspects of network communication
- Model for understanding & designing a network architecture which is flexible, robust & interoperable.
- OSI Model consists of 7 seperate layers each of which defines a part of process of moving info across a network.

Layers in OSI Model

7. Application
6. Presentation
5. Session

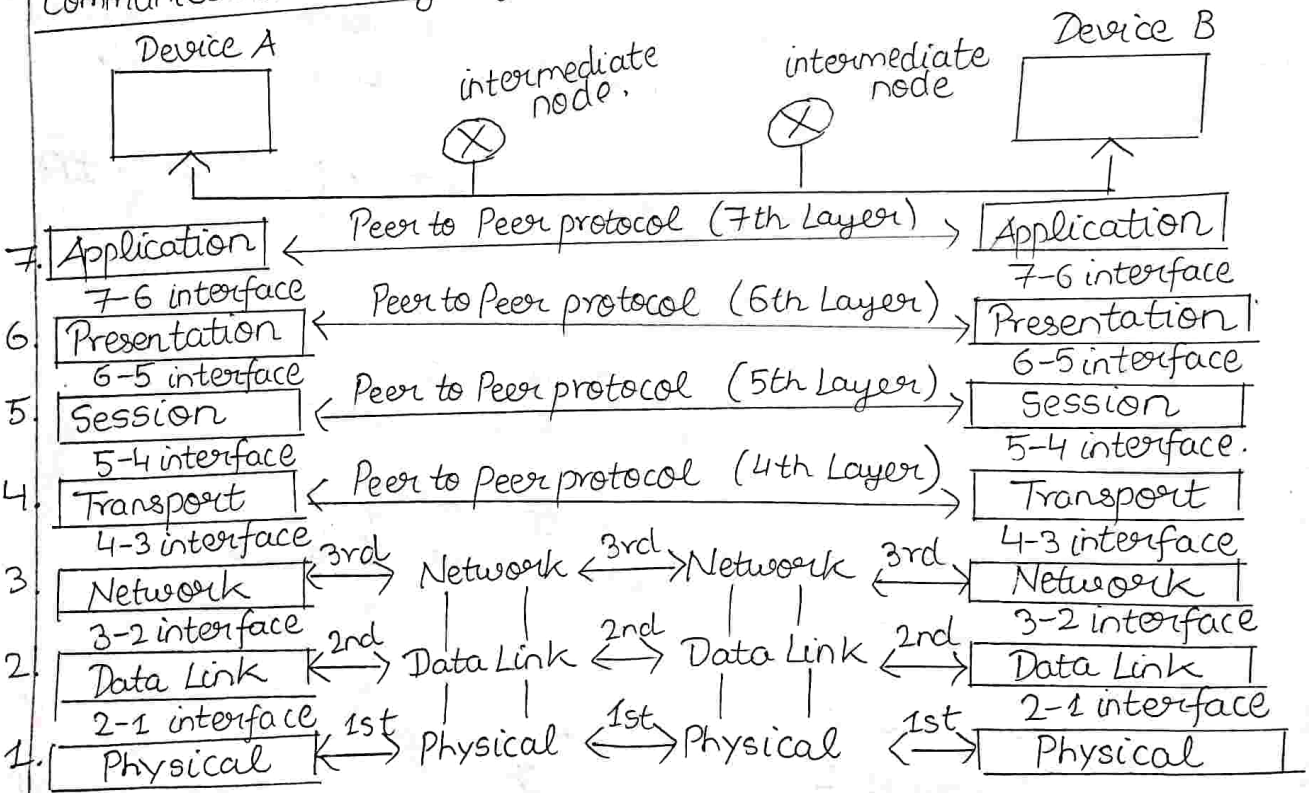
} User Support or Host Layers.

4. Transport → Coordination Layer

3. Network
2. Data Link
1. Physical

} Network Support or Media Layers.

Communication among Layers



Peer to Peer Process

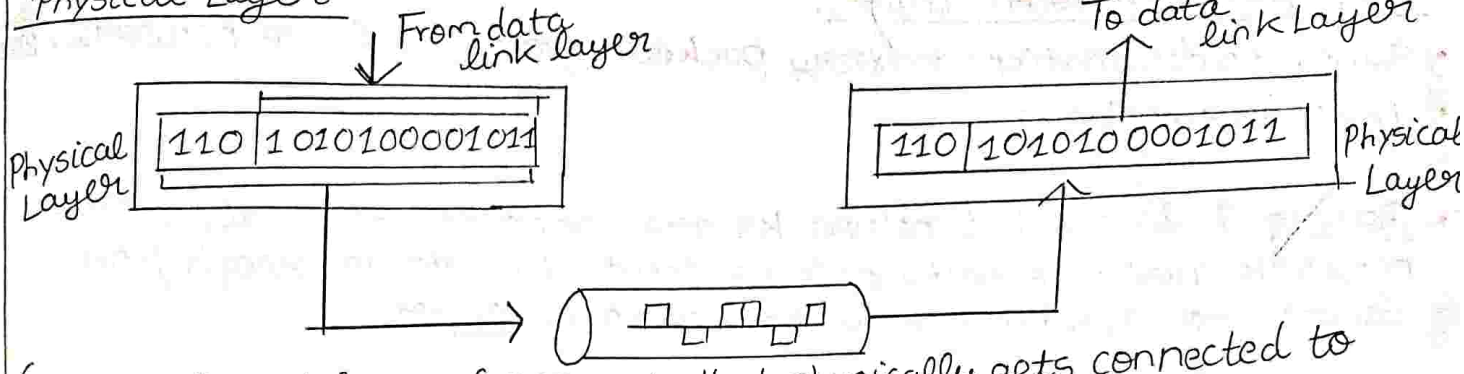
Horizontal communication between similar layers on diff nodes.

Interface.

Vertical communication between different layers on same node.

Function of layers in OSI Model :-

1) Physical Layer

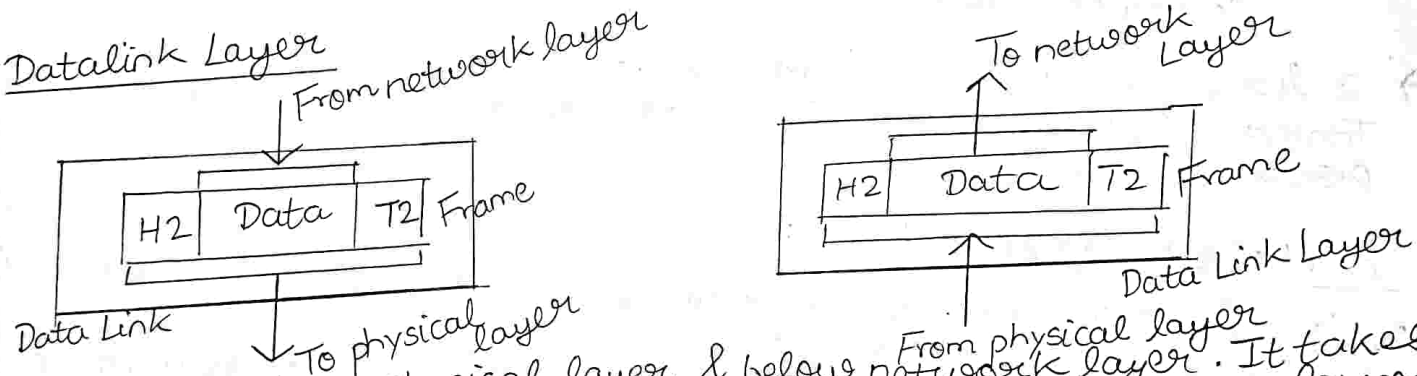


→ (It is the lowest layer of OSI mode that physically gets connected to communication layer.)

Function of Physical Layer

- Movements of individual bits from one hop (node) to next.
- Physical characteristics of interfaces & medium.
- Bit Representation → This layer defines which type of bit encoding to be used.
- Data rate / Transmission rate → It defines no of bits which is sent per sec
- Data sychronization.
- Line configuration → This layer is responsible for connecting devices to media.
- Physical topology → Defines how devices are connected to make network
- Mode of transmission → This layer is responsible for defining the transmission mode.

2) Datalink Layer

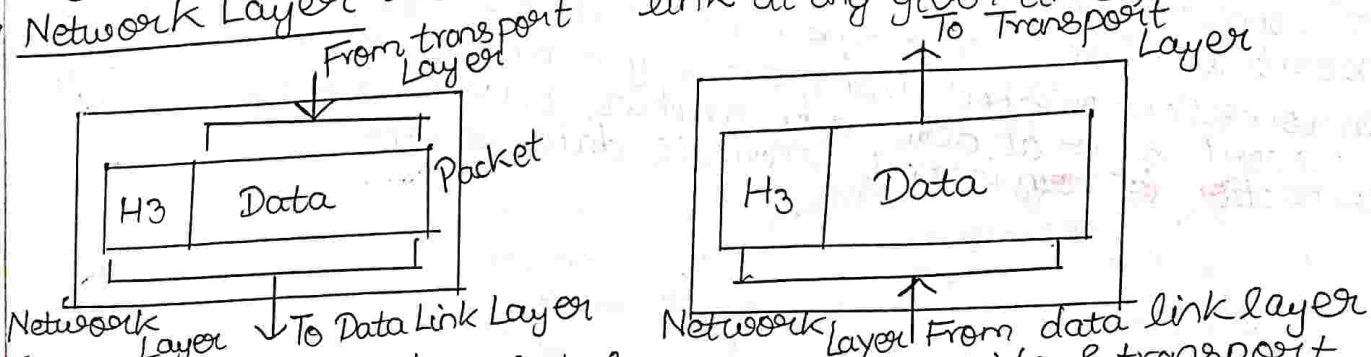


→ (It is layer above Physical layer & below network layer. It takes raw tranmission facility reliable & error free to upper layer.)

Functions of Data Link Layer

- Moving frames from one hop to next.
- Framing → (This layer divides stream of bits from network layer into manageable data units.)
- Physical addressing → (A header is added to physical address of send &/ or reciever of the frame.)
- Flow control → (This layer imposes flow control mechanism on sender on data rate transfer to prevent overwhelming reciever
- Error control → (This layer adds reliability to physical layer by mechanism to detect & transmit lost or duplicate frames.
- Access Control. → (When 2 or more devices are connected to same link, datalink protocol are used to determine which device has control over link at any given time.)

3) Network Layer

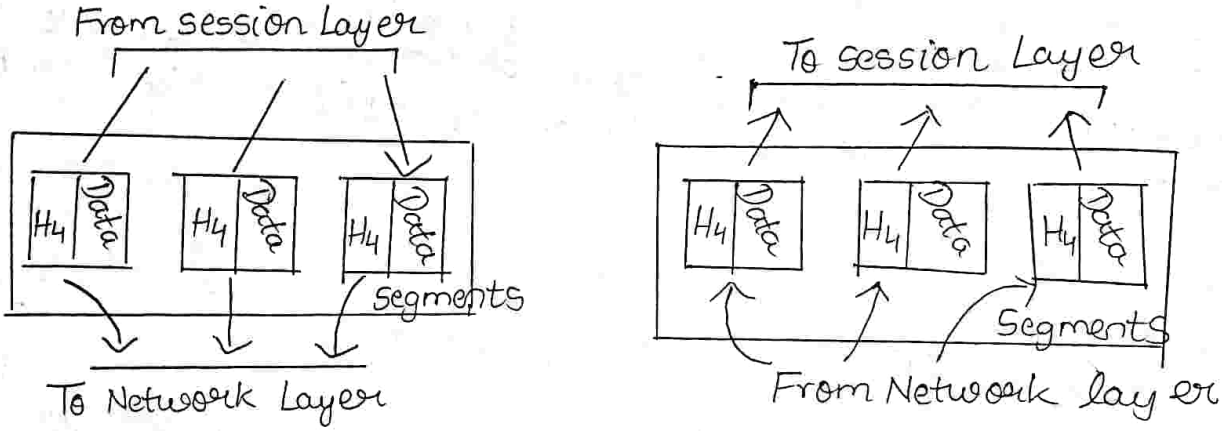


→ (It is layer between data link layer on lower side & transport layer on upper side.)

Functions of Network Layer:

- (Source to destination delivery packet across multiple network (links))
- (Logic addressing) → Physical address implemented by data link layer which handles the addressing problem locally.
- (Routing) → Independent networks are connected to create large (network which connects devices route packets to reach from source to destination by the network layer.)

4) Transport Layer

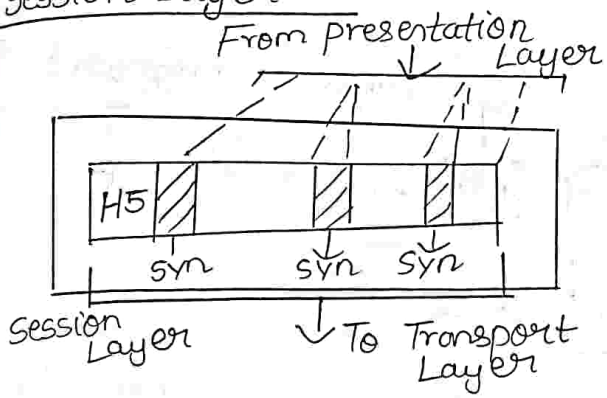


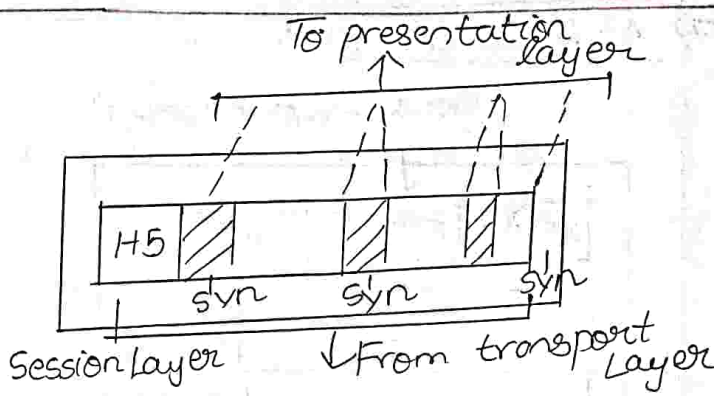
→ (It lies between, network layer and session layer).
Transport layer is (responsible for delivery of entire message from one process to another.)

Functions of Transport Layer:

- (Flow & Error Control) → Both flow & error control at this layer is performed end to end or process to process.
- Segmentation & Reassembly → A message is divided into segment containing number. These number enable transport layer to reassemble message correctly at destination & to identity & replace packets lost in transmission
- Service-point Addressing → This layer include type of address called service point address which is responsible for sending packet to correct computer by network layer & transport layer gets entire message to process on that computer.
correct
- (Connection Control) → Layer can be connection less or connection oriented. In connection less, transport layer treats each segment as independent packet & delivers to transport layer at destination machine.
In connection-oriented, transport layer makes connection with transport layer at destination machine before packet delivery & connection is terminated after all data is sent.

5) Session Layer



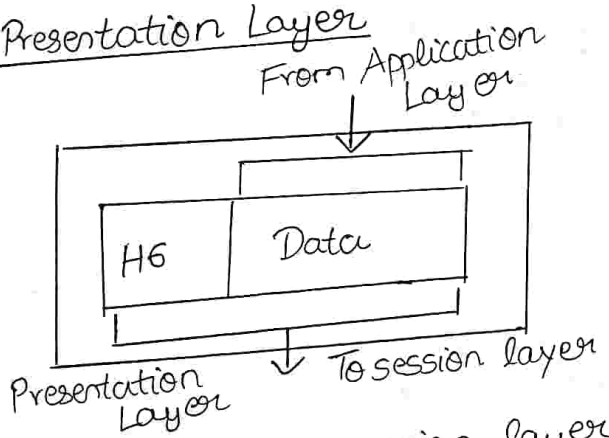


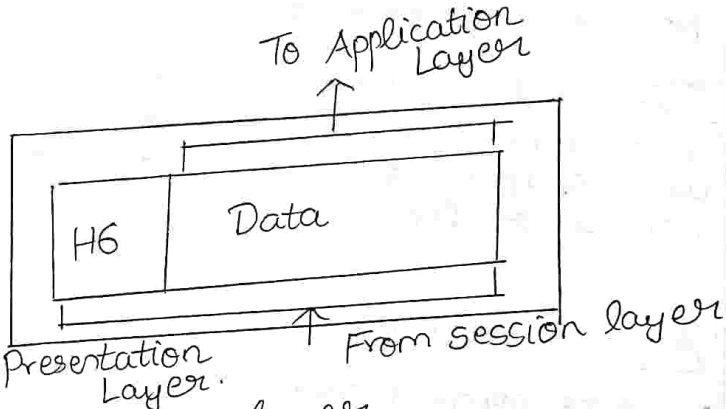
→ Layer lies between transport layer & presentation layer. It allows users on different machines to set up session between them.

Functions on Session Layer:

- It establishes, maintains & synchronises the interaction among communicating systems.
- Dialog Control → Session layer allow 2 systems to enter in a dialog. It allows communication between two processes in either half-duplex or full duplex mode.
- Synchronization → It allows long transmission to resume after a crash by checkpointing

6) Presentation Layer



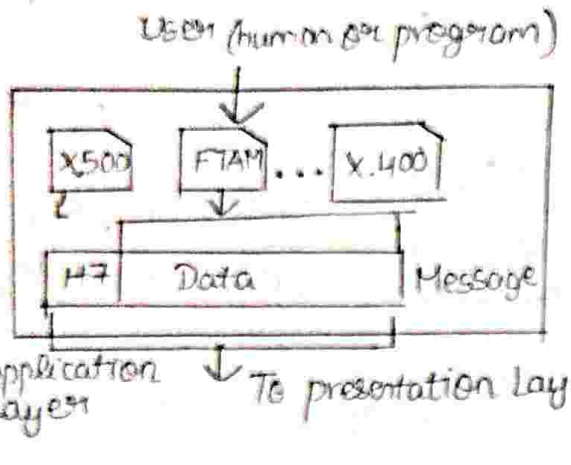


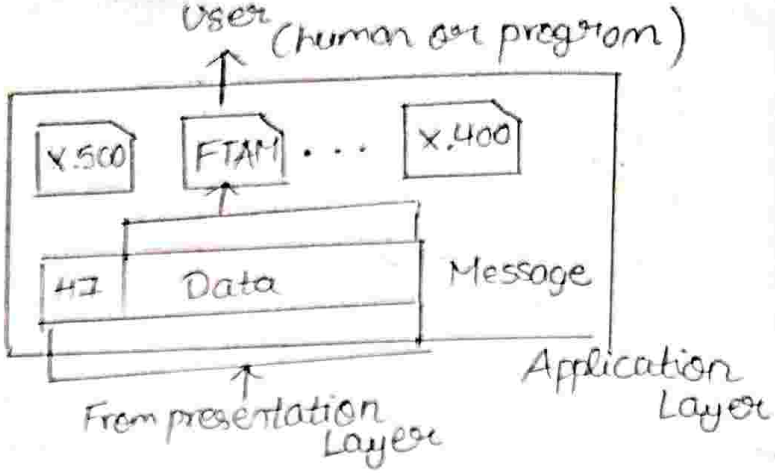
→ It lies between session layer & application layer

Functions on Presentation Layer:

- Concerned with syntax & semantics of information exchanged between the system.
- Encryption → It means sender transform the orginal information to another form & send resulting message out over the network.
- Compression: Data compression reduces no. of bits contained in the information which is particularly important in transmission of multimedia
- Translation: Presentation layer is responsible for operability between these different encoding methods. This layer at sender changes info from its sender dependent format to common format. This layer at recieving machine changes common format into reciever dependent format.

7) Application Layer





→ This layer lies at the top of layer in OSI model.

Functions of Application Layer:

- It is responsible for providing services to the user.
- Mail Services → This application provides basis for e-mail forwarding & storage.
- Directory Services → This application provides distributive database sources & acess for global info about various objects & services.
- Network Virtual Terminal → It is software version of physical terminal This layer is responsible for faciliting the user to log on to remote host through setting up network virtual terminal
- Files transfer, access & management → It allows user to access files in a remote host to retrieve files from remote computer for use in local computer & to manage & control files in remote computer locally.

* Advantages of Layering:

- (Breaks complex tasks into sub tasks)
- (Each layer handles a specific subset of tasks)
- Layer architecture simplifies network design & management becomes easier
- (Easy to debug network applications)
- (Network can change without all programs beign modified)

TCP / IP Model

Transmission Control Protocol (TCP)
Internet Protocol (IP)

The name TCP/IP refers to a suite of data communication protocols
- Suite of data communication protocol is developed by ARPANET.
- **Hierarchical** protocol made of interactive modules each providing a specific functionality.

→ First used protocol suite
→ Universal De-facto standard.
→ Internet Standard communication

TCP/IP Model consist of 5 layer : Physical, Datalink, internet, transport & Application.

Application	
Transport	
Internet	(Network)
Data Link	} Host to Network Layer (Network Interface)
Physical	

(TCP/IP Reference Model)

Application								
Presentation	SMTP	FTP	TELNET	DNS	SNMP	NFS	RPC	TFTP
Session								
Transport	TCP			UDP				
Network.	ICMP	IGMP	IP		ARP	RARP		
Data Link Layer								
Physical Layer								

(Protocols of TCP/IP Model).

Functions of Layers in TCP/IP Reference Model.

1) Physical & Data Link Layer ⇒ They both come under host to network layer. TCP/IP supports all standards & protocols that can be used in LAN's, MAN's, WAN's
- Responsible for transmission for between two device on same network.

2) Network Layer ⇒ The main protocol defined by TCL/IP is Internet Protocol (IP). • Internet layer is concerned with routing of data.
- Internet layer is used to move packets from source to destination
IP, in turn uses 4 supporting protocols : ARP, RARP, ICMP & IGMP.

* Internetworking Protocol (IP) → An unreliable & connectionless protocol – a best effort delivery service or IP provides no error checking & tracking. IP assures unreliability of underlying layer & does its best to get transmission through its destination.

* Address Resolution Protocol (ARP) → It associates IP address with physical address on typical network (such as LAN's), each device on link is identified by physical address.
ARP is used to find physical address of device when IP address is known

* Reverse Address Resolution Protocol (RARP) → It allows host to discover its internet address. It is used when computer is network connected for first time or when a diskless computer is booted.

* Internet Control Message Protocol (ICMP) → It is used by host & routers to send notification of data problems back to sender.
ICMP send query & error reporting messages.

* Internet Group Message Protocol (IGMP) → It is used to facilitate the simultaneous transmission of message to group of recipients.

3) Transport Layer ⇒ It provides end to end data transfer service. It hides the details of underlying networks.
Also used to provide reliable process to process message and error delivery. It includes following protocols.

* Transmission Control Protocol (TCP) → It provides full transport layer services to applications. TCP is reliable connection oriented protocol or connection is established between both ends of transmission. TCP subdivides incoming message of bytes into discrete message & transmit to internet layer. At end, TCL reassembles recieved messages & reorders transmission based on sequence number.

* User Datagram Protocol (UDP) → It is process to process protocol that adds only port address, checksum error control & length info to data from upper layer. It is an unreliable connectionless protocol widely used for client server applications.

* Stream Control Transmission Protocol (SCTP) → It provides support for newer applications such as voice over internet.
It combines the best features of UDP & TCP.

4) Application Layer ⇒ It allows access to network resources.
This layer contains all higher level protocol such as HTTP/FTP, which enables us to surf web & transfer files. It is the most widely implemented layer. Application layer Protocol are:

* File Transfer Protocol (FTP) → Performs basic interactive file transfer between hosts.

* Telnet → Enables users to execute terminal sessions with remote hosts.

* Simple Mail Transfer Protocol : SMTP supports basic message delivery service

→ * Hypertext Transfer Protocol: It supports low overhead transport of files containing mixture of text & graphics.
In addition to widely known protocol, it also includes the following protocols:

- Domain Name Service : This DNS application maps the IP address to name assigned to network devices.

- Routing Information Protocol (RIP) : It is used by network devices to exchange routing information.

- Simple Network Management Protocol (SNMP) → A protocol used to connect/collect management information from network devices.

- Network File System (NFS) → A system developed by sun Microsystems that enables compute to mount drives on remote hosts & operate them as if they are local drives.

Adressing

It is technique used to identify devices under data communication by assigning unique addresses. (info or identification)

It has 4 levels of addressing :

- Physical address
- Port address
- Logical address
- specific address

Each address is related to specific layer in the network architecture

Application Layer	→	Processes	→ [Specific Address]	URL/mailid
Transport Layer	→	SCTP TCP UDP	→ [Port Address]	16-bit
Network Layer	→	IP & other protocols	→ [Logical Addresses]	32-bit
Datalink Layer, Physical Layer	→	Underlying physical networks	→ [Physical Addresses]	48-bit

1) Physical Address → The level of address is associated with physical & data link layer or combined called the network interface / link layer. It is address of node defined by its LAN or WAN & included in frame used by data link layer.
It is lowest level address. The size & format of these address vary depending on the network.
Ex Ethernet uses 6-byte (48-bit) physical address that is imprinted on network interface card (NIC).

2) Logic Address → It is associated with network layer of TCP/IP model. Logical address are designed for this purpose where universal address System needs each host can be identified, uniquely regardless of the underlying physical network.
Logical address in internet is currently 32-bit address that uniquely define a host connected to Internet.

3) Port Address : It is associated with the processes. Computer can run multiple processes at same time, and objective of internet communication is a process communicating with another processes.
Ex Computer A can communicate with computer C by using TELNET. At same time, computer A communicates with B by using FTP. So these process to recieve data simultaneously, a method needed to label the different processes.

* In TCP/IP architecture, label assigned to process is called port address. A port address in TCL/IP is 16 bits in length

4) Specific Address : It is associated with user under particular application. It may be e-mail address to identify user or an URL (Universal Resource Locator) to identify server terminal that provides info. URL or mail-id, these addresses get changed to corresponding part & logical addresses by sending computer.
Ex Mail id,

Data & Signals.

Data Representation :
Data can be represented either in analog or digital form.

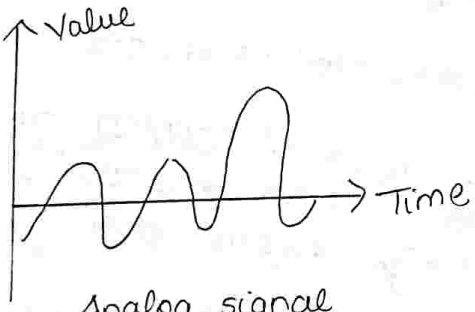
→ Analog Data ⇒ These data are continous & take continous value.
Ex Analog data representation is voice of human that generates continous wave in air. * It can have infinite number of values in a range.

→ Digital Data ⇒ These data are discrete states & take discrete values.
It can only have only limited number of values.

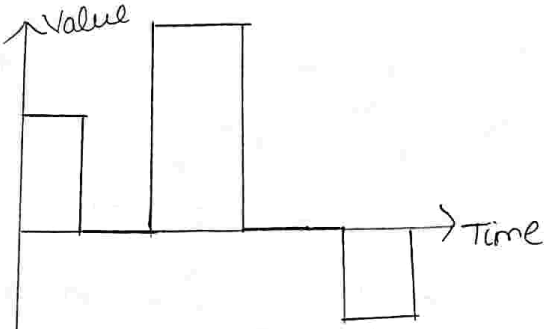
Signal
The energy flow profile of particular representation of data is known as signal.

→ Analog Signals → The way of representation of analog data using energy is known as analog signal. Analog signal is continous waveform that changes smoothly with time.

→ Digital Signals → The way of representation of digital data using energy is known as digital signal. Signal format is discrete in nature. It can have limited no of defined values.



Analog signal

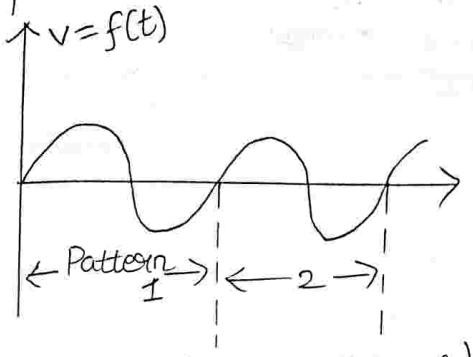


Digital Signal.

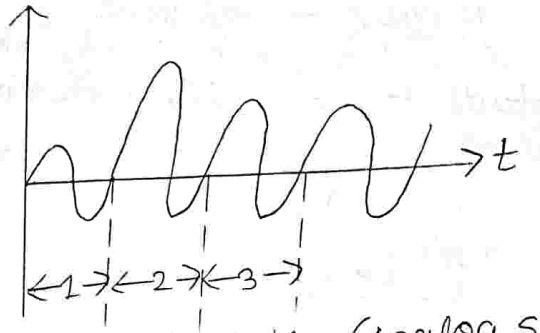
Periodic & Non Periodic signals.
Both analog & digital signals can take one of the two forms.

→ Periodic Signal : It completes a pattern within a measurable time frame called a period & repeats that pattern over subsequent identical periods. The competion of one full pattern is called cycle.
- Periodic analog signal can be classified as simple or composite.
- A simple periodic analog signal, a sine wave can't be decomposed into simpler signals.
- A composite periodic analog signal is composed of multiple sine waves.

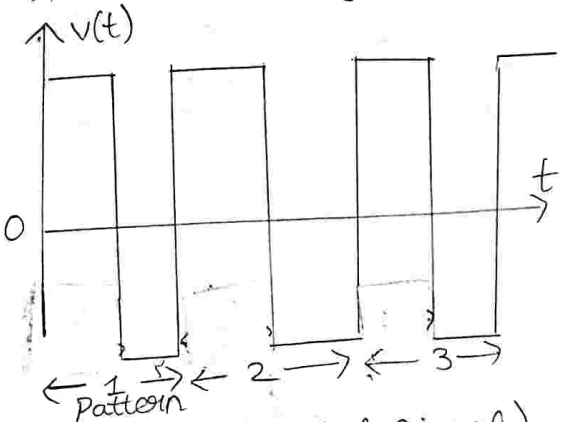
Non-periodic signal → A non periodic signal changes without exhibiting a pattern or cycle that repeats over time.



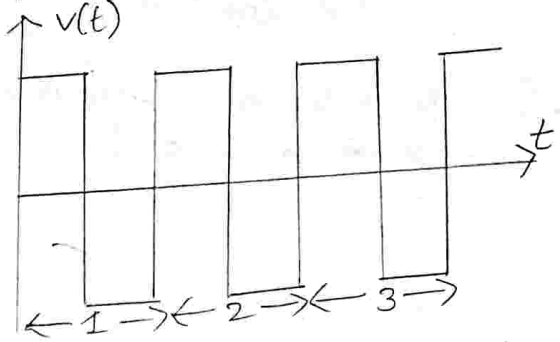
a) Periodic (Analog Signal)



b) Non-Periodic (Analog signal)



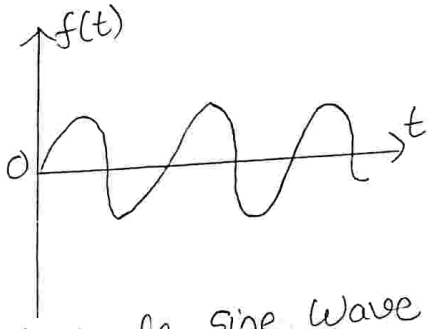
a) Periodic (Digital signal)



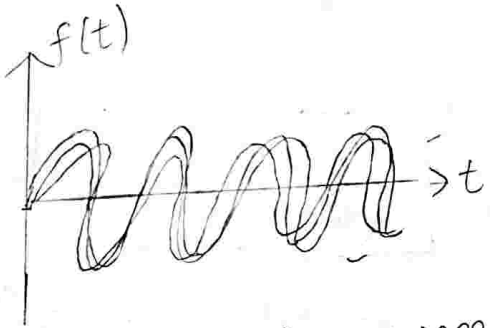
b) Non Periodic (Digital signal)

(↙)

* Sine Waves : Periodic analog signal can be classified as simple or composite Each cycle consists of single arc above time axis followed by single arc below it.



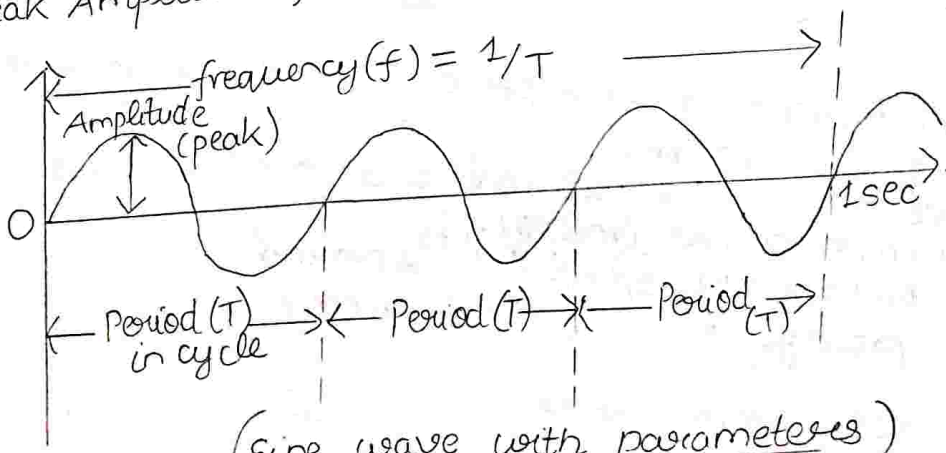
a) simple Sine Wave



b) composite sine-waves

→ A sine waves is a basic form of an analog signal with 3 parameters: Peak Amplitude, Freauency & the phase

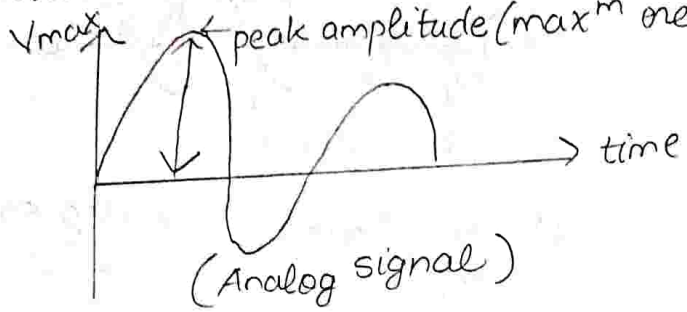
$\left(F = 1/T = \frac{\text{no of cycle}}{\text{sec}}\right)$



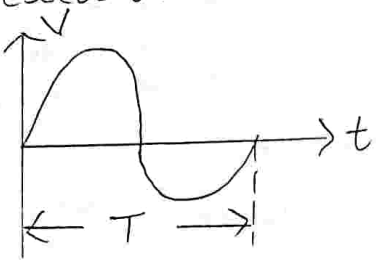
(Sine wave with parameteres)

Analog signal is associated with no of components as given:

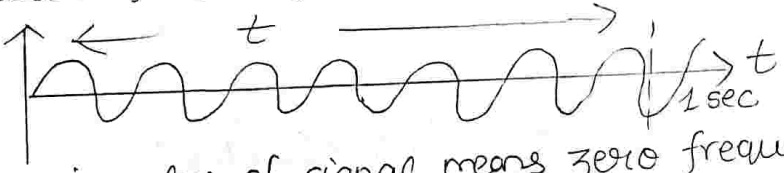
→ Peak Amplitude. – Peak amplitude (V_{max}) of signal represents absolute value of its highest intensity or it carries energy.
Amplitude is normally measured in volts.



→ Period – It is the time required for signal to complete one cycle.
It is expressed in seconds. $[T = 1/f]$; T = period, f = frequency

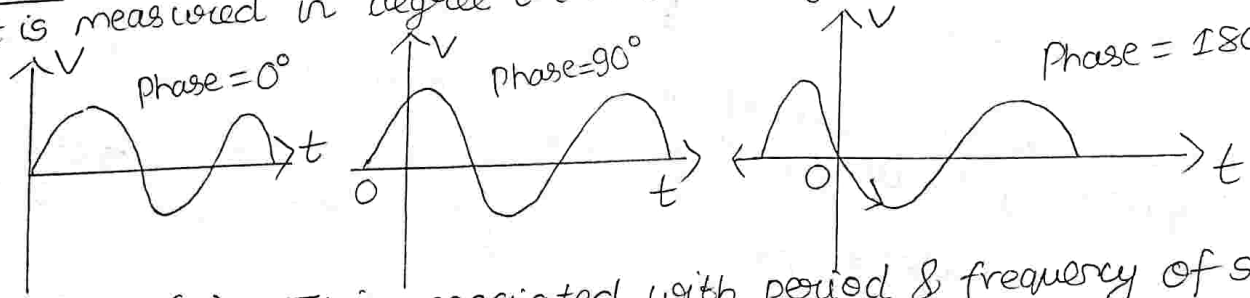


→ Frequency – It refers to number of periods contained by signal in 1sec
It is expressed as Hertz (Hz).
It is rate of change of signal w.r.t. time.
• Period & frequency are inverse of each other.



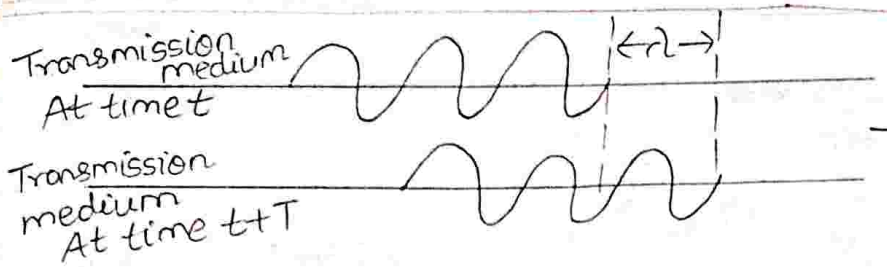
(No change in value of signal means zero frequency ; instant change means infinite frequency.)

→ Phase ⇒ It describes position of waveform relative to time zero.
It is measured in degree or radian ($1° = 2\pi/360$ radian)



→ Wavelength (λ) ⇒ It is associated with period & frequency of signal & propagation speed of the medium.
Wavelength is distance a simple signal can travel in one period.
It is measured in micrometers (microns).
Wavelength (λ) = propagation speed (c) * period
= propagation speed / frequency.

⇒ $[\lambda = c/f]$ microns/micrometers.

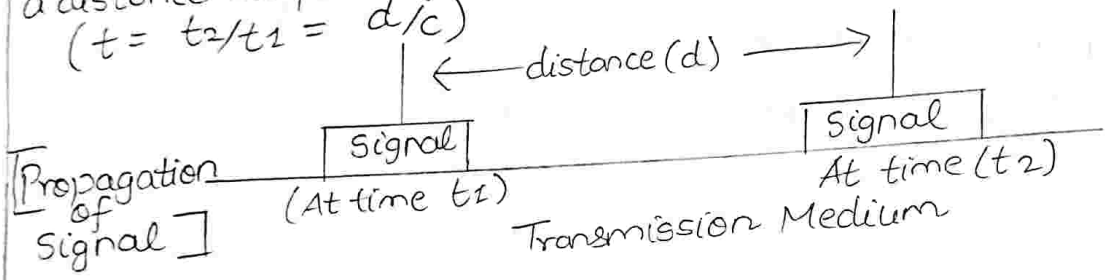


Propagation, Propagation speed & Propagation Time.

→ **Propagation** – Property of signal travelling on a transmission medium/channel.

→ **Propagation Speed (c)** → It is measure for signal to cover certain distance in one second. It is basically speed of light (3×10^8 m/sec) It depends on its travelling medium & frequency.

→ **Propagation Time (t)** → Amount of time that a signal needs to cover a distance at point of transmission medium to another point.
($t = t_2/t_1 = d/c$)

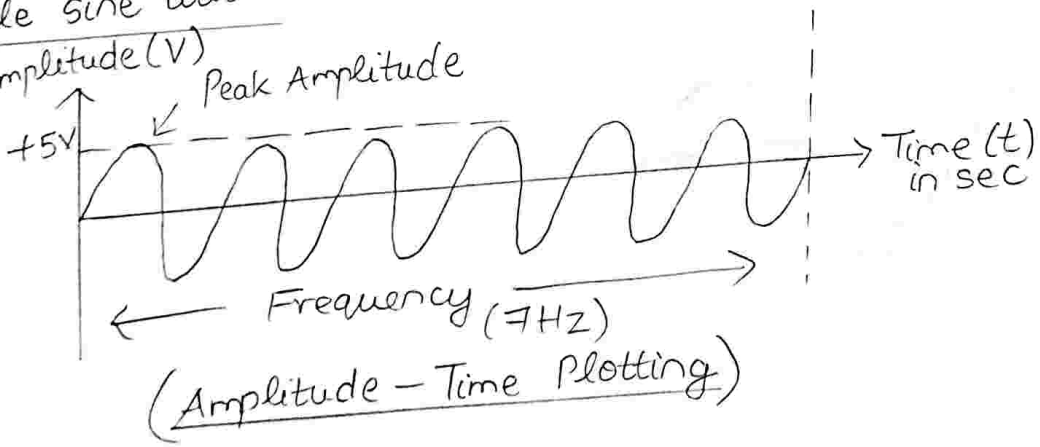


Time & Frequency Domains:

Graphical representation of simple & composite line wave using its time domain & frequency domain w.r.t amplitude of wave

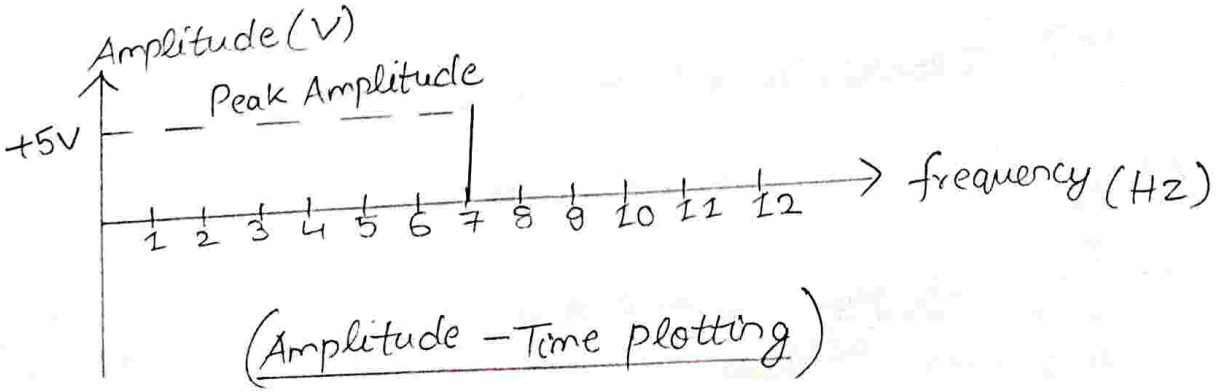
Simple sine wave:

1)



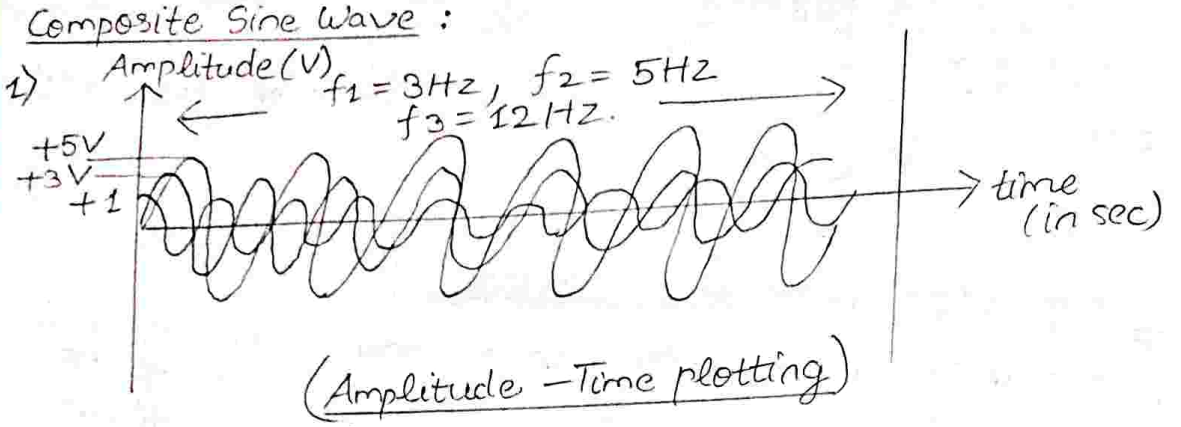
(Amplitude – Time Plotting)

2)

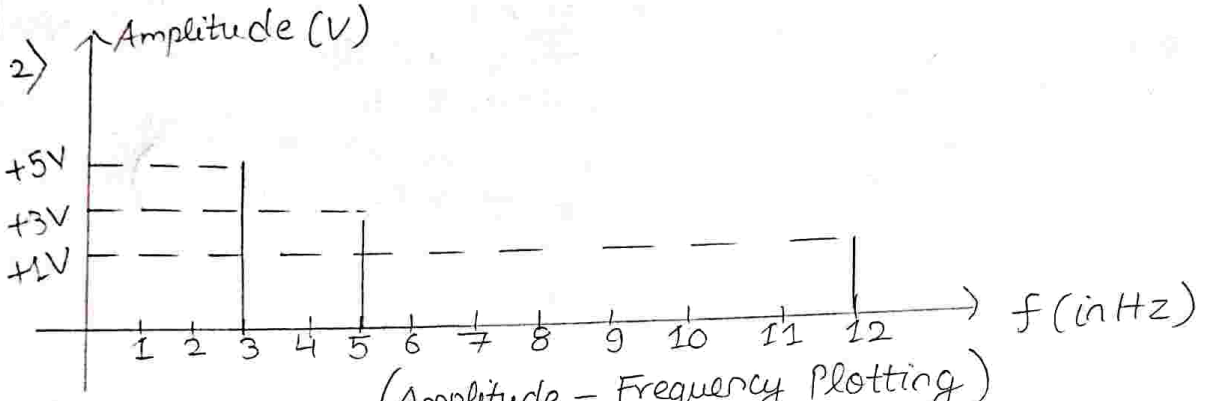


(Amplitude – Time plotting)

Composite Sine Wave :

1) 

(Amplitude – Time plotting)

2) 

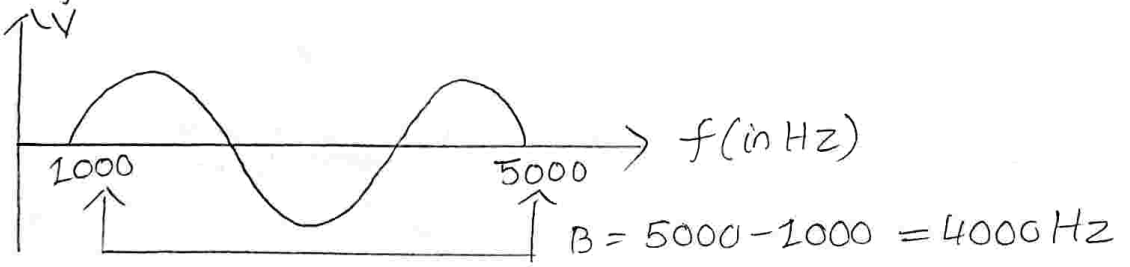
(Amplitude – Frequency Plotting)

Bandwidth

→ The range of frequencies that a medium (channel) can pass through it is called the bandwidth. It is difference between highest & lowest frequency. (It is normally measure in Hz.)

For simple sine wave, bandwidth (Bw) = [f·high − f·low]

For composite sine wave, bandwidth diff between highest & lowest frequencies contained in that signal.



Performance of Network.

The desired performance of network depend on :

→ Bandwidth • Bandwidth in Hz • Bandwidth in bits/sec.

Bandwidth → Bandwidth of channel can be measured in 2 ways:

- Bandwidth in Hertz → It is the range of frequencies contained in a composite signal or (range of frequencies a channel can pass.)
- Bandwidth in bits/sec → (It refers to no of bits/sec that a channel, link or ~~even a~~ network can transmit)

(Bandwidth in Hz is directly proportional to bandwidth in bps)

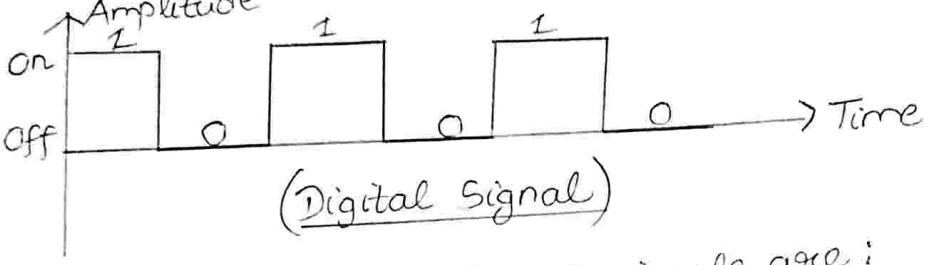
$(Bw_{(Hz)} \propto Bw_{(bps)})$

Digital Signals.

Digital signal is sequence of voltage pulses that are in discrete in nature w.r.t. time.

Ex 1 can be encoded as positive voltage & 0 as zero/negative voltage.

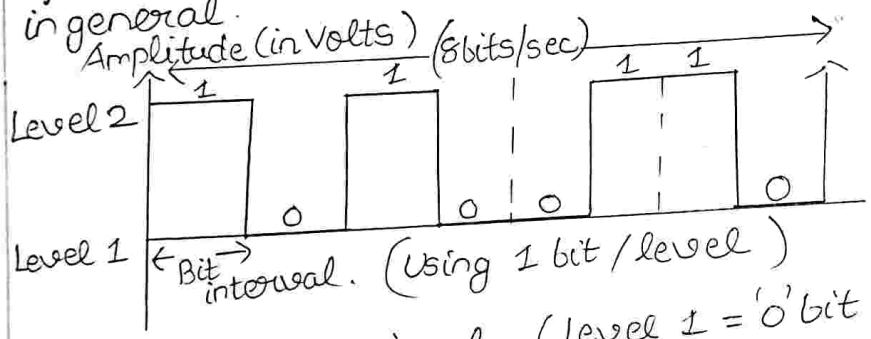
Digital signals also represent information to be transmitted over the communication link i.e. in the form of 1's & 0's



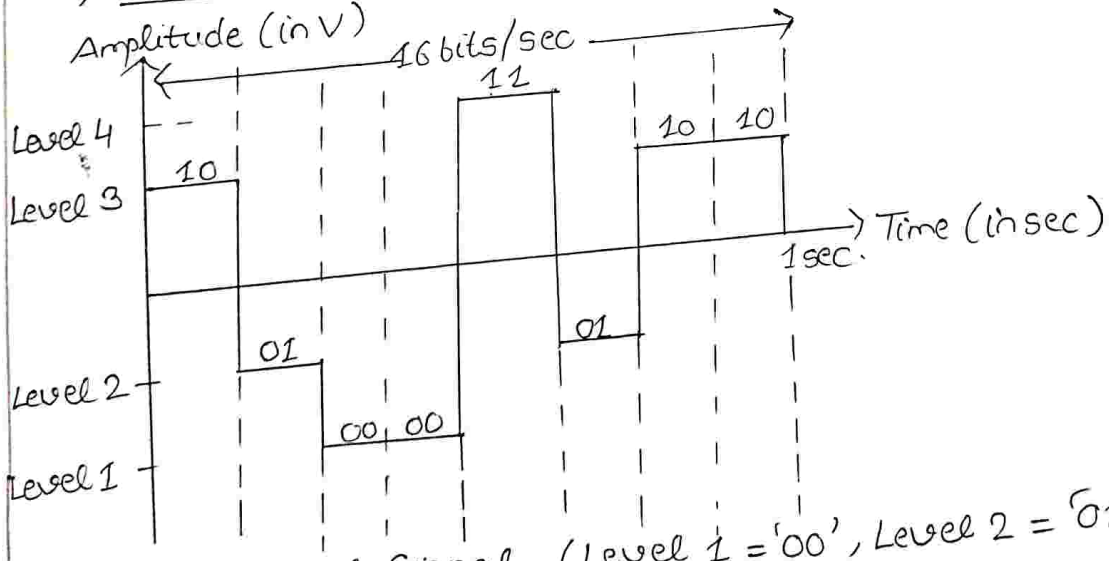
(Digital Signal)

Different parameters of digital signals are:

i) **Level of Digital Signals** → It is no. of bits used to represent an information. If a signal has L levels, each level needs $\log_2 L$ bits, in general.



a) Two level signal (Level 1 = '0' bit & Level 2 = '1' bit)



b) Four Level Signal (Level 1 = '00', Level 2 = '01', Level 3 = '10', Level 4 = '11').

ii) **Bit Rate** → It is the no. of bits sent in 1 second. It is measured in bits per second. Ex 1s = 8 bit interval, Bit rate = 8 bits/sec.

iii) **Bit Interval** → Time required to send a single bit. Bit interval = 1/Bit Rate

iv) **Bit Length** → It is distance one bit covers on transmission link/medium.

[Bit Length = Propagation speed × Bit interval]

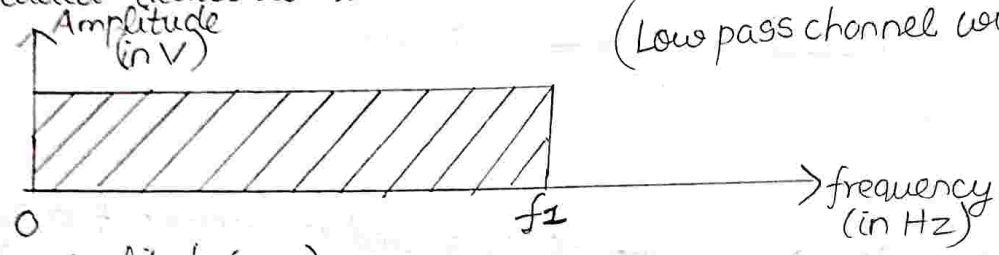
Transmission of Digital Signals

We can transmit digital signal by one of two different approaches:

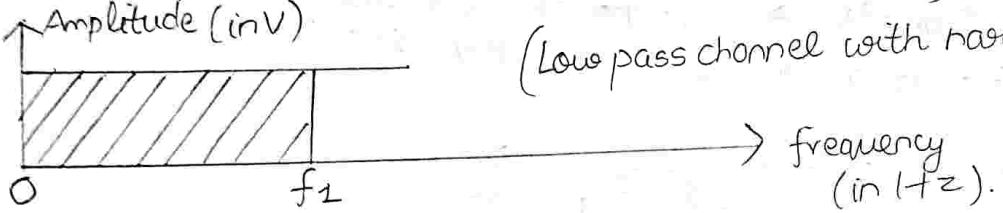
- **Baseband transmission**

→ It means sending a digital signal over a channel without changing the digital signal to analog signal.

- Such transmission requires a low pass channel.
- Low pass channel is a channel with bandwidth starting from zero frequency
- It may be narrow or wide bandwidth.
- Entire bandwidth of this channel is used for one-to-one communication called dedicated link.



(Low pass channel with wide bandwidth)

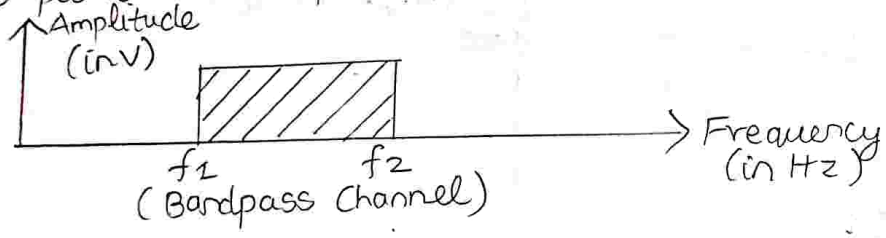


(Low pass channel with narrow bandwidth)

- **Broadband Transmission.** (Using Modulation)

→ It means changing the digital signal to an analog signal for transmission. Modulation allows us to use a bandpass channel.

- Bandpass Channel is a channel with bandwidth that doesn't start with zero
- This channel uses bandwidth with lower limit f_1 & higher limit f_2, where $f_1 > 0$; Bandwidth = $f_2 - f_1$.
- It facilitates no of signal to pass through this channel using specific bandwidth. Ex Radio transmission, Cable TV.
- Bandwidth of transmission link with bandpass channel should be more compared to low pass channel.



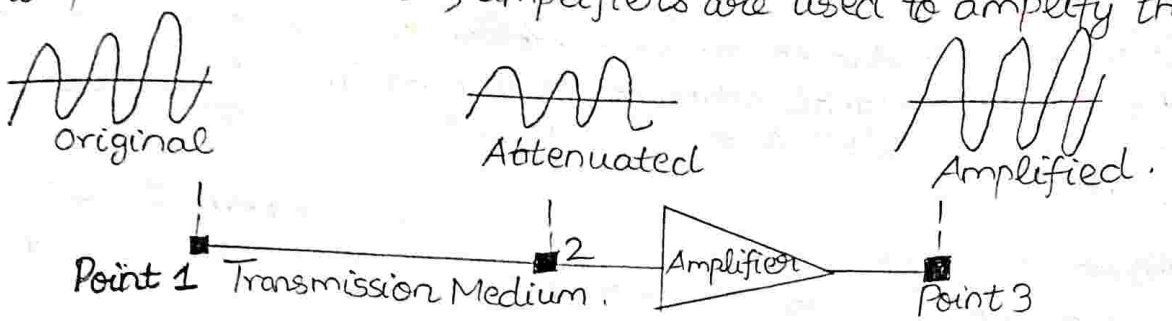
Transmission Impairment

When signal at beginning of medium is not the same as the signal at end of the medium.

- Signal may degrade its shape, size or energy while transmission on link

Cause of Impairment → • Attenuation
• Distortion
• Noise.

- **Attenuation** → It means loss of energy for signal on transmission. when a signal travels through a medium while overcoming resistance.
  - To compensate this loss, amplifiers are used to amplify the signal

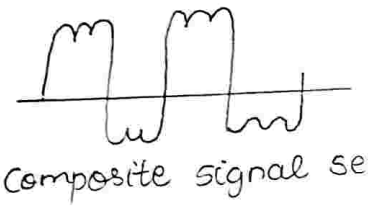


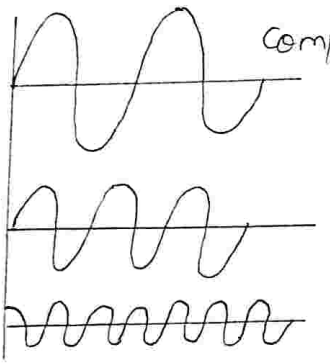
  - It can be expressed as constant no of decibels per unit.

- **Decibel (dB)** → It measures relative strength of two or one signal at two diff points.
  Decibel is -ve if a signal is attenauted & +ve if signal is amplified.
  $$dB = 10 \log_{10} P_2/P_1$$ where P_1 & P_2 → power of signal.

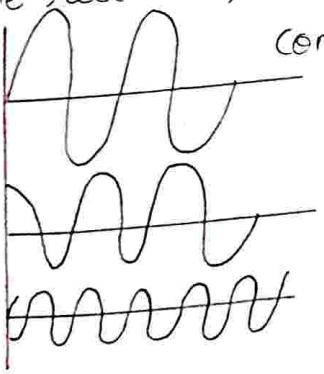
- **Distortion** → It is change in shape or form of the signal on transmission. It usally occurs in a composite signal made of different frequencies. or propagation speed of each signal component through a medium causes diff in phase.

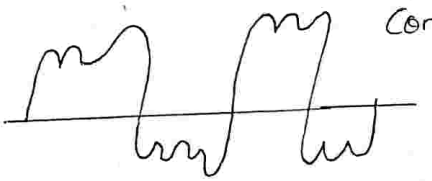
(At the sender.)



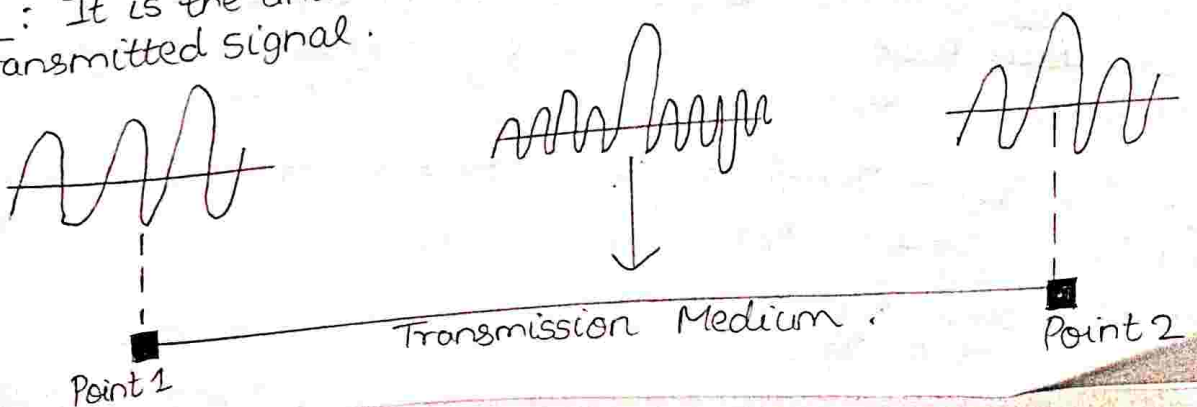


(At the reciever)





- **Noise** : It is the unwanted form of signal which is recieved with the transmitted signal.



It is divided into 4 categories:
- Thermal Noise
- Induced Noise
- Crosstalk
- Impulse Noise

- Thermal Noise → It is due to random motion of electrons in wires that creates an extra signal which is not orginally sent by transmitter. It is uniformly distributed across frequency spectrum and also known as white noise.

- Induced Noise → It comes from sources such as motors & appliances. These devices acts as sending antenna & transmission medium act as a recieving antenna.

- Crosstalk → It is an unwanted coupling between signal paths. It can occur by electrical coupling between nearby twisted pair or coaxial cable lines carrying multiple signal. Crosstalk can also occur when unwanted signal are picked up by microwave antennas.

- Impulse Noise → It is non-continous, unpredictable. irregular spikes or pulses of short duration & relatively of high amplitude. It is due to external electromagnetic disturbances such as lighting or faults in communication system.

Signal to Noise Ratio (SNR)

It is ratio of what is wanted (signal) to what is not wanted (noise).
- A high SNR means signal is less corrupted by noise ; a low SNR means signal is more corrupted by noise.

$$\text{SNR} = \frac{\text{Avg Signal Power}}{\text{Avg Noise Power}}$$

- SNR is often given in decibel also.

$$\text{SNR}_{dB} = 10 \log_{10} \text{SNR}$$

Date Rate Limits

It is measure of data communication speed send in bits per second.
Data rate depends on 3 factors :
- Bandwidth of channel
- Level of signal to be accomodated on channel
- Quality of channels wrt noise

There are two formula to calculate data rate :
i) Nyquist Bit Rate (Noiseless Channel)
ii) Shannon Channel Capacity (Noisy Channel.

i) Nyquist Bit Rate → It defines max^m data rate for noiseless channel

$$\text{Bit Rate} = 2 * B * \log_2 L \text{ Bits per sec}$$

where B = bandwidth of channel
L = no of signal levels.

ii) Shannon Channel Capacity → It is used to determine highest data rate capacity for a noisy channel.

[$C = B * \log_2(1+SNR)$] (bits/sec)

where C : capacity of channel , B : Bandwidth of channel.

→ Network Throughput

It is a measure of how fast we can actually send data through network. It depends on bandwidth, no of signal level & type of intermediate hardware on way of transmission.

→ Latency / Delay → It defines how long it takes for an entire message to completely arrive at destination from time of first bit is sent out from the source.

[Latency = propagation time + transmission time + queuing time + processing delay.]

→ Jitter → It is a problem if different packets of data encounter diff delays & application using data at reciever site is time sensitive.

(Propagation Time → It measure the time required for a bit to travel from source to destination

[t = Distance / Propagation speed]

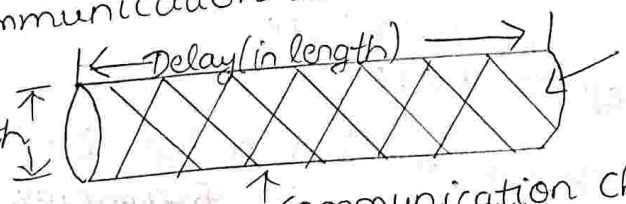
Transmission Time → It measures time required for transmission of message depending upon size of message & bandwidth.

[Transmission time = Message size / Bandwidth]

Queuing time → It measures time needed for each intermediate or end device to hold message before it can be processed.

Processing Delay → It measures time for intermediate device to process the hold message before passing it to next message on way of communication)

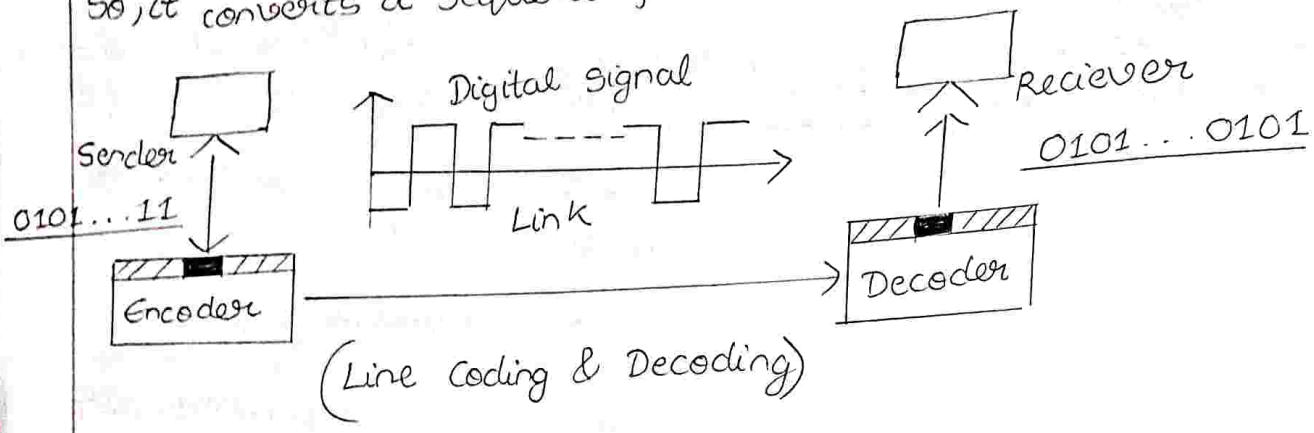
→ Bandwidth-Delay Product ⇒ It defines no of signal bits required to fill a communication link.



Volume = B x Delay

Digital Transmission : Digital to digital conversion

(*) **Line Coding** → Process of converting digital data into digital signals. The data may be in form of text, numbers, images, audio or video, but are stored as sequence of bits in computer memory. So, it converts a sequence of bits to a digital signal.



(Line Coding & Decoding)

Characteristics of Line Coding :

1) **Data element & Signal Element**
A data element is the smallest entity that can represent a piece of information it is the bit. Data element are what we send & signal element are what we can send
A signal element is the shortest unit (timewise) of a digital signal.
A signal element carries the data element.

2) **Data Rate & Signal Rate.**
Data rate defines no of data elements (bits) sent in 1s. Units → bits/sec.
Sometime called as bit rate.
Signal rate is no. of signal elements sent in 1s. Unit → baud.
Sometime called as pulse rate, modulation rate or baud rate

Pulse Rate < Bit Rate.
Increasing the bit rate increases speed of transmission, decreasing the the signal rate decreases the bandwidth requirement.

Relationship, $S = c \times N \times 1/r$ baud

where, S : Signal Rate N : Data Rate C : Case factor
r : previously defined factor

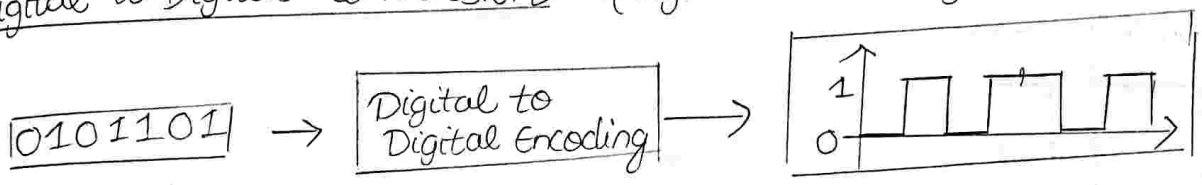
3) DC Components → When a voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies (zero) called as DC components.

4) Self Synchronization → A self synchronizing digital signal includes timing formation in the data beign transmitted. It can be achieved if there are transition in the signal that alert the reciever at beginning, middle or at end of pulse. If reciever clock is out of synchronization then these altering point can reset the clock.

5) Generator code should have a built-in error detector capability to detects the error occured during transmission.

6) Code should be immune to noise & other interference shouldn't be complex.

Digital to Digital Conversion (Digital Data → Digital signal)



The conversion involves 3 techniques :
- Line Coding
- Block Coding
- Scrambling

* Line coding is always needed ; block coding & scrambling may or may'nt be used.

Line Coding Schemes

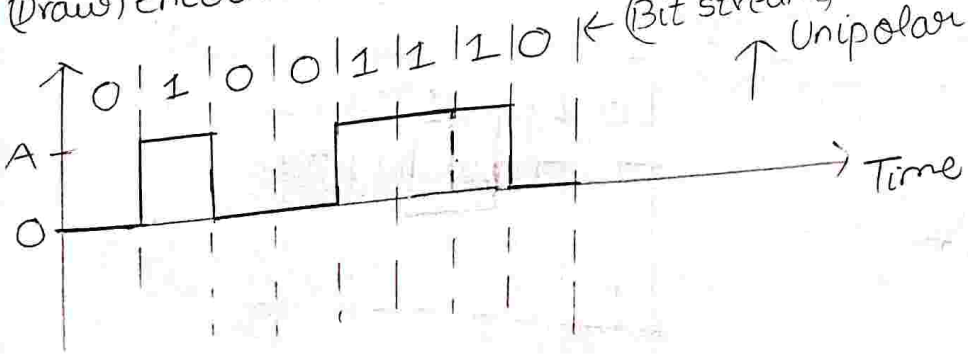
Line Coding →
- Unipolar — NRZ
- Polar — NRZ, RZ & biphase (Manchester & diff Manchester)
- Bipolar — AMI & pseudoternary
- Multilevel — 2B/1Q , 8B/6T & 4D-PAMS
- Multitransition — MLT-3

1) Unipolar Scheme → It uses only one value, either above or below. It is named because it uses only one polarity. This polarity is assigned to one of two binary states either 1 or 0.
- It was designed as NRZ (non-return to zero) scheme, where +ve voltage defines bit 1 & -ve bit defines bit 0.

1 → +ve
0 → 0

Ex NRZ (Unipolar)
(Draw) Encode data 01001110.

→

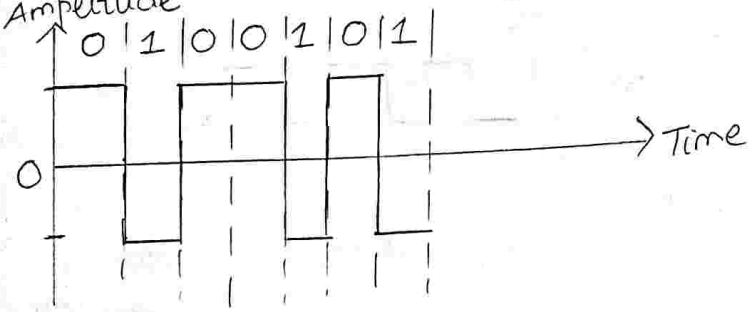


2) Polar Scheme → Polar encoding uses two voltage levels. One level is +ve & another level is negative

- (Polar) NRZ-L Encoding

0 → +ve 1 → -ve

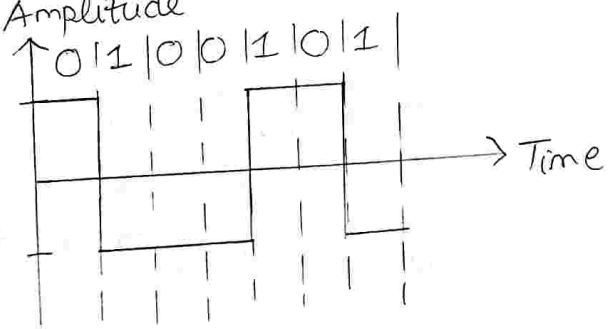
Ex Encode 0100101 using NRZ-L

→ 

- NRZ-I Encoding

0 → No Inversion 1 → Inversion

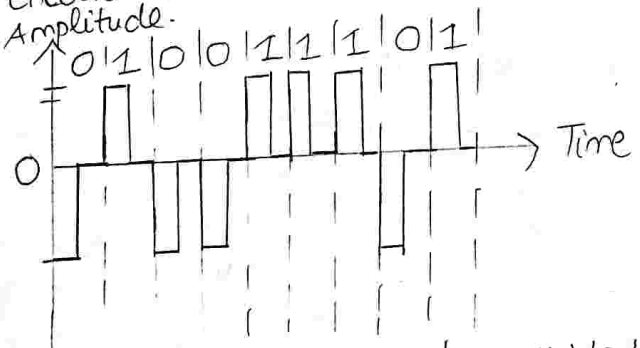
Ex Encode 0100101 using NRZ-I

→ 

- RZ (Return to Zero) Encoding

0 → Low to Base Lvl (LB) 1 → High to Base Lvl (HB)

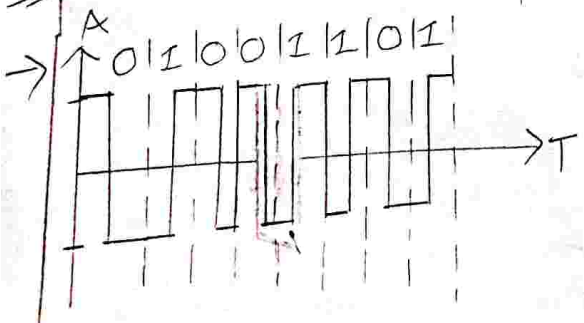
Ex Encode data code 01001101

→ 

- Manchester Endcoding

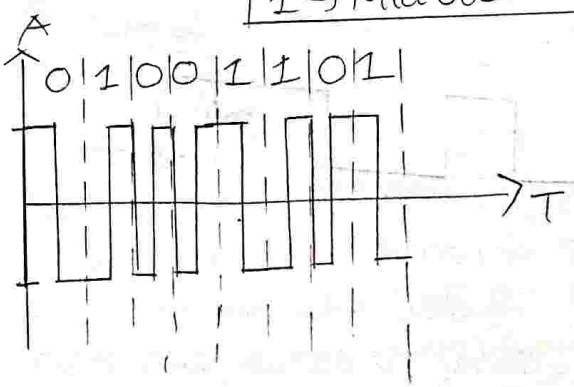
0 → High to Low (H → L) 1 → Low to High (L → H)

Ex Encode 01001101

→ 

- D Manchester Encoding (1)

0 → Begin Bit (or) & Mid bit 1 → Mid bit.



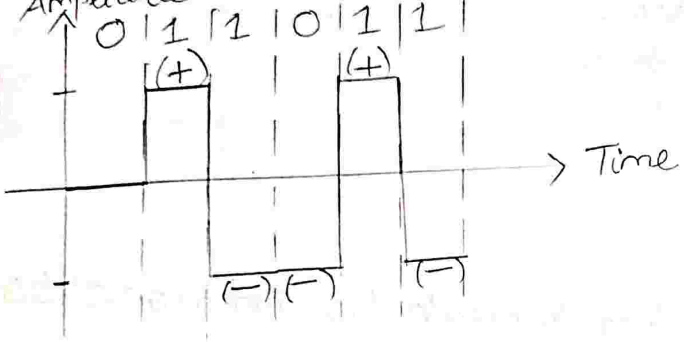
3) Bipolar schemes → There are 3 voltage level : +, −, 0. The voltage level for one data element is 0, while voltage level for other element alternate between + or −

- AMI (Alternate Mark Inversion)

0 = No signal 1 = Alternative +, −

Ex Encode data code 0 1 1 0 1 1

→ Amplitude.

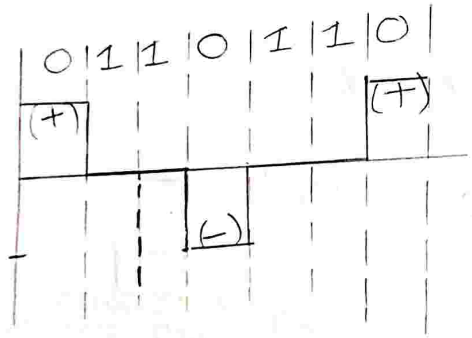


- Pseudoternary

0 = Alt +, − 1 = No signal.

Ex Encode data code 0 1 1 0 1 1 0

→



ii) Block Coding

Referred as mB/nB coding.
It replaces each m-bit group with an n-bit group.

Division of stream into m-bit groups.

m-bits 110....1 | n-bits 000....1 | .... | m-bits 010...1

↓

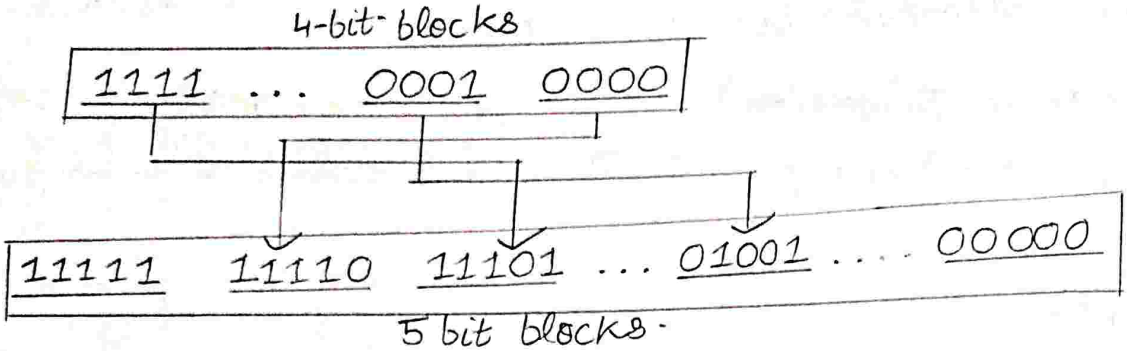
mB-to-nB substitution.

↓

n-bits 010...101 | n-bits 000...001 | ... | n-bits 011...111.

Combining n-bits groups into a stream.

Substitution in 4B/5B Block Coding.



iii) Scrambling

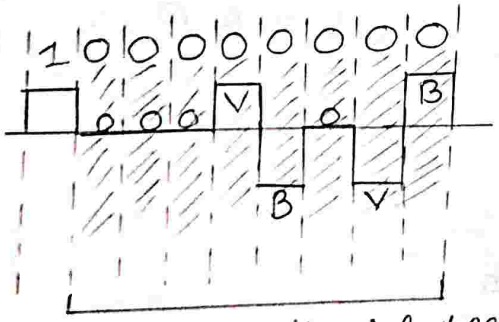
→ Modifying part of rules in line encoding to create bit synchronization is called as Scrambling.

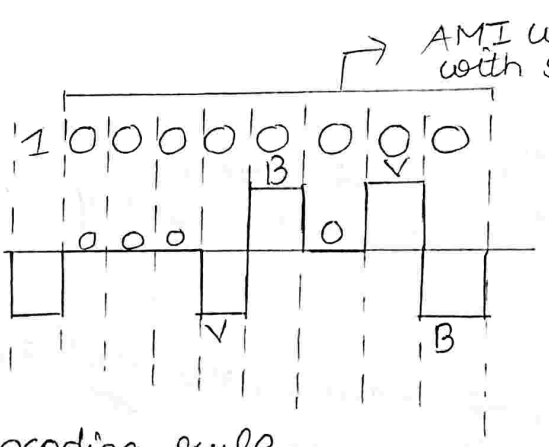
- Used to replace sequencences that would produce constant voltage
- Substituties long zero-level pulses with a combination of other level to provide synchronization.

Two most common scrambling technique are:
- B8ZS
- HDB3.

- Application: Long distance communication (WAN)

- B8ZS (000V or B0VB)





V → Violation, it violates line encoding rule.
B → Bipolar, it implement/follow the bipolar line encoding rule.

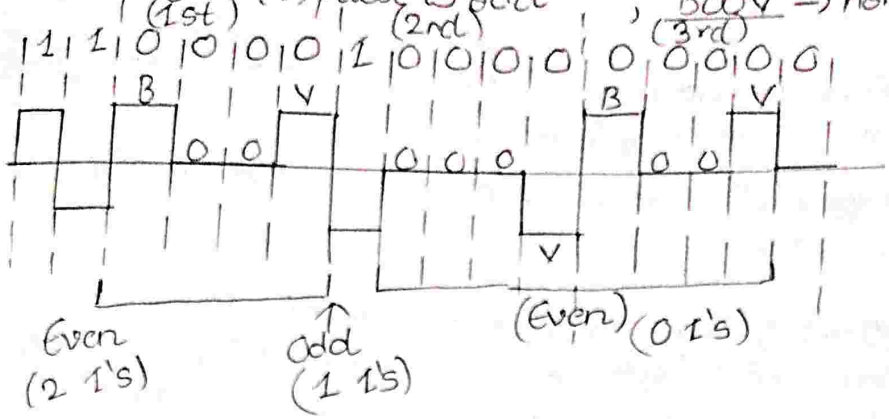
* B8ZS substitutes 8 consecutive zero with 000V B0VB.

- HDB3

If # of non-zero pulses is even, the substitution is B00V to make total # of non-zero pulse even.
If # of non-zero pulses is odd, substitution is 000V to make total # of non-zero pulses even.
* HDB3 substitute 4 consecutive zero with 000V or B00V depending on number of non zero pulses after last substitution

000V → non-zero (1) pulse is odd ; B00V → non-zero pulse is even.

1 → Alt +, −



Steps in Block Coding:

1) **Division:**
- In this step, a sequence of bits is divided into groups of m-bits.

Ex 4B/5B encoding, orginal bit sequence is divided into 4-bit groups.

2) **Substitution:**
- Heart of block coding is substituting step
- we substitute an m-bit group for an n-bit group.

Ex 4B/5B encoding, we substitute a 4-bit code for a 5-bit group

3) **Line Coding:**
- After substitution, we can use one of line coding schemes to create a signal.
- The n-bit groups are combined together to form a stream. New stream has more bits than original one.

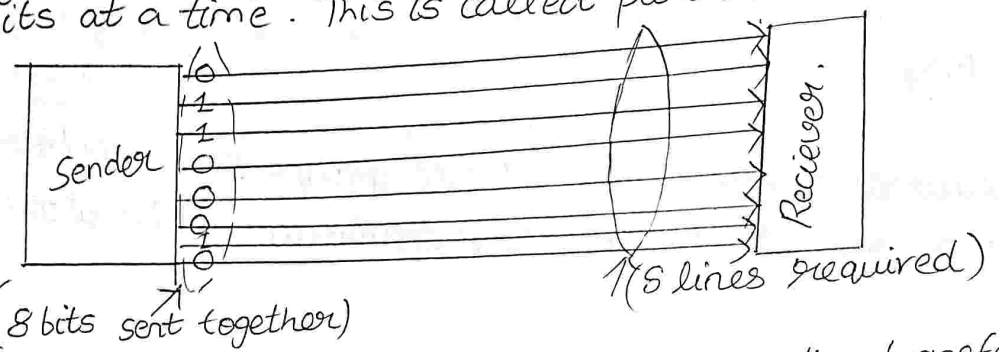
8B/10 B Block Coding:

In 8B/10B encoding, a group of 8-bits of data is encoded into 10bits code. It provides more error detection capability than 4B/5B. The 8B/10B encoding table is very long.
To prevent a long run of consecutive 0's & 1's the code uses a disparity controller which keeps track of excess 0's over 1's.
It also provides better synchronization than 4B/5B

= Transmission Modes.

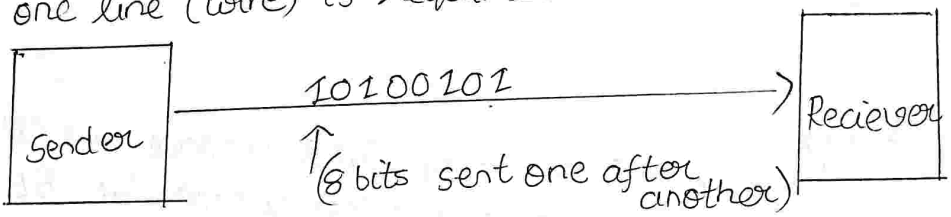
Data transmission refers to movement of bits over same physical medium connecting two or more devices.
The transmission of binary data across a link can be accomplished either in parallel or serial.

1) Parallel Transmission → Binary data consisting of 1's & 0's may be organised into groups of n-bits each. By grouping we can send 'n' bits at a time. This is called parallel transmission.



- Advantage → Transmission speed can increase the transfer speed by a factor of 'n' over serial transmission.
- Disadvantage → Cost is high because it requires 'n' communication lines to transmit the data stream & it is limited to short distance.

2) Serial Transmission → One bit is sent with each clock tick one after another. We need one communication channel to transmit data between two communication devices.
Hence, one line (wire) is required.

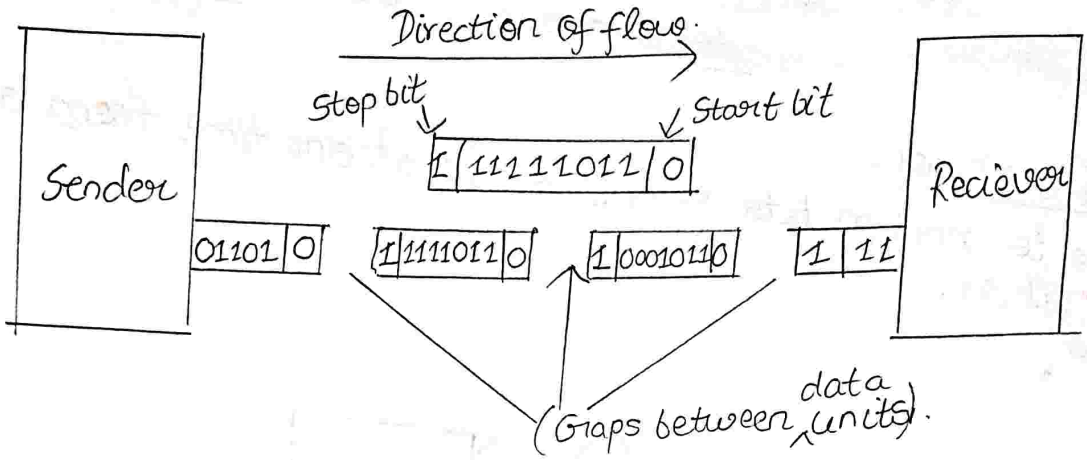


- Advantage → It uses only one communication channel & this way serial transmission reduces cost of transmission, over parallel by a factor n.
Therefore, serial transmission is suitable for transmission over long distance.

→ Serial transmission occurs in one of following two modes:

i) Asynchronous Transmission → The time gap between sending another byte after sending byte from send to reciever can be arbitrary. Here, one byte is sent at a time.
- It is synchronous at byte level but bytes are still synchronized.
- We send 1 start bit (0) at beginning & 1 or more stop bits (1's) at end of each byte. There may be gap between each byte too.

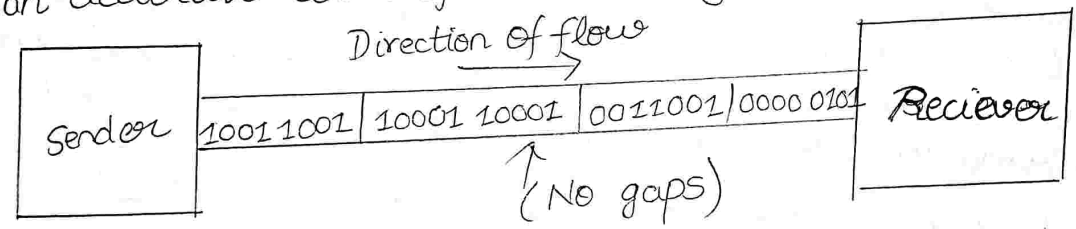
• Advantages ⇒ It is cheap & effective which makes it an attractive choice for low speed communication.



ii) Synchronous Transmission → Bits are always schynchronized & bits are send one after another without start or stop bits or gaps.

• A frame is identified with start & an end byte.

• In this transmission, timing is very important because accuracy of recieved information is dependent on recieving device to keep an accurate count of bits as they come in.



iii) Isochronous Transmission.

In this transmission, we can't have uneven gaps between frames. Transmission of bits is fixed with equal gaps.

Classfication