Data Communication is exchange of data b/w 2 devices via some transmission medium such as a wired cable. The effectiveness of data communication system depends on 4 fundamental characteristics:,

(1) Delivery - Data must be delivered to correct destination

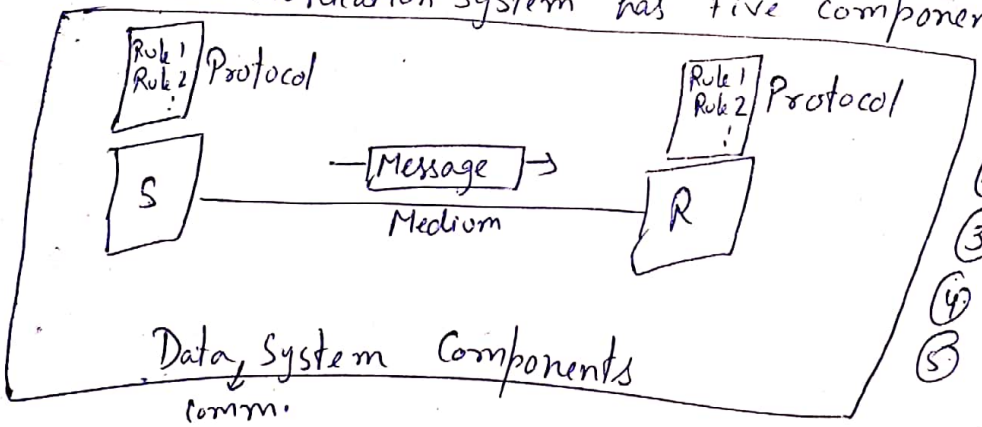
(2) Accuracy - Data must be delivered accurately without any alteration during transmission.

(3) Timeliness - The system must deliver data in a timely manner without delay.

* In case of Audio & Video, timely delivery means delivery the data as they are produced, in the same order that they are produced & without significant delay. This kind of delivery is known as real-time transmission

(4) Jitter - Jitter means the variation in the packet arrival time. It is an uneven delay in delivery of audio or video packets

The Data Communication System has five components-



(1) Message
(2) Medium
(3) Protocol
(4) Sender
(5) Receiver.

(1) Message - The Actual Data we want to transmit. It can be text, numbers, Audio, Video and Pictures etc.

(2) Medium - The communication channel through which data will be transferred. It is the physical path through which data will travel from Sender to receiver.
E.g - Twisted Pair Cable, Coaxial Cable, Fibre-optic cable & Radio waves

(3) Sender - The machine which has some data/information/message to transfer. like Computer, Mobile Phones, Camera etc.

(4) Receiver - The device that receives the data/information/message. It can be a computer, telephone, television etc.

(5) Protocol - A protocol is a set of rules that direct or manage the data communications. Both Sender & Receiver will use/follow some kind of protocol for proper communication.

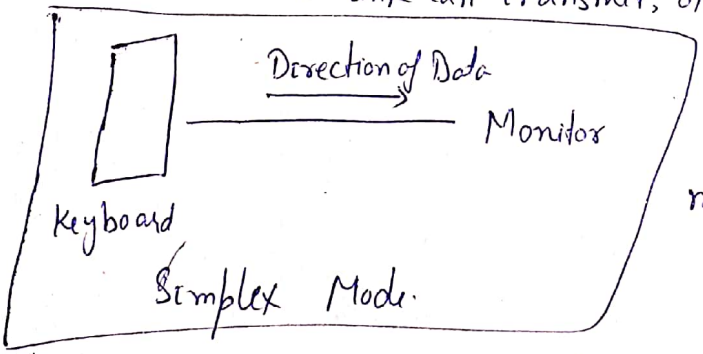
* Without a protocol, Two devices may be connected but not communicating Like, a person speaking French can't be understood by a person who speaks only Japanese.

⇒ Data Flow -

The Data can travel between Sender & Receiver in either one direction or both directions.

The communication b/w two devices can be
- ↳ Simplex
- ↳ Half-Duplex
- ↳ Full-Duplex.

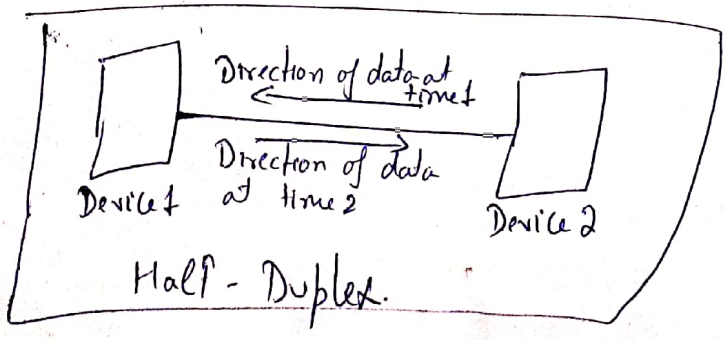
(1) Simplex - In this mode, communication is unidirectional. Only one of the two devices on a link can transmit; other can only receive.



e.g. Keyboard can only produce input for Monitor & monitor can only accept O/P.

The simplex mode can use the entire capacity of the channel to send data in one direction.

(2) Half-Duplex - In this mode, each sender & receiver device can send & receive data but not at the same time. When One device is sending, the other can only receive & vica-versa.



e.g. - Walkie-Talkies.

(3) Full-Duplex - In this mode, both devices can transmit & receive data at same time.
In this mode, signals going in one direction share the capacity of the link with signals going in the other direction.

Network - A N/w is a set of devices connected by communication links. A node can be a computer, printer, or any other device capable of sending & receiving data generated by other nodes on the N/w.
Efficiency of N/w is evaluated on the basis of various N/w criterias.
The main criterias are

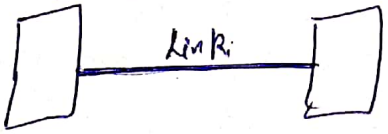
→ (1) Performance - The performance of N/w depends upon various factors like no. of users, type of transmission medium, capabilities of connected H/w & efficiency of S/w. Two parameters to measure performance are Throughput & delay.

→ Reliability → In addition to accuracy of delivery, N/w reliability is measured by
→ by frequency of failure
→ time it takes to recover from a failure
→ N/w's robustness.

→ Security
It includes the protection of data from unauthorized access
→ from damage & development.

⇒ Type of Connection :-
The devices in N/w are connected with each other through link.
Two type of connections are possible-

↳ Point-to-Point - when two devices are connected directly with the same link.

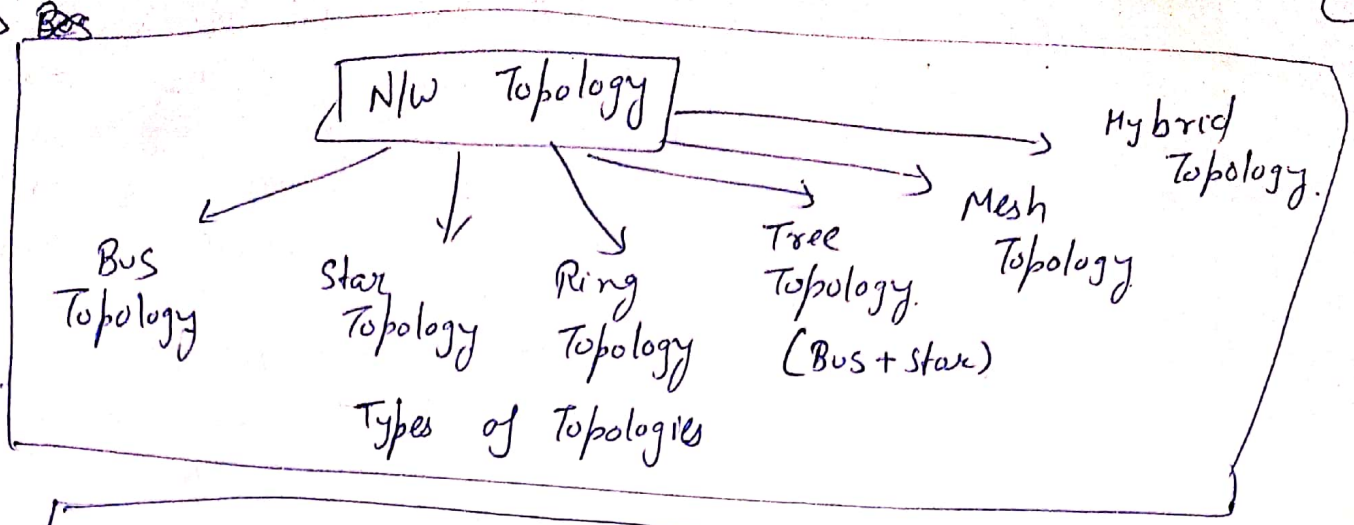


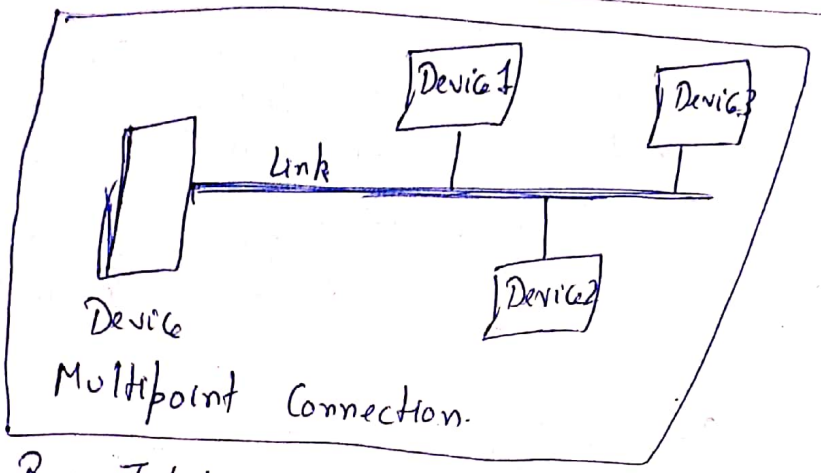
e.g. Remote Control & T.V's Control System link is point-to-point when you want to change channel

↳ Multipoint - In this more than two specific devices share a single link. The capacity of channel is shared.

The physical topology refers to the way in which a N/w is laid out physically. There are various topologies. like

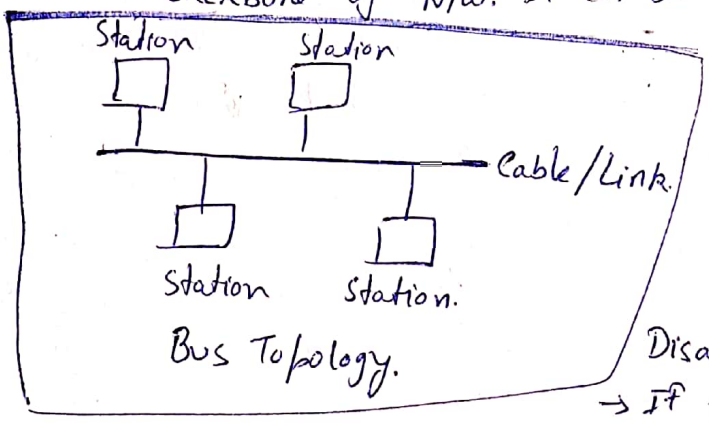
→ Bus





① Bus Topology –

In this topology all the devices are connected with a long cable which acts as a backbone of N/W. It can be used in LANs.



Advantages –

→ Easy Installation.
→ Works very efficiently for small N/W
→ It requires less cable length than other topologies.

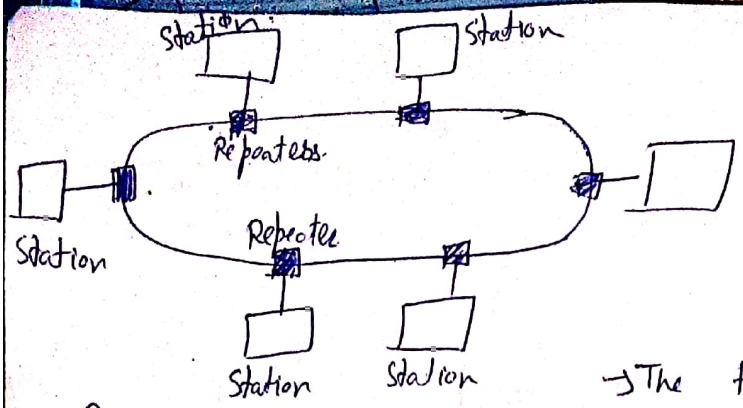
Disadvantages –

→ If there is a fault or break in Bus link, all transmissions will be interrupted.
→ Additional devices slow down the N/W.
→ Fault recognition is difficult.
→ Bus topology is not great for large N/Ws.

② 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.

It can be either used in LANs or WANs.



Ring Topology.

→ A free token is circulating on the ring. If any host want to send data it has to first capture the token, then writes the data and address of destination on the token.

→ The token can be sent to the next connected device, who will read the address if address is not of its own it will pass token to next hop.

→ The process is repeated until token reaches the destination

→ After receiving the data, the destination node will forward the Acknowledgement with the help of token & send to the Source.

→ After ACK, the token is released & circulated to the ring again.

Advantages

→ Failure is easy to detect.

→ Data transfer speed is high.

→ No centralized device required.

→ Additional Nodes can be added to N/w without impacting the performance of N/w.

Disadvantages

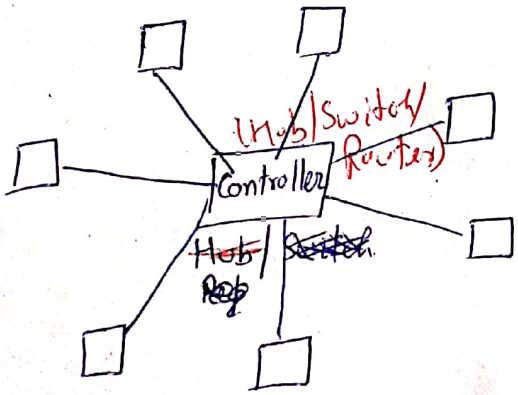
→ All data being transferred through each Node can make it slower than a Star topology.

→ The entire N/w will be impacted if one Node shuts down.

→ Adding & Removing Nodes disrupts the N/w.

→ Delay is directly proportional to the no. of nodes present in N/w.

(3.) Star Topology- Each node has a dedicated Point-to-Point link only to a central controller, called a Hub. The devices are not connected to each other directly. Use in LANs.



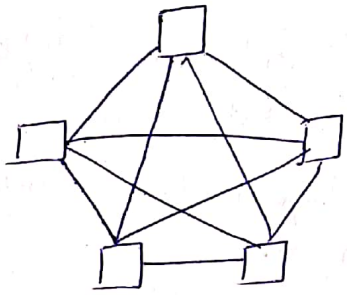
Every information is sent to the controller first & then controller passes the information to the destination.

In case of Hub, it broadcasts the message.

Advantages
→ Less expensive than Mesh topology.
→ Installation & Reconfiguration is easy.
→ Robustness. If one link fails, other N/W wouldn't be interrupted.
→ Easy fault detection.

Disadvantages
→ Whole N/W depends upon a single point, controller if it goes dow, whole system will be dead.
→ More expensive as compair to Bus topology.

(4) Mesh Topology - Every device has a dedicated Point-to-Point link to every other device.



Mesh Topology.

Advantages:
→ Robust.
→ Eliminates the traffic Problems.
→ Privacy & Security.
→ Fault detection is easy.

Disadvantages:
→ Cabling cost is more.
→ Installation & Configuration are difficult.

Categories of N/W.
→ LAN - Local Area N/W (within office, Building or Campus). Limited to few kilometers.
→ MAN - Metropolitan Area N/W (within a city or town.
→ WAN - Wide Area N/W (over long distance, like country, Continent or whole World ..)

Protocols → Protocol is a set of rules that govern the data communications. A protocol defines what is communicated, how it is communicated & when it is communicated.

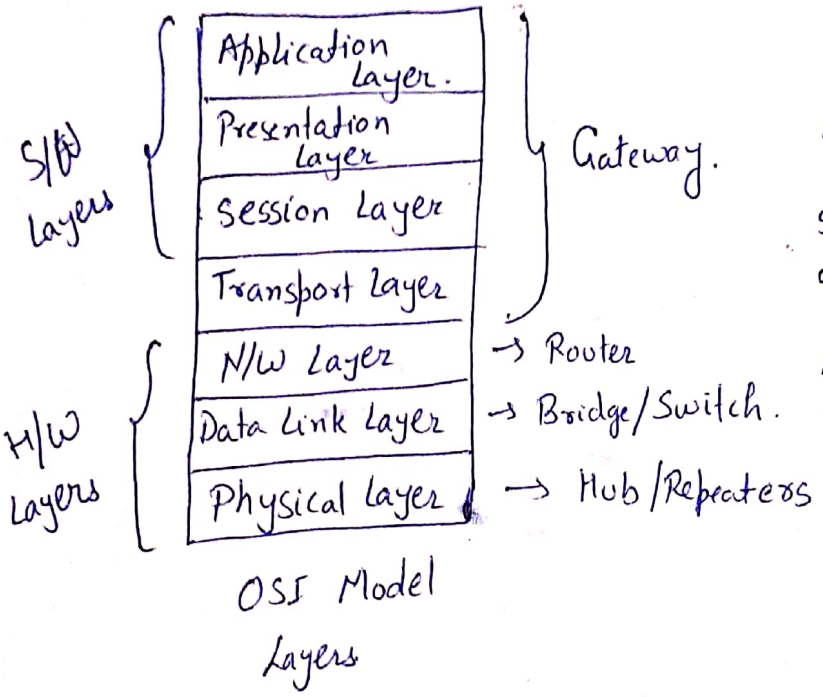
The key elements of a Protocol are
→ Syntax: The structure or format of data, meaning the order in which they are presented.
→ Semantics: It refers to the meaning of each section of Bits. How is a particular pattern to be interpreted & what action is to be taken

→ Timing — It refers to two characteristics: when data should be sent & how fast they can be sent.

⇒ OSI Model

Open Systems Interconnection Model. It is a layered framework for the design of N/w systems that allows communication b/w all types of computer systems.

It consists of 7 seperate but related layers, each of which defines a part of the process of moving information across a N/w.



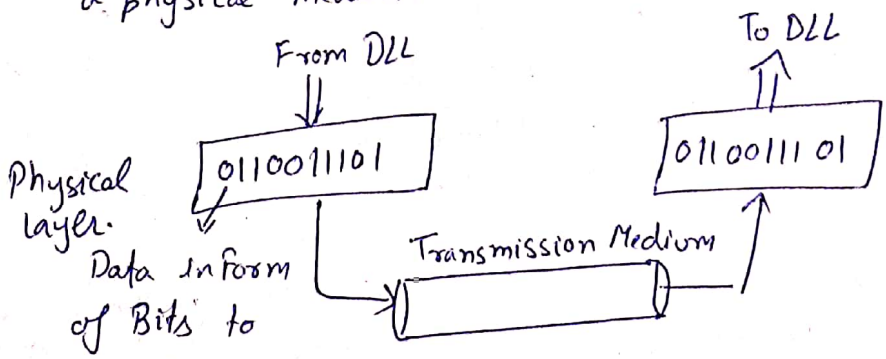
OSI Model Layers

Physical, DLL, N/w layer are N/w support layers.

Session, Presentation & Application are User support layers.

And Transport Layer links the two subgroups.

1.) Physical Layer - It deals with the transmission of bit stream over a physical medium.



Fxns or Responsibilities of Physical layer.

1.) It defines the transmission Medium.
It is a physical Path b/w Sender & Receiver.

Types of Transmission Medium

- Guided Media
  - Twisted Pair Cable
  - Coaxial Cable
  - Optical Fibre Cable
- UnGuided Media.
  - Radiowaves
  - Micro-waves
  - Infrared.

2) Representation of bits.

3) Data rate. - The transmission rate - the no. of bits sent each second. It defines the duration of bit, which is how long it lasts

4) Line Configuration → Point-to-Point Connection
→ Multipoint Connection.

5) Physical Topology. → Bus
→ Ring
→ Star
Mesh etc.

6) Transmission Mode
- Simplex
- Half-Duplex
- Full-Duplex.

⇒ Data link layer-

It is responsible for moving frames from one hop to another hop. Works on MAC address. Hop to Hop communication is there.

Fxns -

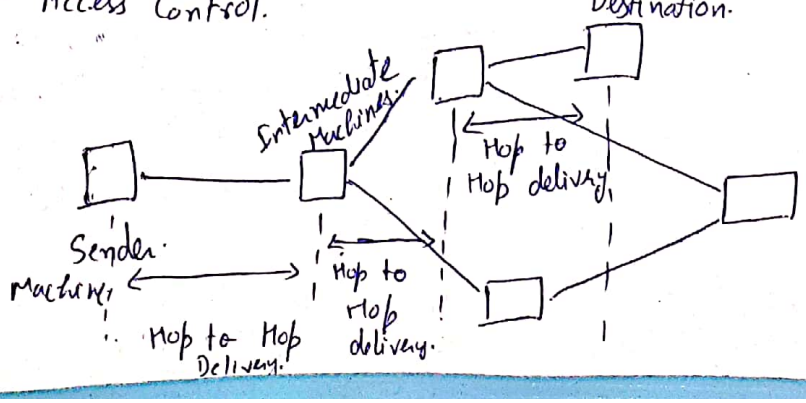
1) Framing - DLL divides the stream of bits received from the physical layer into manageable data units called frames

2) Physical Addressing - DLL adds a Header to the frame to define the sender & or receiver of the frame.

3) Flow Control. - Manage the rate of data transmission.

4) Error Control - works to detect the damaged frame while transmitting data from Machine. Sender to Reciever.
It may ~~ask~~ or may not ask for the retransmission of Damaged Packet.

5) Access Control.



⇒ N/w Layer - Responsible for Source to destination delivery of a packet across multiple N/Ws. End-to-End delivery of data is there.

↳ Logical Addressing

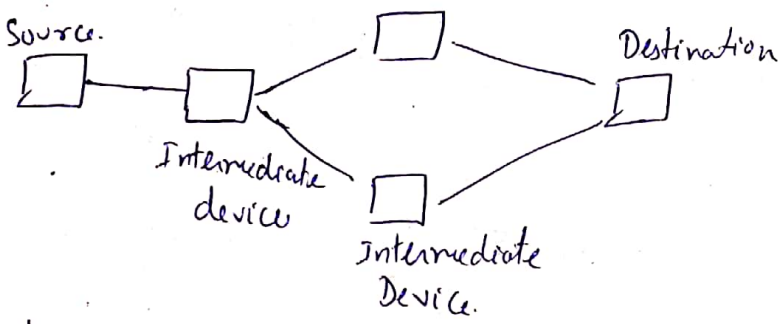
IP address is provided to each device if we want to communicate beyond the N/w.

IPv4, IPv6 addresses are there.

↳ Routing

To Pass or Route the data from Source to destination.

↳ DVRP
↳ OSPF
↳ RIP
↳ IGRP



End-to-End delivery. , Host-to-Host Communication.
or
Source-to-Destination delivery.

⇒ Transport Layer - Responsible for Process to Process Communication.
A Process is an application program running on a host.

Fxns -

↳ Service-Point Addressing. - Port Addressing.
↳ Segmentation & Reassembly -
↳ Connection Control ↳ Connection Oriented. - TCP
↳ Connectless. - UDP
↳ Flow Control - End to End rather than across a single link.
↳ Error Control - Process-to-Process Error control. Port to Port delivery helps to ensure the delivery of data to only to that Process to which it belongs

FTP-21 , SMTP-25
, HTTP-80
HTTPS-443
↳ SSL Layer used

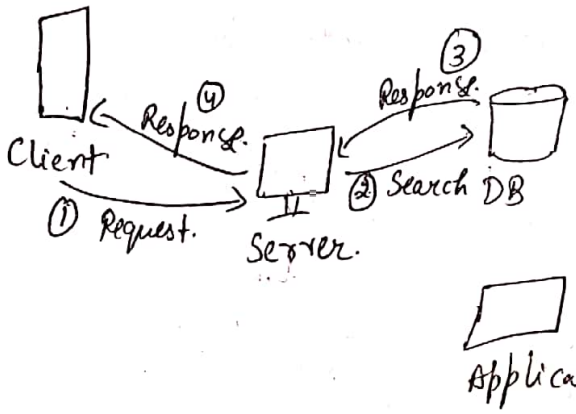
⇒ Session Layer - Responsible for Dialog Control. Communication will be either half-duplex or full Duplex mode.

Synchronization - allows a process to add checkpoints to a stream of data.
Suppose 1000 pages are to be send, checkpoint after 100 pages to ensure the correct receiving of data.

Presentation Layer – Concerned with the syntax & semantics of the information exchanged b/w two systems. Data is in the form of character or Number & convert to Machine level language (6)
It is responsible for translation, compression & encryption.
↳ for security.
Chrome → Firefox. ↳ compress the data

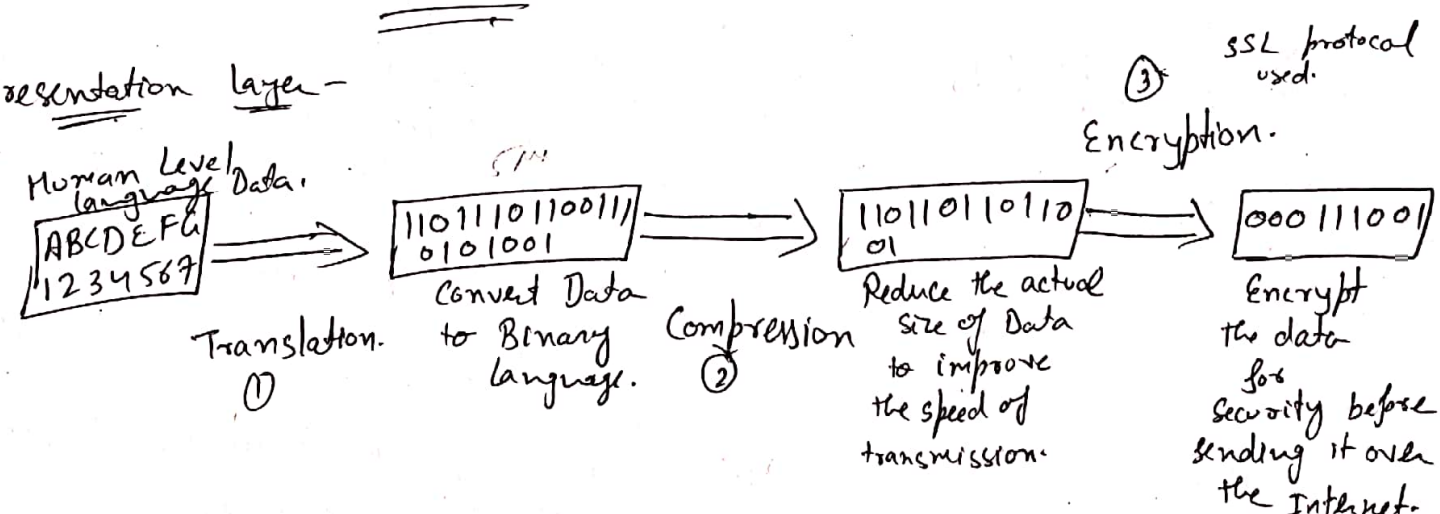
Application layer – responsible for providing services to user. It provides user interfaces & support for services such as email, remote file access & transfer and other types of distributed information services.
↳ File transfer, Access & Management. FTP HTTP, HTTPS
↳ Mail Services SMTP, POP
↳ Directory Services.
↳ Virtual Terminals (TELNET)
It allows the user to use the Internet or communicate over N/w.

The Application layer Programs are based on the client-Server Model.

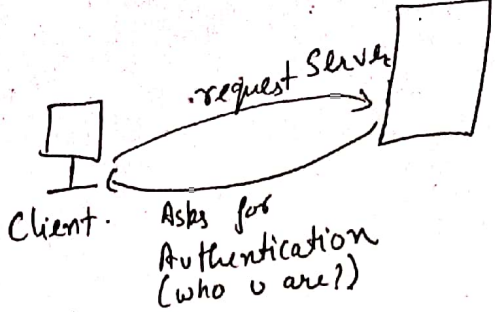


Applications of Application layer.
→ Email
→ WWW
→ Multimedia (Online)
→ Remote file transfer & Access (like Google Drive)

Presentation Layer –

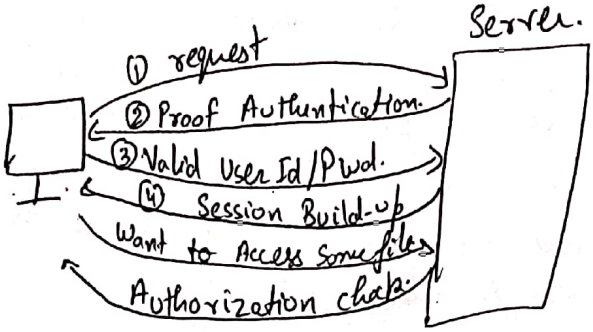


Session Layer – responsible for the comm. of app. on different systems. It helps us in setting up & managing connections & sending & receiving of information and also closing the connections & sessions.
NETBIOS is an e.g. of APIs which allows session setup, comm & termination of session.



Session Layer Fxns

1) Authentication.
2) Authorization.
3) Session Management.

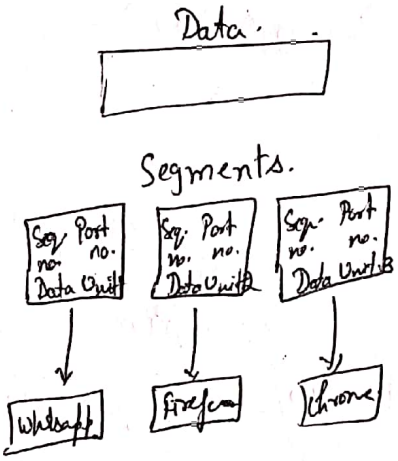


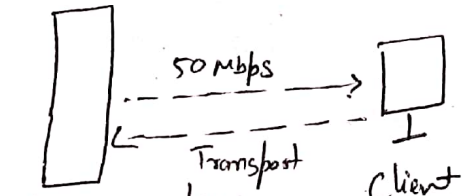
Transport Layer -

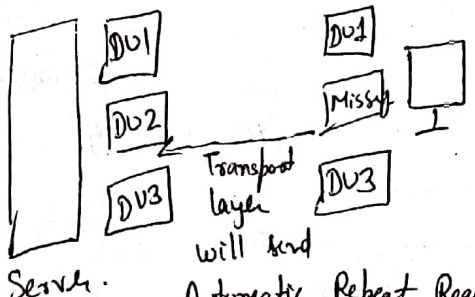
→ Segmentation
→ Flow Control
→ Error Control.

Protocols of TL.

↳ TCP – Connection Oriented, slow. Email, www.
↳ UDP – Connection less, fast, Online Streaming of Audio, Video.

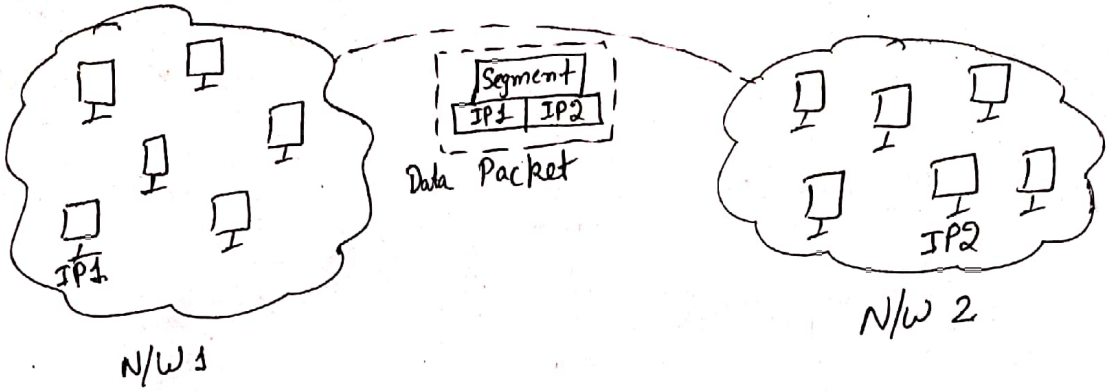






* Transport Layer for Error Control adds a grp of bits with each Data Unit to check/find the missing ~~corr~~ corrupted or damaged Data Unit.

N/W Layer -



→ Logical Addressing.

IPv4 IPv6.

unique address given to each PC for global identification

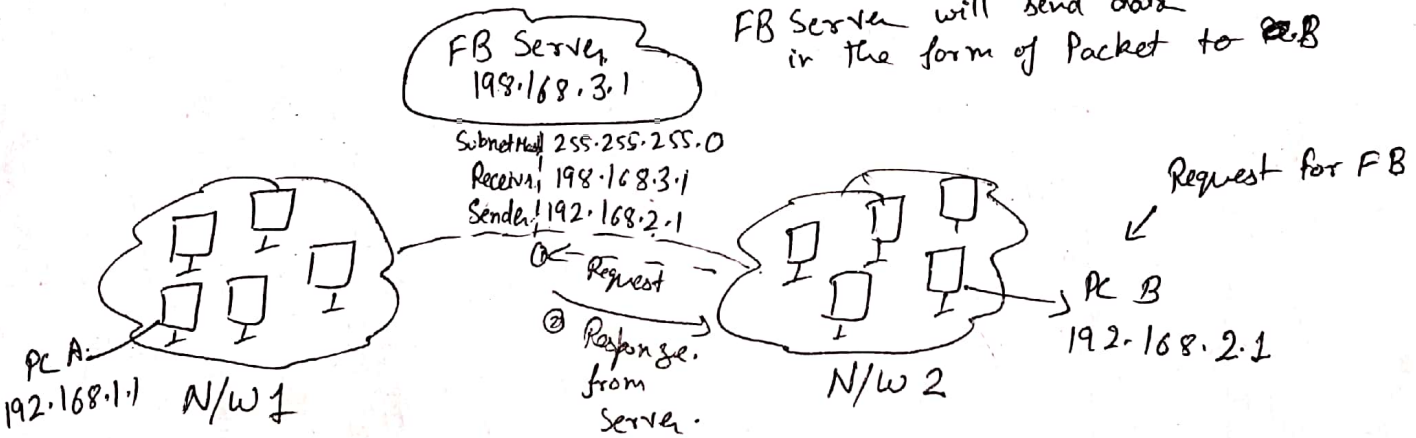
→ Routing.

It is based upon the logical address format to send the data Packet to correct destination.

→ Data determination.

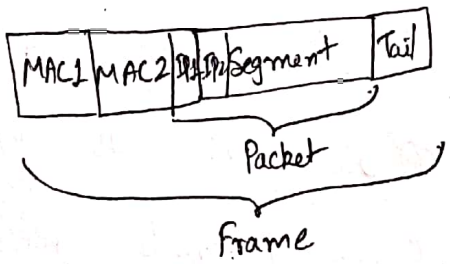
OSPF
BGP
IS-IS.

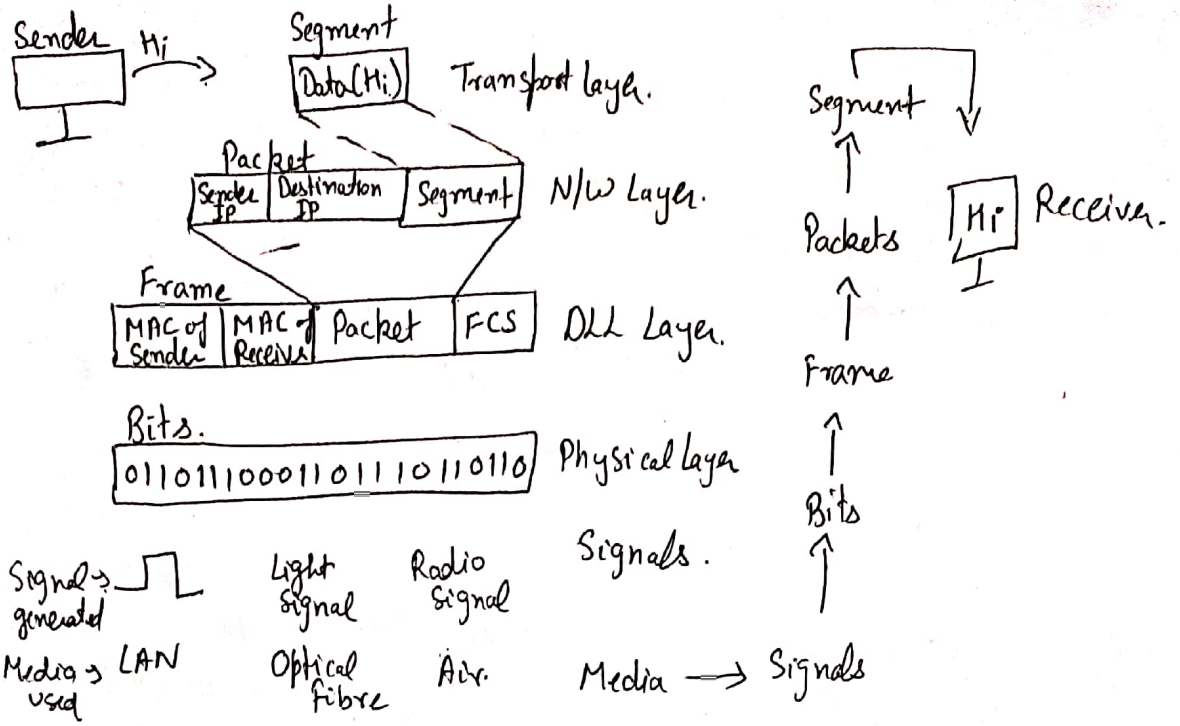
} To get best possible path to send data.



Routing.

DLL Layer.

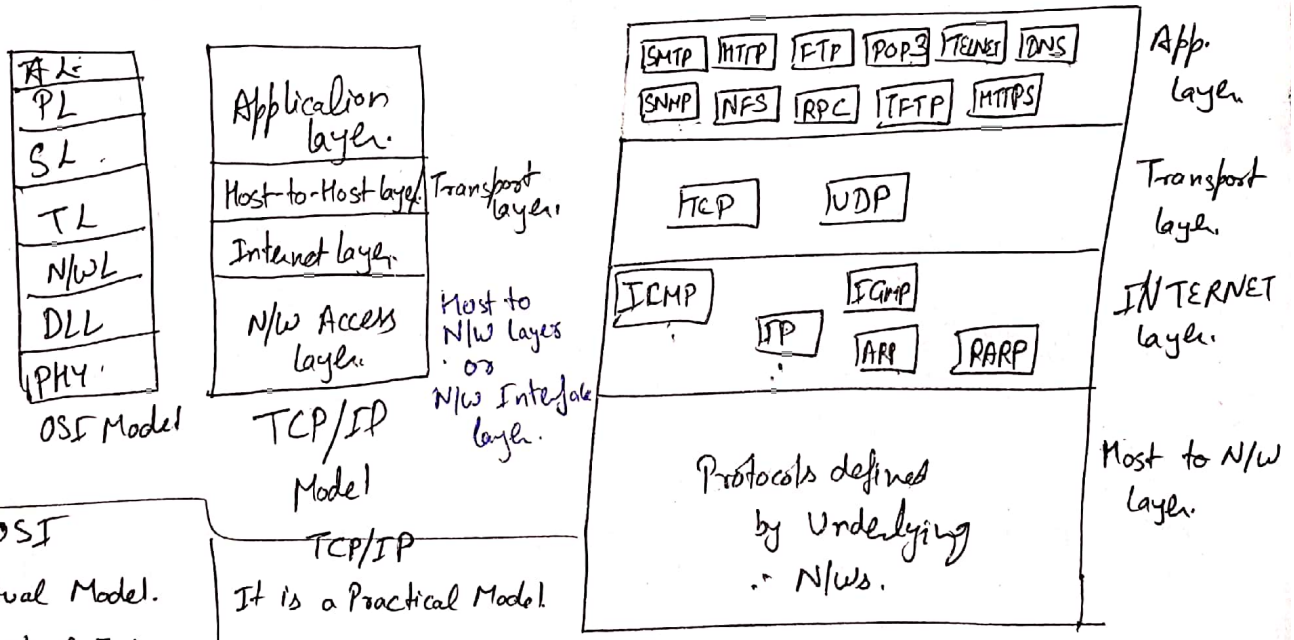




Transmission of Data from One device to Another.

TCP/IP Model

Transmission Control Protocol/Internet Protocol.



OSI	TCP/IP
① Conceptual Model.	It is a Practical Model.
2) It consist of 7 layers.	4 layer Model.
3) Developed by ISO. (International Standard Organization.)	Developed by ARPANET (Advanced Research Project Agency N/w).
4) OSI refers to Open Systems Interconnection.	4. TCP/IP refers to Transmission Control Protocol/Internet Protocol.
5) Uses N/w layer to define routing standards.	5. Uses Internet Layer.
6) Follows ~~Vertical~~ Horizontal Approach	6. It follows ~~Horizontal~~ vertical. ~~Approach~~.
7) Minimum size of OSI header is 5 byte.	7) The minimum header size is 20 bytes.

TCP/IP Protocol Suite.

⑧ OSI Model is less Reliable.	TCP/IP model is more reliable.
⑨ OSI Model provides both Connection & Connectionless services	TCP/IP provides Connectionless services through N/w layer.

protocols - ARP, RARP, ICMP & IGMP. TCP/IP - It is 4 layered Mode N/Wing model for communication. TCP handles the data transmission & IP handles addresses. It is mostly used for interconnecting computers over the internet.

IP - Internetworking Protocol

1) Host-to N/w Layer-
Acts as interface b/w hosts & transmission links & used for transmitting datagrams. Also specifies what operation must be performed by links like serial link & classic ethernet to fulfil the requirements of connectionless internet layer.

2) Internet Layer -
The purpose of this layer is to transmit an independent packet into any N/w which travels to the destination. Packet switching is used to send the data packet. It includes Internet Protocol (IP), ICMP (Internet ctrl Msg Protocol) ARP & RARP as standard Packet format for the layer.

3) Transport layer -
It enables a fault free end-to-end delivery of the data b/w the source to destination hosts in form of Datagrams.
The protocols defined by this layer are TCP & UDP.

4) App. layer - This layer permits users to access the services of global or private internet. Various protocols described in this layer are Virtual Terminal (TELNET), Electronic Mail (SMTP), File Transfer (FTP), HTTP (Hyper Text Transfer Protocol).
The working of this layer is a combination of App, Presentation & Session layer of OSI model.

TCP/IP is robust (assurety), flexible & more reliable as compare to OSI Model.
↓
ability of systems to cope with errors.

Data & Signals

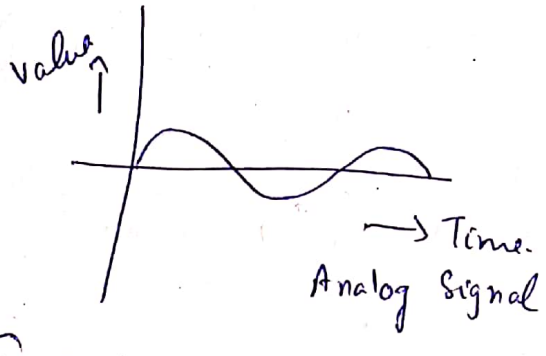
One of the major fun of Physical layer is to move data in the form of electromagnetic signals accross a transmission medium. To be transmitted data must be transformed to electromagnetic signals

→ Data can be Analog or digital.

Analog Data are continuous and take continuous values. Digital Data have discrete states and take discrete values.

(1) Analog Signal – It is a kind of continuous wave form that changes over time. An analog signal is described using 3 parameters.

- Amplitude :- It marks the maximum height of the signal. (measured in volts)
- Period or frequency – It marks the rate at which signal is changing
- Phase. – It marks the position of the wave with respect to time zero



Analog Signal

An Analog signal is not immune to noise, hence, it faces distortion & decrease the quality of transmission.

The range of value in an anlog signal is not fixed.

(2) Digital Signal –

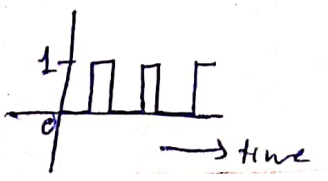
It is non-contiguous, discrete time signal. Digital signal carries information or data in the binary form i.e. a digital signal represent information in form of bits.

→ Digital Signal can be decomposed in simple sine waves. Each simple wave has diff. amplitude, frequence & Phase.

→ It is described with bit rate & bit interval. Bit interval describes the time require for sending a single bit.
Bit rate describes the frequency of bit interval.

→ A digital signal is more immune to the noise; hence it hardly faces the distortion.

→ Easier to transmit & more reliable when compared to Analog signals

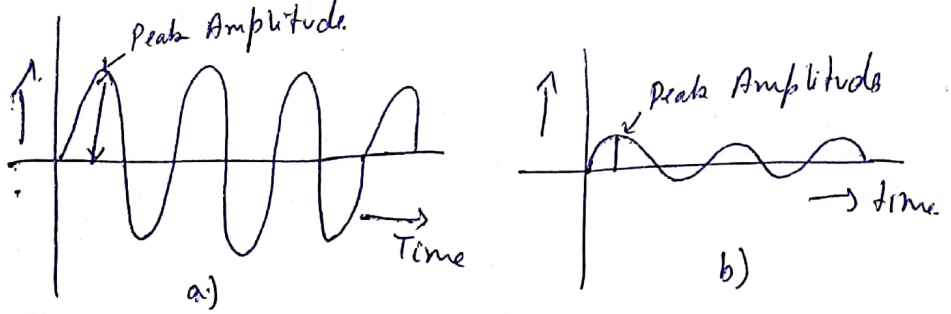


Diff. b/w Analog & Digital Signal.

Analog Signal	Digital Signal
1) An Analog Signal is a continuous wave that changes over a time period.	1) A Digital signal is a discrete wave that carries information in binary form.
2) It is represented by a Sine wave.	2. It is represented by square wave
3) It is described by the amplitude, frequency & Phase.	3. It is described by the bit rate & bit intervals.
4) Analog signal has no fixed range.	4. Digital signal has a finite no.s i.e. 0 & 1.
5) Data or Orignal Signal can be corrupted easily.	5. Orignal Signal's chances of corruption are very low.
6) Transmit data in the form of wave.	6. It carries data in the binary form i.e. 0 & 1.
7. e.g. - Human Voice.	7. e.g. Signals used for transmission in a computer are the digital signals

Analog Signal Parameters

1) Peak Amplitude - it is a absolute value of its highest intensity, proportional to the energy it carries



Two signals with same phase & frequency bt diff. amplitudes

2) Period & Frequency -

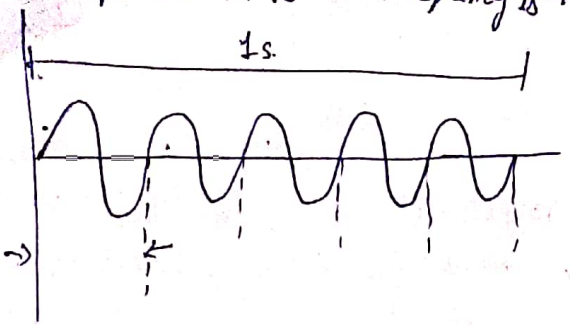
Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.

Frequency refers to the no. of periods in 1s.

Frequency & period are the inverse of each other.

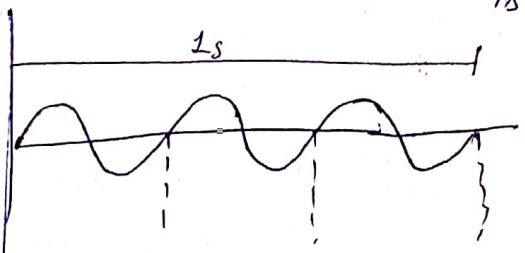
$$f = \frac{1}{T} \quad \& \quad T = \frac{1}{f}$$

5 periods in 1s → Frequency is 12Hz



$P = \frac{1}{5}$ s

3 periods in 1s → Frequency is 3Hz



$P = \frac{1}{3}$ s

If a signal doesn't change at all, its Frequency is zero. If a signal changes instantaneously, its frequency is infinite

Units of Period & Frequency

Period		Frequency	
Seconds (s)	1s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	KiloHertz (kHz)	10^3 Hz
Microseconds (μs)	10^{-6} s	MegaHertz (MHz)	10^6 Hz
Nanoseconds (ns)	10^{-9} s	GigaHertz (GHz)	10^9 Hz
Picoseconds (ps)	10^{-12} s	TeraHertz (THz)	10^{12} Hz

Q → Express Period of 100 ms in μs.

→ 1 ms ⇒ 10^{-3} s

100 ms = 100×10^{-3} s

= $10^2 \times 10^{-3}$ s

= 10^{-1} s

To convert it to μs as we know

1 μs = 10^{-6} s. ⇒ So, 1s = 10^6 μs.

~~not so, multiply 10^{-1} s with 10^{-6} s~~

10^{-1} s = $10^{-1} \times 10^6$ μs.

= 10^5 μs.

Q.2 For following frequency, calculate corresponding periods

1) 24 Hz Ans → 0.24 s

2) 8 MHz → 0.8 μs

3) 140 kHz. → 7.14 μs

Q3. For given periods, calculate frequ

1) 5s → for 0.2Hz ⇒ 220 ns.

2) 12 μs

Q.) The period of a signal is 100 ms. What is its frequency in kHz.

$F = \frac{1}{P}$; ~~so ⇒ F = 100~~

P = 100 ms ⟶ convert to secons.

100×10^{-3} s = 10^{-1} s.

$f = \frac{1}{P}$ Hz = $\frac{1}{10^{-1}}$ Hz ⇒ 10 Hz. to convert it to kHz ⇒ 10^3 Hz

⇒ 1 kHz = 10^3 Hz ⇒ 1 Hz = 10^{-3} kHz

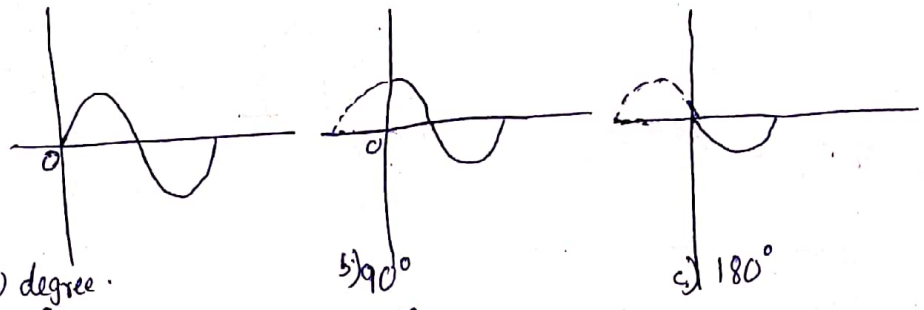
10 Hz = 10×10^{-3} kHz

= 10^{-2} kHz

Ans

Phase – It describes the position of the waveform relative to time 0. It indicates the status of the first cycle.

* 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.



a) 0 degree. b) 90° c) 180°

Sine wave with diff. Phases.

1) A sine wave with phase of 0° is not shifted.

2) A sine wave with phase 90° is shifted to the left by 1/4 th cycle. It means like that the signal does not really exist before time 0.

3) A sine wave with phase 180° is shifted to left by 1/2 cycle.

Phase can be measured in degree or radian.

360° = 2π radian

1° = $\frac{2\pi}{360°}$ radian

1 radian = $\frac{360°}{2\pi}$

Q. A sine wave is offset 1/6 cycle with respect to time 0. What is its phase in degree & radian?

⇒ We know 1 ~~cycle~~ completed cycle is 360°.

So, 1/6 cycle = $\frac{1}{6} \times 360°$

= 60°

In radian.

1° = $\frac{2\pi}{360°}$ radians.

60° = $\frac{2\pi}{360} \times 60$ radian.

= 1.046 radian ✓

Wavelength –

The wavelength is the distance a simple signal can travel in one period.

Wavelength = $\frac{\text{Propagation Speed (Light speed)}}{\text{frequency.}}$

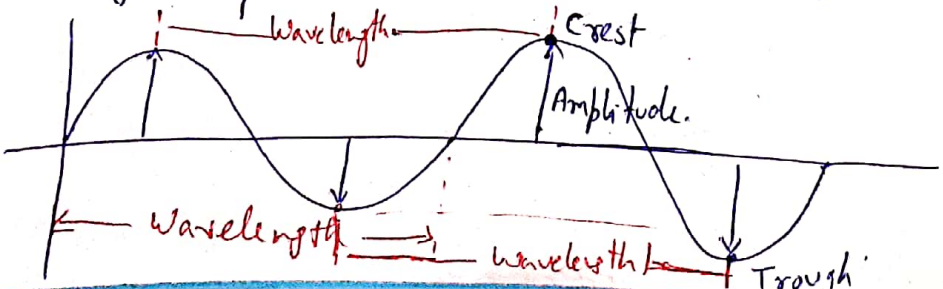
or

Light Speed × period

⇒ ~~Bandwidth~~.-

Wavelength is a property of any type of signal. In data communications we often use wavelength to describe the transmission of light in an optical fibre.

Wavelength depends on both the frequency & the medium.

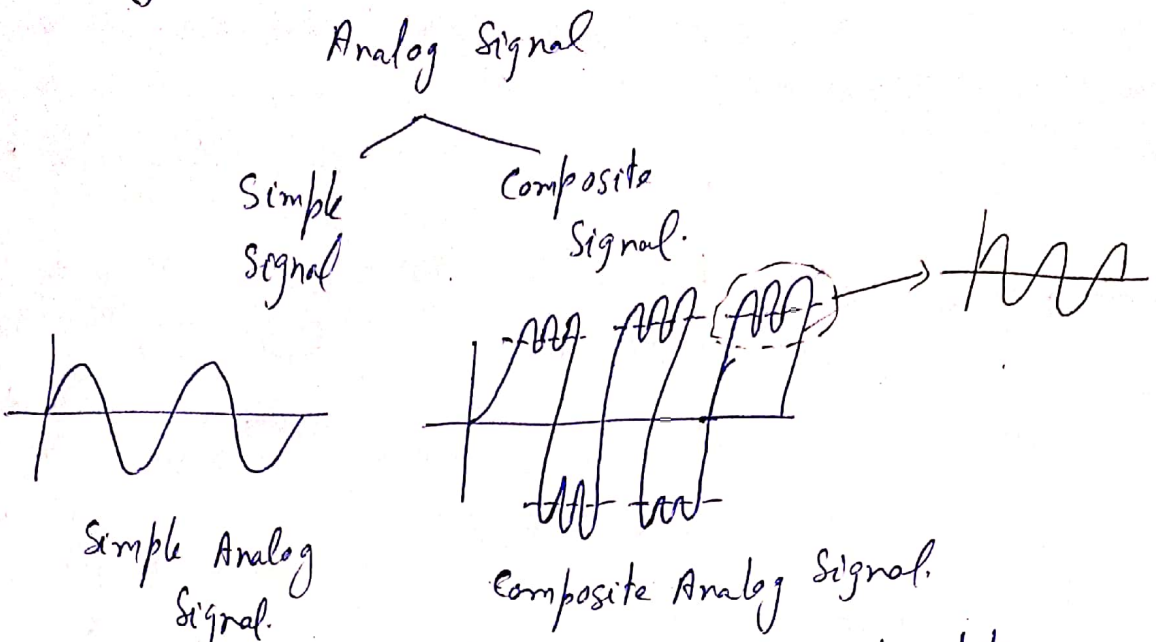


Wavelength is represented by λ.

Propagation Speed by C i.e. Speed of light.

$\lambda = \frac{c}{f}$

Analog Signal can be classified as Simple or Composite Signal



→ Used for distributing electric energy to houses & businesses

→ A Single Sine wave is sent.

→ Used to communicate data.

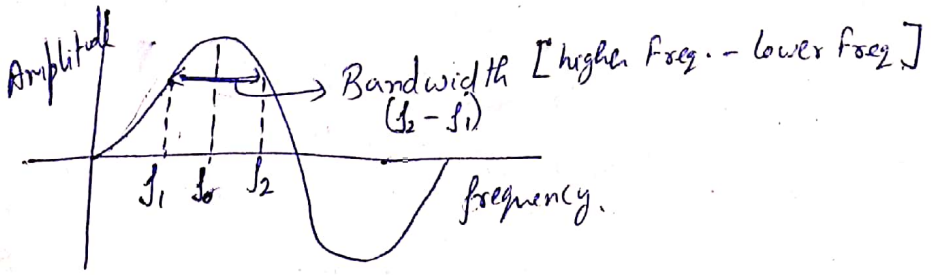
→ A composite signal is made of many simple sine waves

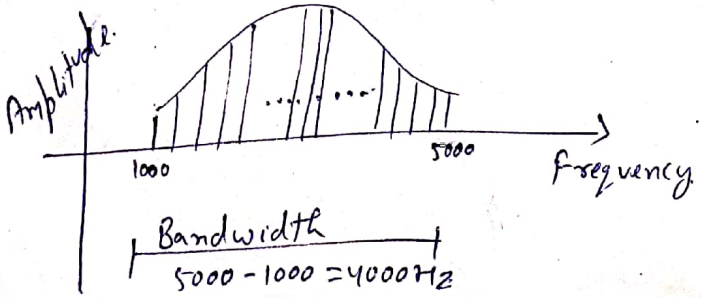
⟹ Bandwidth –

The Bandwidth of a composite signal is the difference b/w the highest and the lowest frequencies contained in that signal. In other words, It is a frequency range over which a signal can expand itself. It can be measured as $B = f_h - f_l$ Unit of Bandwidth is Hertz (Hz)

Bandwidth = Higher Frequency – Lower Frequency.

A Signal with zero bandwidth has zero information.





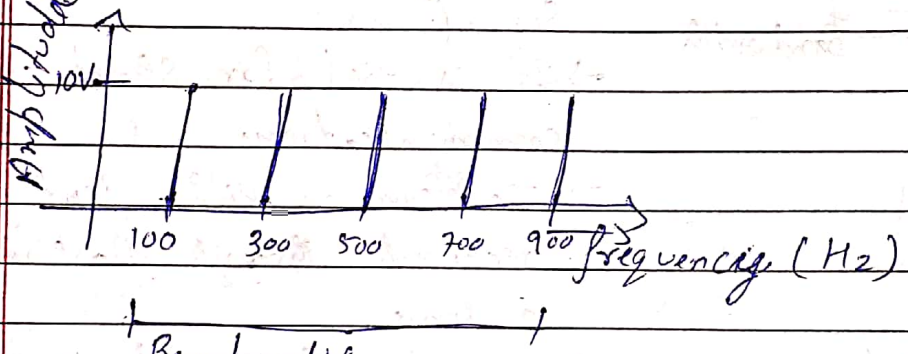
Q.) If a period signal is decomposed into 5 sine waves with frequencies of 100, 300, 500, 700 & 900 Hz. What is its Bandwidth. & Draw the spectrum, assuming all components have a max amplitude of 10 V.

=> Higher Frequency (f_H) = 900
lower Frequency (f_L) = 100

Bandwidth (B) = $F_H - f_L$

= 900 - 100 = 800Hz

The spectrum having these frequecies is.



900 - 100 = 800Hz.

Q. A period signal has Bandwidth of 20Hz. The highest frequency is 60Hz. Find the lowest Frequency.

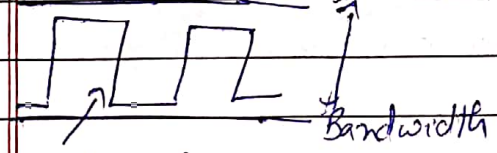
=> B = 20Hz.
f_H = 60Hz.

=> $B = f_H - f_L$
=> $20 = 60 - f_L$
=> $f_L = 60 - 20 = 40Hz$. Ans

The electromagnetic Band can in Bandwidth can be used in 2 different ways :-

→ Baseband transmission
→ Broadband transmission

Baseband - It uses the whole capacity to send one signal of information. It is used in Ethernet connection or in LAN. The signal is transmitted over the channel without changing the digital signal to an analog signal.

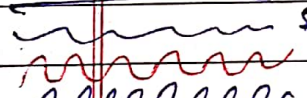


One Signal transmission.

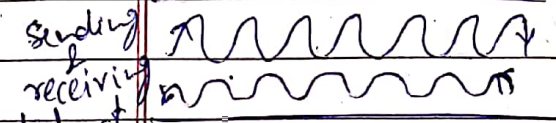
→ It is used for short distance communication.
→ The data can be either sent or received through Baseband at a time.

Broad Band -

It uses the modulation to convert the digital signal to analog signal before sending it over the transmission medium. The multiple signals can be transmitted at the same time.



→ This transmission is used for long distance communication like in Radio & T.V.
→ It uses the high frequency rates to transmit the signals.
→ Broadband allow to send and receive the signals at same time.



Broadband transmission.

Transmission Impairment

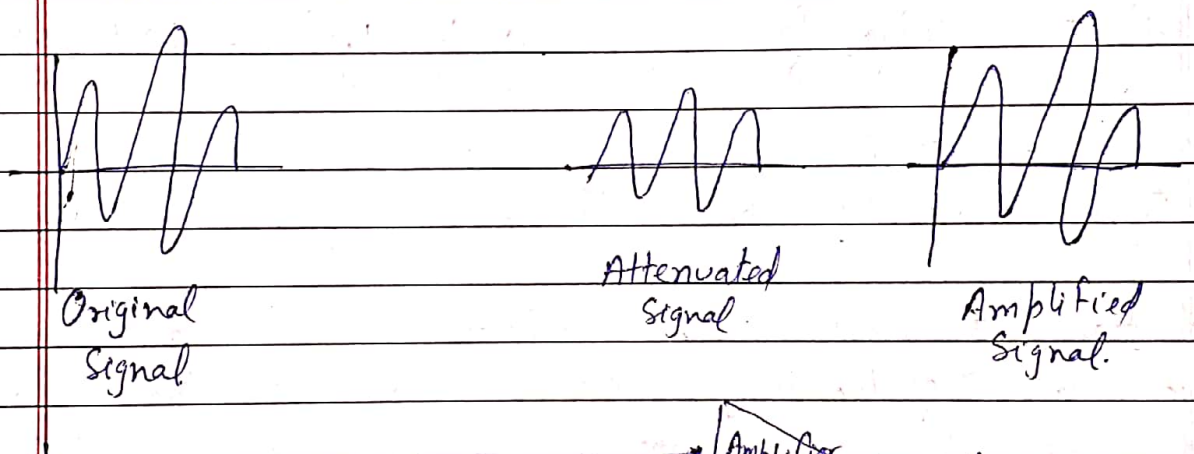
Signals travel through transmission medium which are not perfect. The imperfection causes the signal impairment. This means that the signal at the beginning of medium is not the same as the signal at the end of the medium.

The types of impairment are

→ Attenuation
→ Distortion
→ Noise.

① Attenuation - It means the loss of energy. When a signal travels through a medium, it losses some of its energy in overcoming the resistance of the medium. The signal strength is reduced during the transmission.

It is measured in Decibles (dB).



→ Amplifier is used to amplify the signal.

→ The decibel (dB) measures the strengths of the signals at two different points.

If the dB is -ve it means that the signal is attenuated i.e signal has lost some energy.

If the dB is +ve it means that the signal is amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

Q. Suppose a signal travels through a transmission medium & its power is reduced to One-half. Attenuation will be?

$\Rightarrow P_2 = \frac{1}{2} P_1$

$\Rightarrow dB = 10 \log_{10} \frac{P_2}{P_1}$

$= 10 \log_{10} \frac{\frac{1}{2} P_1}{P_1} \Rightarrow 10 \log_{10} 0.5$

$\Rightarrow 10(-0.3) = -3dB.$

Attenuation is $-3dB$.

Q. A Signal travels through an amplifier & its power is Ted to 10 times. What is the amplification?

$P_2 = 10P_1$

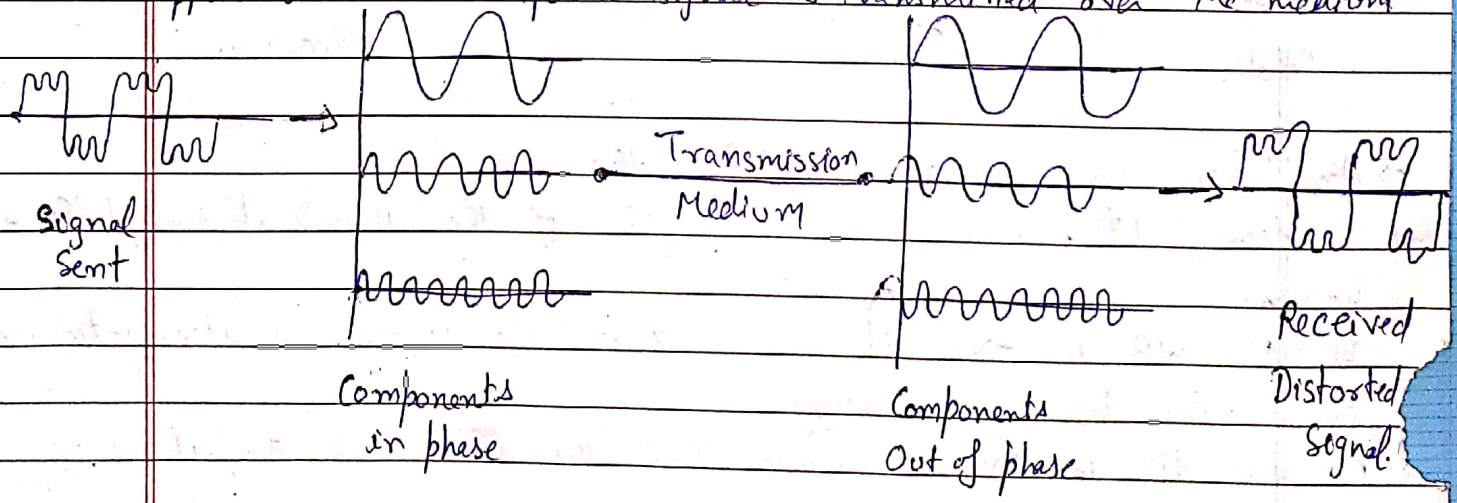
$dB \Rightarrow 10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{10P_1}{P_1} = 10 \log_{10} 10$

$= 10dB.$

Signal Amplified by 10dB.

(2) Distortion – It means that the signal changes its form or shape. The alteration of the orignal signal is known as the distortion. This may happen due to the properties of the medium.

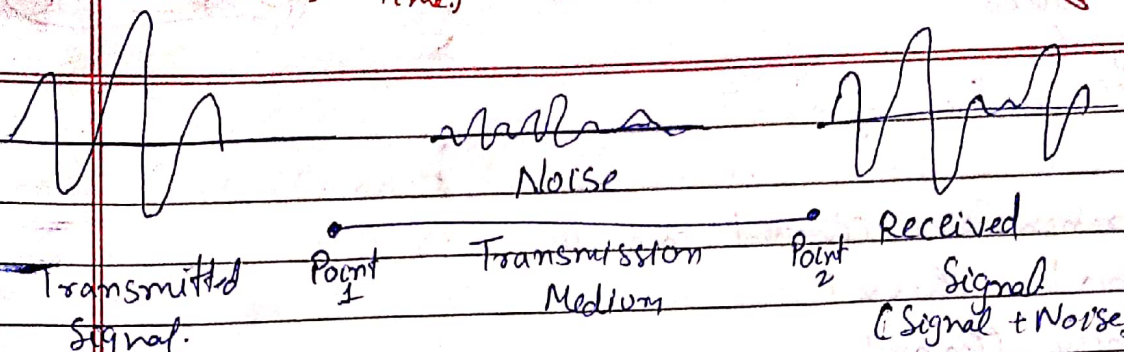
→ It happens when a composite signal is transmitted over the medium



(3) Noise – Noise is an external random signal added to the orignal signal.

It is an unwanted signal that interferes with the communication of another signal. Several types of noise, such as thermal noise, (Random motion of electrons in wire) induced

motors & appliances)
Noise, crosstalk & impulse noise, may corrupt the signal.
(effect of one wire over other) (a signal with high energy in a very short time)



Signal to Noise Ratio (SNR) is the ratio to know how much the signal is corrupted by the unwanted noise.
The SNR is defined as -

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

* High SNR means Signal is less corrupted by Noise.
→ Low SNR means signal is highly corrupted by Noise.

Bcoz SNR is the ratio of two powers, it is often described in decibel units. SNR_{dB} defined as:

$$SNR_{dB} = 10 \log_{10} SNR$$

Q) The power of signal is 10 mW & the power of noise is 1 μW. What are the values of SNR & SNR_{dB}?

$$SNR = \frac{10\,mW}{1\,\mu W}$$

$$= \frac{10\,mW}{1/1000\,mW}$$

$$= 10 \times 1000 = 10{,}000$$

$1\,mW = 1000\,\mu W$
$\Rightarrow 1\,\mu W = \frac{1}{1000}\,mW$

$$SNR_{dB} = 10 \log_{10} SNR = 10 \log 10{,}000 \Rightarrow 10 \log 10^4$$

$$= 40 \text{ dB}$$

* The SNR & SNR_{dB} for noiseless channel are

$$SNR = \frac{\text{Signal Power}}{0} = \infty \; ; \; SNR_{dB} = 10 \log_{10} 0 = \infty$$

⇒ Data Rate Limits -

The Data rate depends on three factors:

1.) Bandwidth available.

2.) ~~Level of Signal~~

3.) Quality of Channel [level of Noise]

The Transmission Channel can be

→ Noiseless Channel

→ Noisy Channel

For Noiseless Channel Nyquist Bit Rate formula is defined to get the maximum bit rate theoretically. Bit rate = 2 x Bandwidth.

Bit rate = 2 x Bandwidth x $\log_2 L$

where L is no. of levels of digital Signal.

Q If Given Bandwidth B = 3100, GHz ; then Max. Bit rate will be

2 * Bandwidth

2 * 3100 = 6200 bps.

Q If a noiseless channel have Bandwidth of 3000 Hz transmitting a signal with 2 signal levels. The max. Bit rate will be

→ Max. Bit rate = $2 * B * \log_2 L$

B = 3000 Hz

L = 2

⇒ BitRate = $2 * 3000 * \log_2 2$ = 6000 bps.

Q. If we need to send 265 kbps over noiseless channel with Bandwidth of 20 kHz. How many signal levels do we need?

⇒ Bit rate = $2 * B * \log_2 L$

$265 = 2 * 20 * 10^3 * \log_2 L$

$\Rightarrow \log_2 L = \frac{265}{2 * 20 * 10^3} \Rightarrow \log_2 L = 6.625$

$L = 2^{6.625} = 98.7$ levels

Since result is not a power of 2. So we need either to ↑ the no. of levels

or reduce the bit rate.
like if we have 128 levels → Bit rate will be 280 kbps
if 64 levels → Bit rate will be 240 bbps

⇒ For Noisy Channel : Shannon Capacity.

In reality we don't have noiseless channel, the channel is always noisy. So, to determine the max. Bit rate for noisy channel we have Shannon Capacity.

Capacity = Bandwidth * $\log_2(1+SNR)$

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

Q.) Bandwidth allocated is 3000Hz. SNR ratio is 3162. The capacity of channel can be calculated as

$= B * \log(1+SNR)$
$= 3000 * \log(1+3162) = 3000 \log_2 3163 = 3000 \times 11.62$
$= 34,860$ bps

* The Shannon Capacity Gives us the upper limit; the Nyquist formula tells us how many signal levels we need.

⇒ Performance

The N/W's performance can be measured on the basis of various parameters.

→ Bandwidth : The no. of bits per second that a channel can transmit.
→ Throughput : Measure of how fast we can actually send data through N/W.
→ Latency : how long it takes for an entire msg to completely arrives at the destination from the time the first bit is sent.

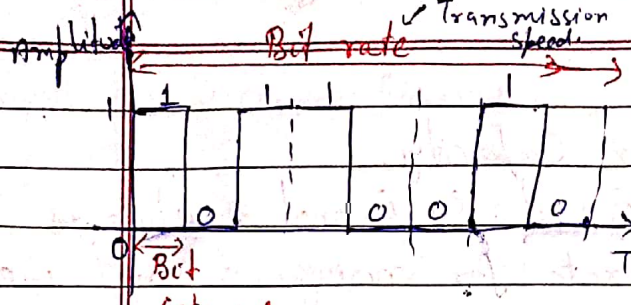
Latency = Propagation time + transmission time + Queuing time + Processing delay.

→ Jitter :- Different delays encountered by data packets.

⇒ Digital Signal Parameters
→ Bit rate
→ Baud rate.
→ Bit Interval.

Bit rate - It is the number of bits transmitted per second.

Baud rate - It is the rate at which signals can change. In other words, the no. of signal unit per second that are required to represent those bits.

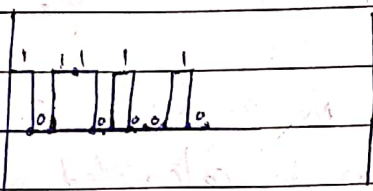


Bit interval - time taken to send one single bit.

* Bit rate is equal to Baud rate times the no. of bits represented by each signal unit.

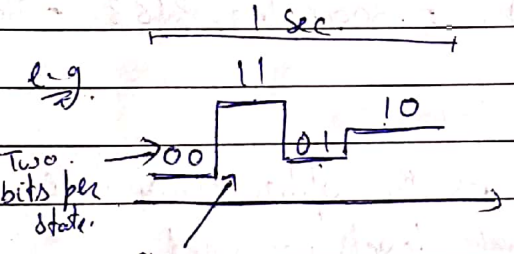
Bit rate ≥ Baud rate.

Bit interval = 1 / Bit rate



Bit rate = 10 bps. Baud rate = 08

Baud rate = 10. Bit rate = 16 bps.



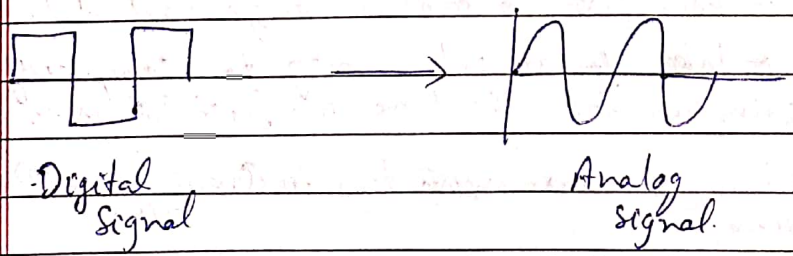
Bit rate = 8 bps.

Baud rate = 4

Four signals are required to send 8 bits.

⇒ Digital to Analog Conversion [DAC]

A process of changing the digital signal to the analog signal.



As we have three properties of an analog signal - Amplitude, frequency & phase, we can create a different version of that wave if we vary anyone of these features.

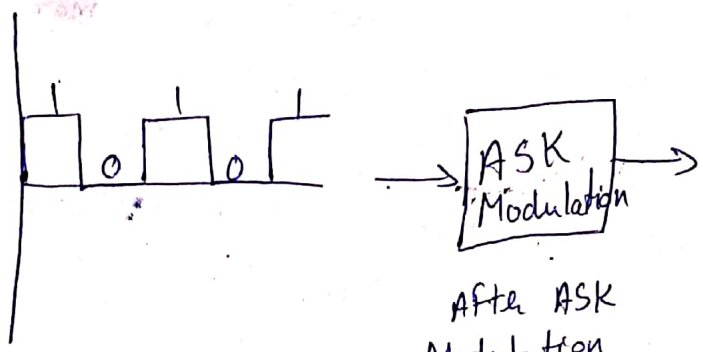
The modulation techniques used for DAC are -

1.) Amplitude Shift Keying 2.) Frequency Shift Keying

3.) Phase Shift Keying. 4.) Quadrature Amplitude Modulation.

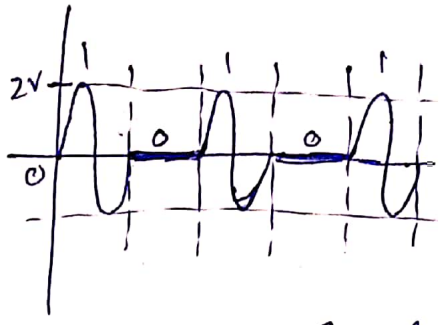
① Amplitude Shift Keying (ASK)

→ The amplitude of the carrier signal is varied to create signal elements.
→ The frequency & Phase remain constant while the amplitude changes.
→ ASK is normaly implemented using only 2 levels. This is referred to as binary amplitude shift Keying or On-off Keying (OOK).
→ The ~~frequency~~ amplitude of one signal level is 0;
The other is the same as the amplitude of the carrier frequency.



Data bits to transmit in Digital form are 1 0 1 0 1

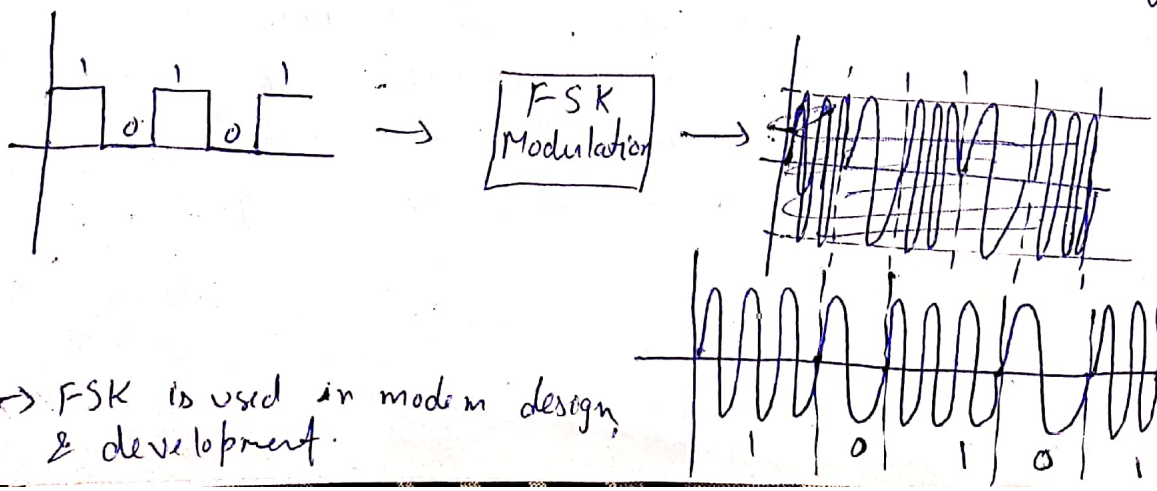
After ASK Modulation at Modulator the Amplitude of '0' bit will be 0 & Amplitude of 1 will be same as the carrier frequency



Analog Signal After ASK Modulation

2.) Frequency Shift Keying (FSK)

In this, the frequency of signal is varied to represent bit 1 or 0.
→ Both Peak Amplitude & Phase remain constant.
→ Two diff. frequencies are used to carrier 0 & 1 bit. Suppose we have f_1 & f_2 frequencies. So.
↳ for transmitting '0' bit we will use 'f_1' frequency.
↳ for transmitting '1' bit we will use 'f_2' frequency.



Analog Signal After FSK.

→ FSK is used in modem design & development.

3.) Phase Shift Keying (PSK)

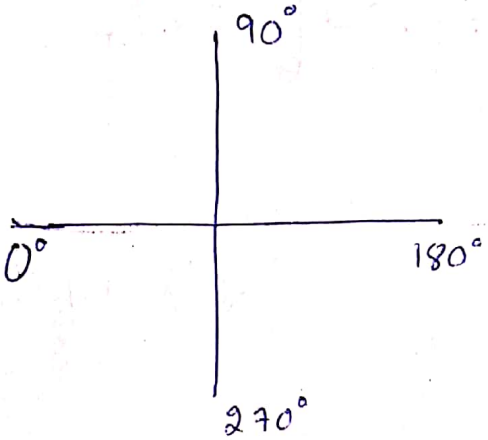
→ The Phase of the carrier is varried to represent two or more diff. signal elements.

→ Both Peak Amplitude & frequence remain constant.

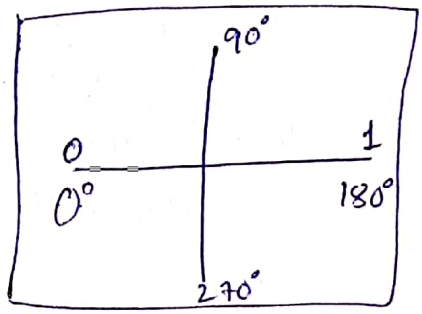
→ Most commonly used modulation technique as compare to ASK & FSK.

PSK ↘ Binary PSK - Two Phases are used to represent the both bits 0 & 1.

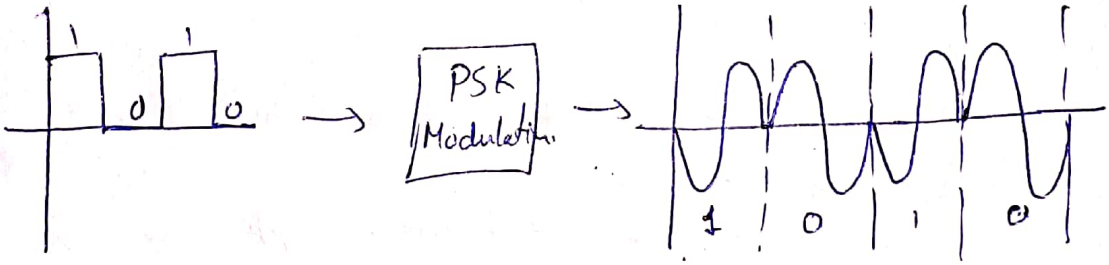
↘ Quadrature PSK - More than two Phases are used to represent the bits if we want to send more than 1 bit in single signal.



If we are using Binary PSK, then we will use two Phases 0° & 180° to represent bit '0' & '1' respectively.



0's Phase → 0°
1's Phase → 180°
in BPSK



Digital Signal

PSK Modulator

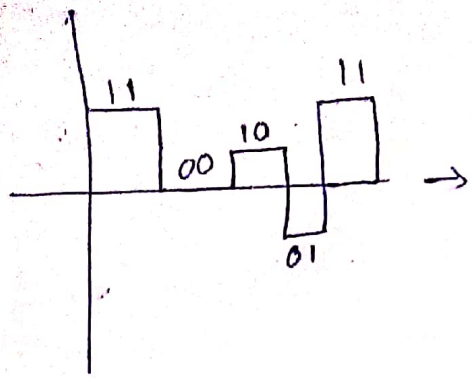
Phase of bit 1 → 180°
Phase of bit 0 → 0°

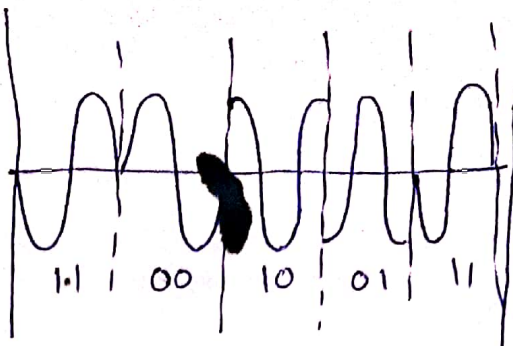
Analog Signal After PSK Modulation

→ PSK modulation is widely used in wireless transmission.

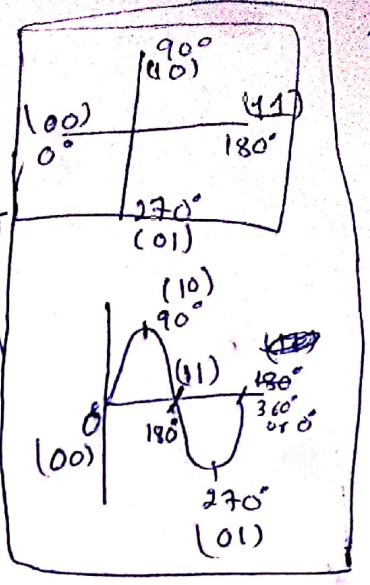
→ Probability of error in PSK is less. SNR value is high.

⇒ If we want to transmit more that one bit on one signal then we have Quadrature PSK.





After Quadrature Modulation



⇒ Diff. b/w ASK, FSK & PSK

Parameters	ASK	FSK	PSK
1) Noise immunity.	Low	High	High
2) Complexity.	Simple	Moderate	Very Complex.
3) Error Probability.	High	Low	Low
4) Performance in presence of Noise.	Poor	Better than ASK	Better the FSK
5) Bit rate	upto 100 bps.	Upto 1200 bps	for high bit rates