Unit - 1

Introduction Concepts

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Data Communication:

Data refers to the information presented in whatever form is agreed upon by the parties creating and using the data. Communication means sharing of information.

Telecommunication which includes telephony, telegraphy, television means communication at a distance. 'Tele' is a greek word for 'far'.

Data communication are the exchange of data between two devices via some form of transmission medium such as a wire cable. For data communication to occur, the communicating devices must be part of a communication system made up of a combination of hardware and software.

Characteristics of effective data communication:

The effective of data communication system depends on four fundamental characteristics:

1) Delivery:

The system must deliver the data to the correct destination. The data must be received by the intended device or user and only by that device or user.

2) Accuracy:

The system must deliver the data accurately without any error or alteration.

3) Timelyness:

The system must deliver the data in a timely manner. Data deliver late are useless.

4) Jitter:

It refers to the variation in the packet arrival time. It is the uneven delay in the delivery of audio or video packets.

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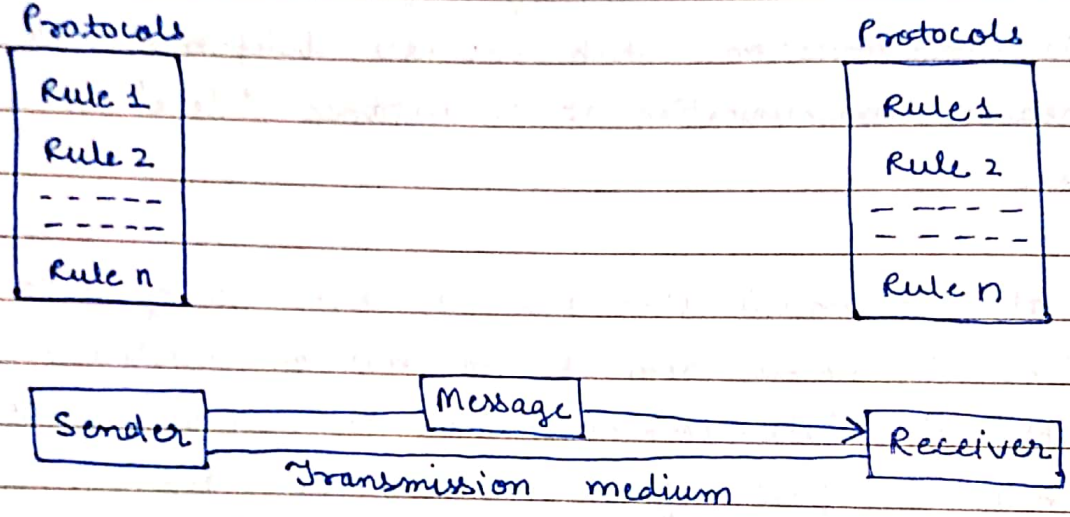
Jitter should be minimum for effective data communi

Components of data Communication system:



A data communication system have five components:

1) Message:

It is the information or the data to be communicated. Message can be text, picture, audio or video etc.

2) Sender:

It is the device that sends the message. for ex- computer, workstation, telephone, video camera.

3) Receiver:

It is the device that receives the message. for ex- computer, workstation, telephone, television.

4) Transmission medium:

It is the physical path by which a message travels from sender to receiver.

Ex- wired
a) twisted pair cable
b) co-axial cable
c) fibre optics cable

& wireless
a) Radio waves
b) micro waves
c) Infrared waves

5) Protocol:

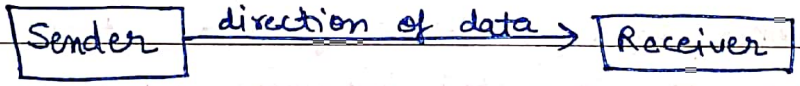
It is a set of rules that govern the data communication. It is an agreement between communicating devices.

Data flow or Modes of data communication:

Communication between two devices can be
1) Simplex 2) Half duplex 3) Duplex

1) Simplex

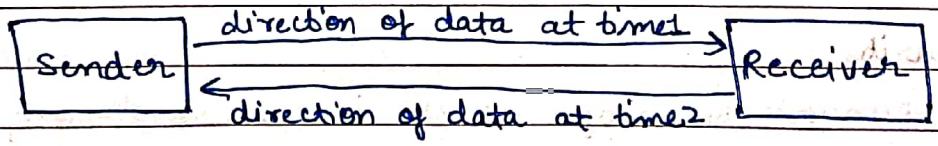
In this mode, the communication between sender and receiver occurs in only one direction. The sender can only send the data and the receiver can only receive the data. The receiver cannot reply to the sender.



Ex- Radio and television system can only transmit.

2) Half duplex

The communication between sender and receives occurs in both directions in half duplex transmission, but only one at a time. The sender and receiver can both send and receive the information, but only one is allowed to send at any given time.

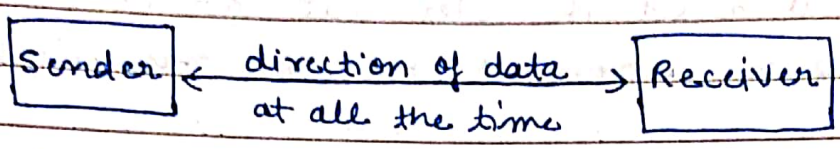


Ex- Walkie-Talkie

3) Duplex

The communication between sender and receiver can occur simultaneously. The sender and receiver can both transmit

and receives at the same time.



Ex- Mobile phone

Network: is a set of devices connected by communication link. A device can be a computer, printer or any other device capable of sending and receiving data generated by other nodes on the network.

Network Criteria:

1) Performance:

It can be measured in many ways such as transit time, response time, number of users, transmission medium, capabilities of connected hardware, efficiency of software. Performance is often evaluated by two network matrices: throughput and delay (time).

2) Reliability:

Network reliability is measured by frequency of failure, the time it takes a link to recover from failure and the network robustness in a catastrophe.

3) Security:

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

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Physical Structure or Types of Connection:

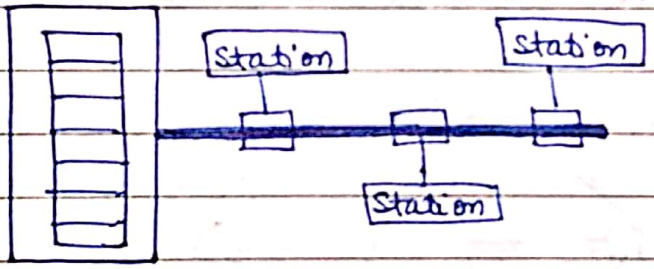
1) Point to Point Connection (P2P):

This provides a dedicated link between two devices. The entire capacity of link is reserved for transmission between two devices.

2) Multipoint (multidrop) connection:

It is one in which more than two specific devices share a single link. The capacity of the channel is shared either spatially or temporarily.

If several devices can use the link simultaneously then it is spatially shared connection and if users must take turns then it is time shared or temporarily shared connection.



Physical Topology

It refers to the way in which a network is laid out physically. Two or more devices connect to a link, two or more links form a topology.

There are four basic topologies:

1) Mesh topology
2) Star topology
3) Ring topology
4) Bus topology

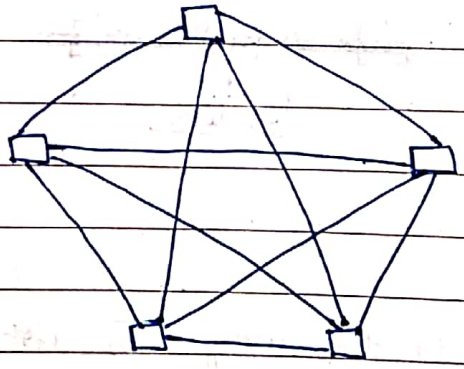
1) Mesh topology:

In this topology, every devices has a dedicated point to point connection or link to every other device. In this topology, we need $n*(n-1)/2$ duplex mode links to connect n devices and every device on the network must have $(n-1)$ input / output ports.

Advantages: 1) Eliminating the traffic problem.
2) Advantage of privacy & security.
3) fault identification & fault isolation is easy.
4) This is robust i.e. if any link fail then entire system don't stop.

Disadvantages: 1) Amount of cabling in number of I/O ports
2) Expensive hardware.

Ex: connection of telephone regional offices in which each regional office needs to be connected to every other regional office.



2) Star topology:

It is mostly used topology. In this topology, each device has a dedicated point to point link only to a central controller usually called a hub. The controller acts as an exchange. If one device wants to send data to the other device, then it sends the data to the controller, which they relays the data to the other connected devices.

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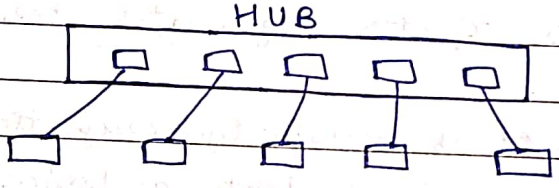
Advantages: 1) Easy to install and reconfigure
2) Addition, move and deletion involve only one connection between that device & hub.
3) Less expensive than mesh topology.
4) Far less cabling needed.
5) It is robust.
6) Easy fault identification and fault isolation.

Disadvantage: The dependency of whole topology is one single point the hub. If the hub goes down, then the whole system dead.

Ex- Ethernet.

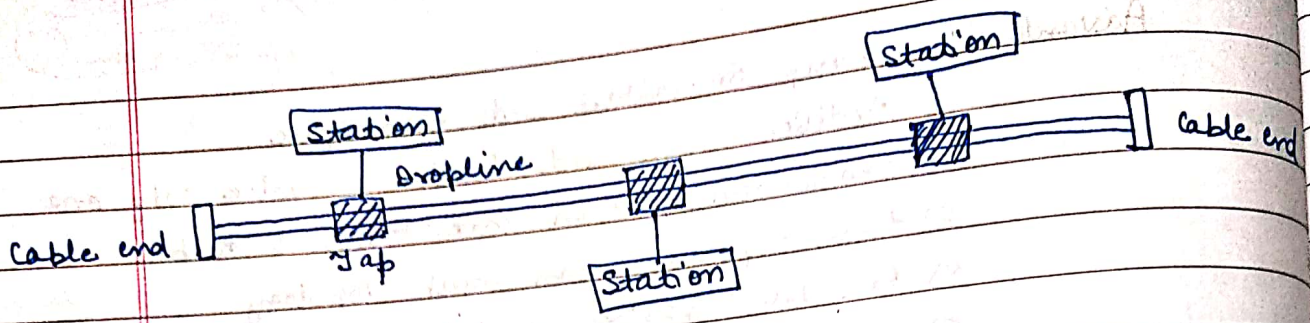


3) Bus Topology:

It is multipoint one long cable acts as a backbone to link all the devices in a network. Nodes are connected to the bus cable by the dropline and tap. A dropline is the connection running between the device and main cable. A tap is a connector that splices in to the main cable to create contact with metallic part. As a signal travels along the backbone some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it travels further & further. For this reason, there is a limit on the number of taps a bus can support and on the distance between two taps.

Advantage: 1) Easy of installation
2) Require less wire than mesh topology.

Disadvantage: 1) Difficult fault isolation.
2) Difficult to reconnect.
3) A fault or break in the bus cable stops all transmission.



4) Ring topology

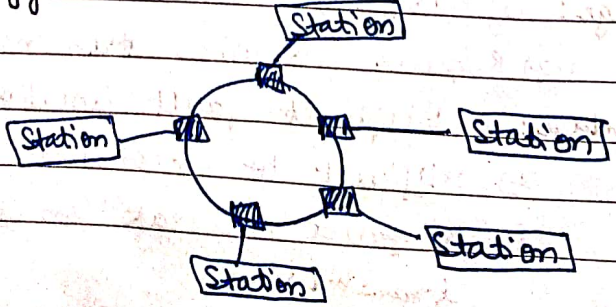
Each device has a dedicated point to point connection with only the two devices on either side of it. A signal is passed along the ring in one direction from device to device until it reaches its destination. Each device in a ring incorporates a repeater. When a device receives a signal intended for other device, its repeater regenerates the bits and passes them along.

Advantages: 1) It is relatively easy to install & recovery.
2) To add or delete a device, requires changing in only two connections.
3) Fault isolation is simplified.

Disadvantage: 1) In a simple ring, a break in the ring can disable the entire network.
2) Unidirectional traffic is a major disadvantage.

Ex- Token ring

	No. of links	I/O ports per node
Mesh topology	$n(n-1)/2$	$(n-1)$
Star topology	n	1
Bus topology	n	1
Ring topology	n	1



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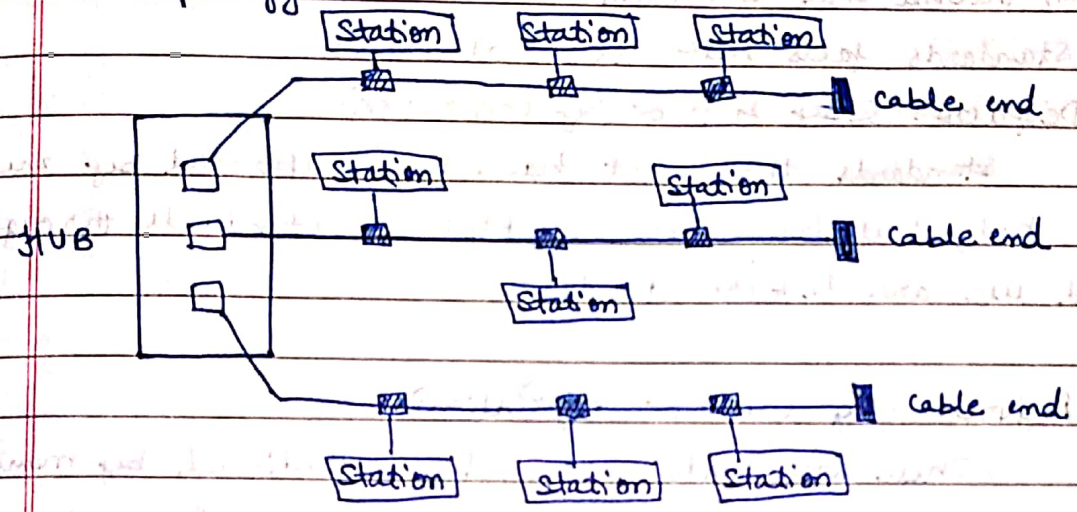
Hybrid topology:

A network can be hybrid. for ex- we can have a main star topology with each branch connecting several stations in a bus topology.



Protocol: is a set of rules that governs data communication. A protocol defines what is communicated, how it is communicated and when it is communicated. It represents the agreement between communicating devices. The key elements of a protocol are syntax, semantics & timing.

1) **Syntax:** refers to the structure & format of the data i.e. the order in which they are presented.

2) **Semantics:** refers to the meaning of each section of bits. How is a particular pattern to be interpreted & what action is to be taken based on that interpretation.

3) **Timing:** refers to the two characteristics:
   a) when data to be send.
   b) how fast data can be send.

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Standards: provides guidelines to manufacturers, vendors, government agencies and other service providers to ensure the kind of interconnectivity necessary in today's market place and in international communication.

Standards falls into two categories:

1) De facto: (By fact or by convection)

Standards that not have been approved by any organized body but have been adopted as standards through widespread use are de facto standards.

These standards are often established by manufacturers whose seeks to define the functionality and technology of new product.

2) Dejure: (By laws or regulations)

Standards that have been legislative by an officially recognized body are de jure standards.

Computer Network:

Can be defined as a collection of nodes. A node can be any device capable of transmitting and receiving data. The communicating nodes have to be connected by communication links. Categories of network are categorized on the basis of their size.

The three basic categories of computer networks are:

1) Local Area Network (LAN):

A LAN is a computer network that interconnects computer within a limited area such as a residence, school, laboratory, university campus or office building.

(2) Metropolitan Area Network (MAN):

A MAN is a computer network that interconnects users with computer resources in a geographic region of the size of a metropolitan area.

(3) Wide Area Network (WAN):

A WAN is a telecommunication network that extends over a large geographical area for the primary purpose of computer networking.

Goals of Network:

1) Cost reduction by sharing hardware and software resources.
2) High reliability by having multiple sources of supply.
3) Greater flexibility because of possibility to connect devices.
4) Increase productivity by making it easier to access data by the several users.
5) Computer networks provide a powerful communication medium.

Network Models:

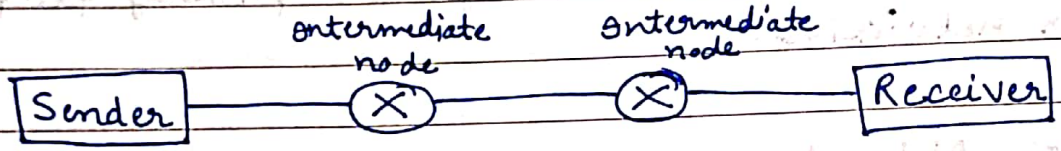
(1) OSI model:

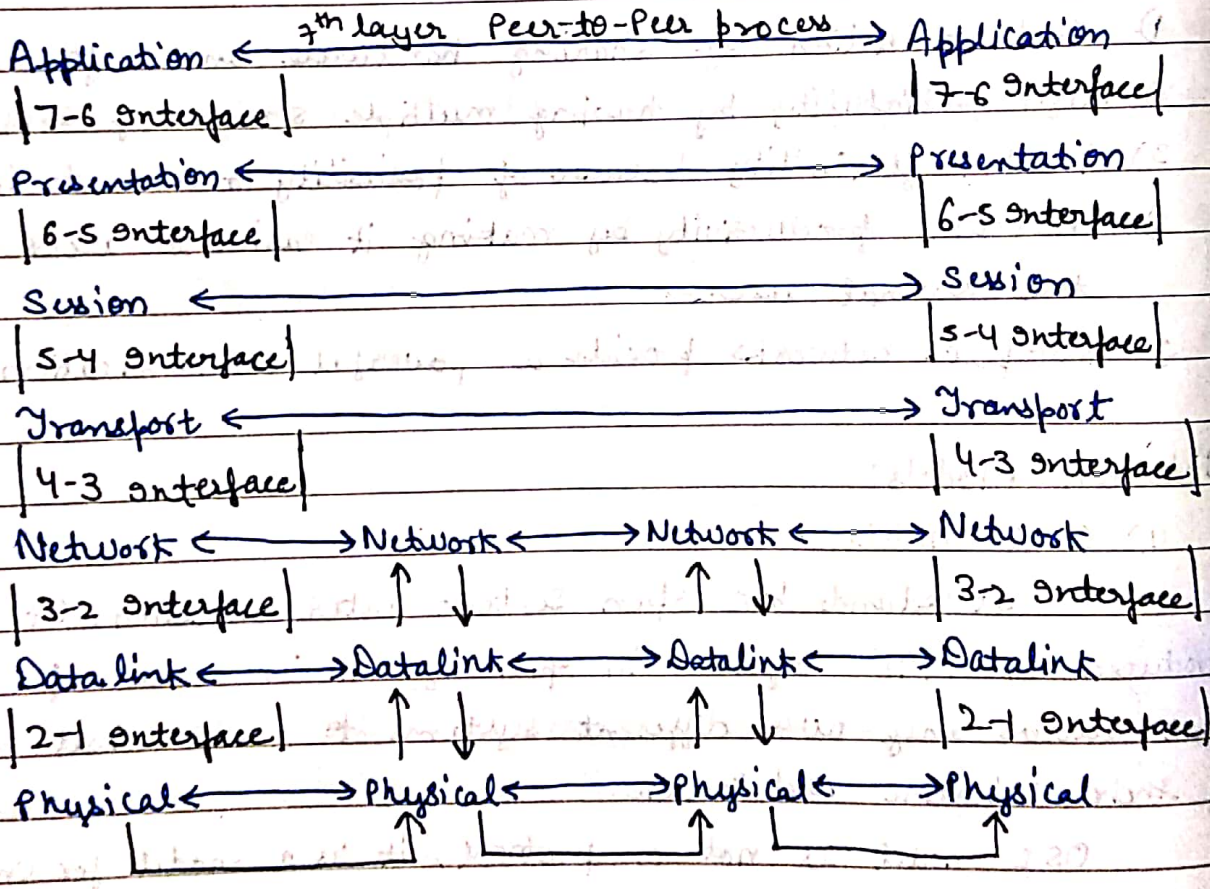
It stands for open System Interconnection. It was introduced in 1970 by ISO. An open system is a set of protocols that allows any two different systems to communicate regardless of their underline architecture.

OSI model is not a protocol, it is a model for understanding and designing a network architecture. OSI model is a layered framework for the designing of network system that allows communication between all types of computer system.

It consist of seven separated layers, but related layers each of which defines a process of moving information across the network.

1) Physical layer
2) Datalink layer
3) Network layer
4) Transport layer
5) Session layer
6) Presentation layer
7) Application layer





This figure is about the interaction between the layers of OSI model.
1) Within a single machine, each layer calls upon the services of the layers just below it. Between machine, layer x on machine 1 communicate with only layer x on another machine.

2) This communication is governed by protocols. The processes on each machine that communicates at a given layer are called peer-to-peer process.

3) The passing of the network information & data down through layers of the sending device (top to bottom) & backup through the layers of the receiving device (bottom to top) is made possible by an interface between each pair of adjacent layers.

4) Each interface defines the information & services that a layer must provide for the layer above it.

Organisation of layer:

The seven layers can be grouped into three sub-groups:

Layer 1, 2 & 3: Physical, data link and network layer are network support layers. They deal with the physical aspects of moving data from one device to another device.

Layer 4: Transport layer links above two sub-groups and ensures that what the lower layer have transmitted in a form that upper layer can ~~record~~ used it.

Layer 5, 6 & 7: Session, presentation & application are upper support layers. They deal with the interoperable team among unrelated software system.

User support layer are fully software & network support layer are combination of software & hardware in which physical layer is totally hardware layer.

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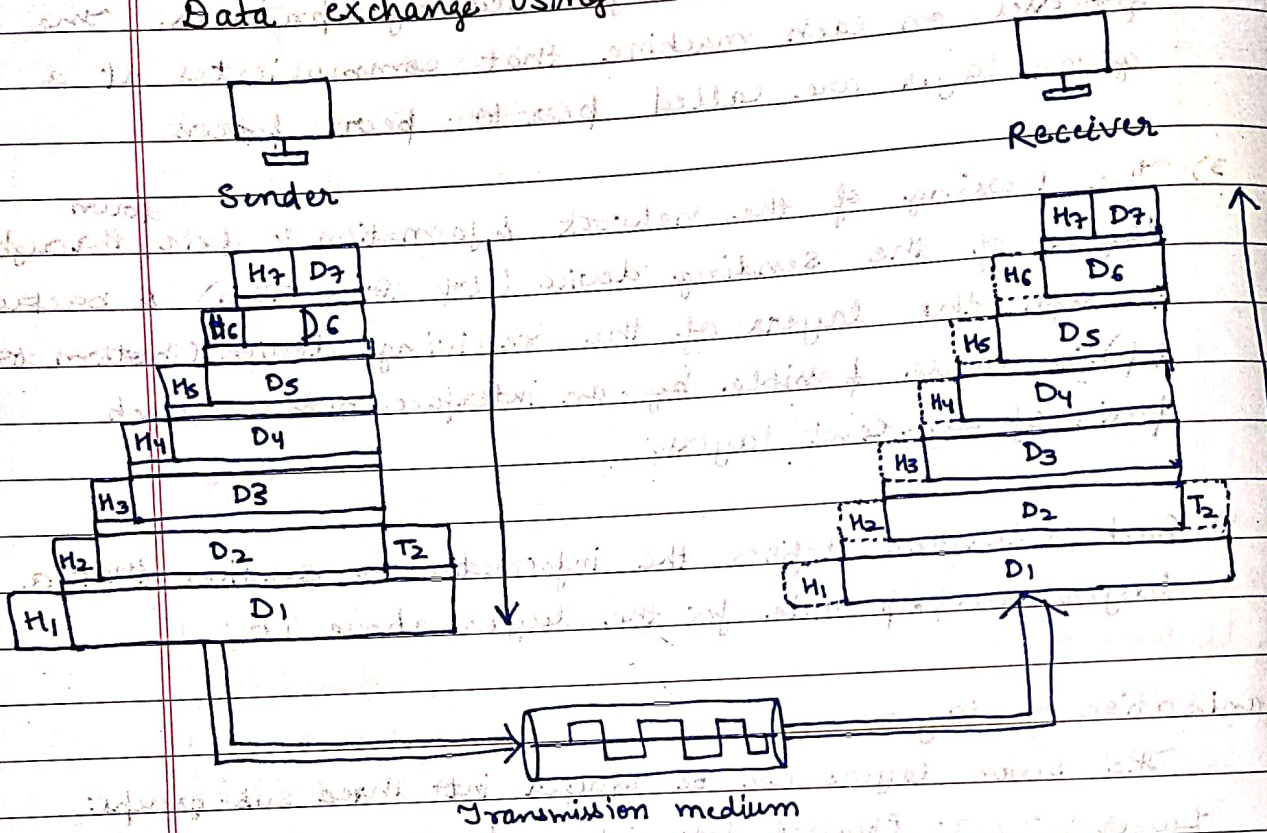
Data exchange using OSI model



Layers in the OSI model:

1) Physical layer: is responsible for movement of individual bits from one node to another node.
other responsibilities are as follows:
a) Physical characteristics of interfaces & medium
b) Representation of bits (electrical or optical)
c) Data rate or transmission rate.
d) Synchronisation of bits
e) Physical topology
f) Line configuration (type of connection)
g) Transmission mode

2) Datalink layer: is responsible for moving frames from one hop to next hop.

Other responsibilities are as follows:
a) Framing
b) Physical addressing
c) Error control
d) Flow control
e) Access control

3) Network layer: is responsible for delivery of packets from source host to the destination host.
Other responsibilities are as follows:
a) Logical addressing
b) Routing

4) Transport layer: is responsible for transfering the segments from one process to another process.
Other responsibilities are as follows:
a) service point addressing (Process number)
b) connection control
c) Error control
d) Flow control

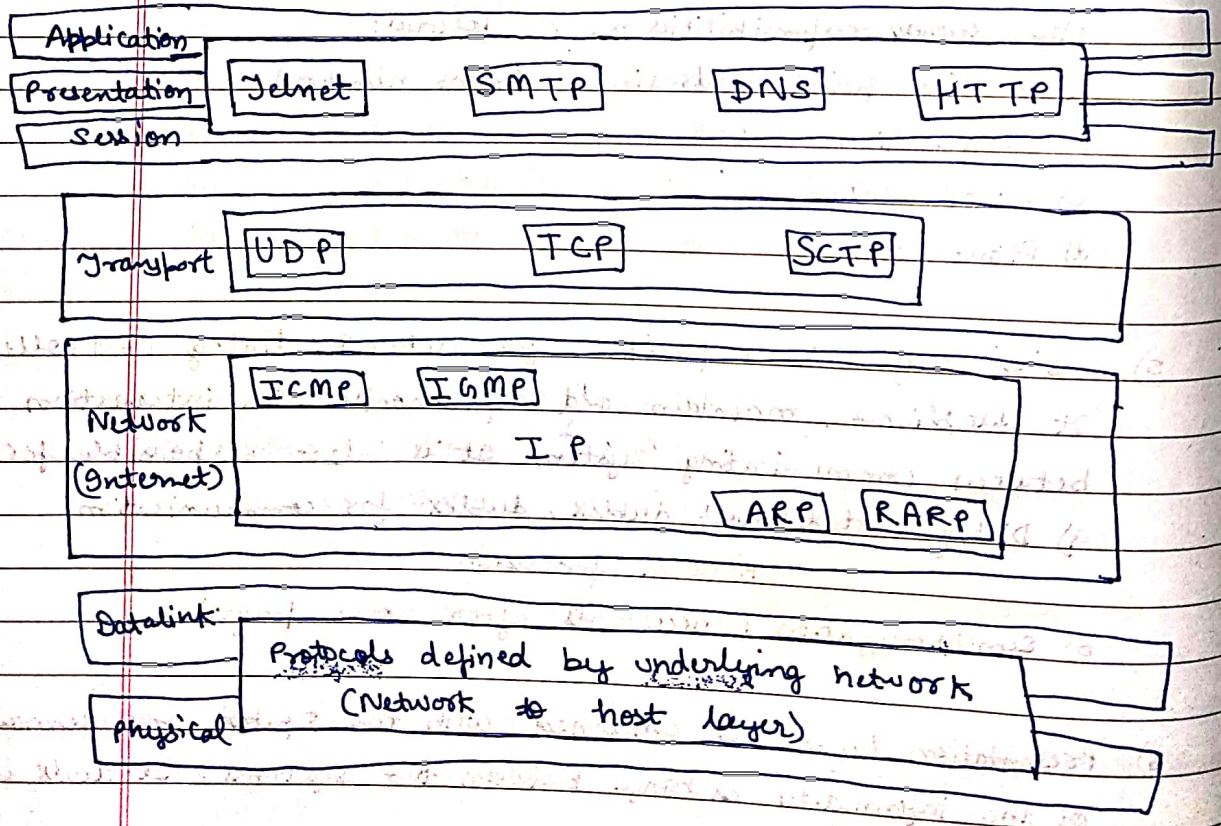
5) session layer: is responsible for network dialog controller. It establishes, maintain and synchronise the interaction between communicating system. It is also responsible for:
a) Dialog control (half duplex, duplex for communication between processes)
b) Synchronization (checkpoints after some pages)

6) Presentation layer: is concerned with the syntax and semantics of the information exchange between two systems. It deals with:

a) Translation
b) Compression
c) Encryption & decryption (Cryptography)

7) Application layer: It provide interface between user and system. It enables the user (human & software) to access the network. It provides user interface & support for following services:
a) Mail services
b) Directory services
c) file transfer, access & management
d) Shared database management
e) Network virtual terminal

(2) TCP/IP Protocol Suit



The TCP/IP protocol suit was developed prior to OSI model. It was defined as having 4 or 5 layers.

1) Host to Network layer	1) Physical layer
2) Internet layer	2) Datalink layer
3) Transport layer	3) Internet layer
4) Application layer	4) Transport layer
	5) Application layer

When TCP/IP is compare to OSI model, we can say that host to network layer is equivalent to the combination of physical layer and data link layer. The internet layer is equivalent to the network layer and the application layer roughly doing the job of session, presentation & application layer of OSI model with the transport layer.

TCP/IP is a hierarchical model made up of interactive modules. Each of which provides a specific functionality. The modules are not necessarily interdependent.

1) Host-to-network layer:

In this layer, TCP/IP does not define any specific protocol. It supports all the standards & proprietary protocols.

2) Internet layer:

In this layer, TCP/IP supports Internet protocol. IP uses four supporting protocols:

a) ARP (Address Resolution Protocol)
mapping logical address to physical address.

b) RARP (Reverse Address Resolution Protocol)
mapping physical address to logical address

c) ICMP (Internet Control Message Protocol)
error reporting.

d) IGMP (Internet Group Message Protocol)
It allows simultaneous transmission of a message to a group.

3) Transport layer: in TCP was represented by two protocol: UDP (User Datagram Protocol) & TCP (Transmission Control Protocol). Letter for newer application SCTP was introduced (Stream control Transmission Protocol).

4) Application layer: in TCP/IP is equivalent to the combination of session, presentation and application layers of OSI model. Many protocols are defined in this layer such as TELNET, SMTP, DNS, HTTP, FTP, SNMP.

Similarities between these two model:

1) Both are based on concept of the stack of independent protocols.
2) The functionality of the layers are roughly similar.
3) The layer above the transport layer are application-oriented in both models.

Differences between these two model:

OSI	TCP/IP
1) It has 7 layers.	1) It has 4/5 layers.
2) It has separate presentation, and session layer.	2) It does not have separate presentation and session layer.
3) It has separate data link and physical layer.	3) TCP/IP combines data link and physical layer into network access layer.

4) OSI is a reference model.	4) TCP/IP is an implementation of OSI model.
5) It clearly distinguishes between services, protocols and interfaces.	5) It does not originally clearly distinguish between services, protocols and interfaces.
6) Protocols in OSI model are better hidden and can be replaced relatively easily.	6) Protocols in TCP/IP model are not hidden & thus cannot be replaced easily.
7) OSI model supports both connectionless or connection-oriented services in network layer but only connection-oriented service in transport layer.	7) TCP/IP model support only connection less services in network layer but support both connection less and connection oriented in transport layer.
8) OSI model is a generic protocol independent standard.	8) TCP/IP model is considered as a standard around which internet was developed.

Physical layer and media:

Bandwidth (B):

The range of frequencies contain in a composite signal is its bandwidth. The bandwidth is normally a difference between highest frequency and lowest frequency contained in the signal: for ex:

$$B = f_h - f_l \qquad \text{Unit: Hz}$$

Q. If a periodic signal is decomposed into five sine wave with frequency of 100 Hz, 300 Hz, 500 Hz, 700 Hz and 900 Hz. find the bandwidth of the signal.

Sol. Bandwidth = 900 − 100 = 800 Hz.

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Q. A periodic signal has a bandwidth of 20 Hz, the highest frequency is 60 Hz. What is the lowest frequency?

Sol. $20 = 60 - f_l$

$f_l = 40$ Hz.

Bit rate or Data rate:

Most digital signals are non-periodic and thus period & frequency are not appropriate characteristics. Therefore, bit rate is used to describe digital signal. Bit rate is the number of bits send in one second expressed in BPS (bits per second).

A digital signal can have more than two levels. In general, if a signal has L levels then each level is represented by $\log_2 L$ bits.

Bitrate $\propto$ Bandwidth

Q. We need to download the text document at the rate of 100 pages per minute. What is the required bit rate of the channel?

Sol. 1 page = 24 lines

1 lines = 80 character

1 character = 8 bits

$$\text{Bit rate} = \frac{100 \text{ page}}{60 \text{ sec}} = \frac{100 \times 24 \text{ lines}}{60 \text{ sec}} = \frac{100 \times 24 \times 80 \text{ characters}}{60 \text{ sec.}}$$

$$= \frac{100 \times 24 \times 80 \times 8}{80} \text{ bits} = 100 \times 4 \times 64$$

$$= 25600 \text{ bits/sec.}$$

$$= 25.6 \text{ Kbps.}$$

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Q. What is the bit rate of HD TV?

Sol. HD TV screen is normally a ratio of 16:9. Resolution of screen is 1920 x 1080 pixels and the screen refreshes 30 times/sec and one colour pixels is represented by 24 bits.

So, bit rate = $1920 \times 1080 \times 30 \times 24$

$= 1.49 \times 10^9$ bits/sec

$\simeq 1.5$ Gbps.

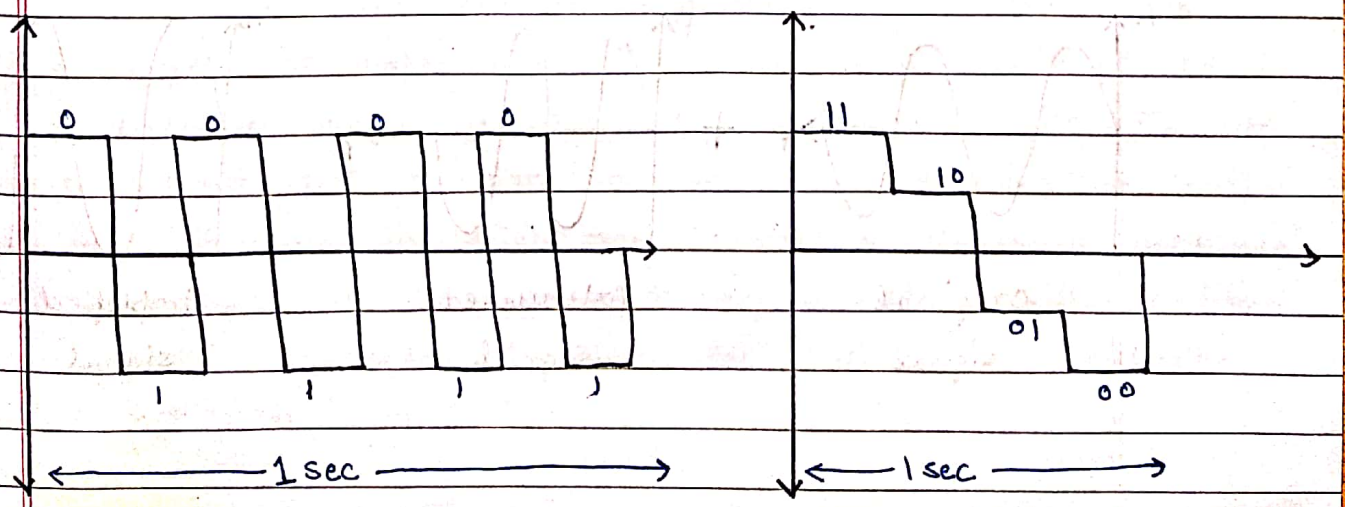
Bit interval: also known as bit duration. It is represented as T_b. It is time taken to send one bit.

Bit length: is the distance 1 bit occupies in the transmission medium. So, bit length = Propogation speed x bit interval

Baud Rate (Modulation Rate):

Baud is the unit of speed modulation or the rate of symbol transmission. It indicates the rate at which signal level changes over a given period of time.

When binary bits are transmitted as electric signals with two levels. The bit rate and baud rate are same but when more than two levels are used then baud rate and bit rate will be different.



Level 2	Level 4
$\log_2 2 = 1$ bits	$\log_2 4 = 2$ bits
bit rate = 8 bps	bit rate = 8 bps
baud rate = 8 bands	baud rate = 4 bands

The unit of baud rate is baud or levels/sec.

Transmission impairments:

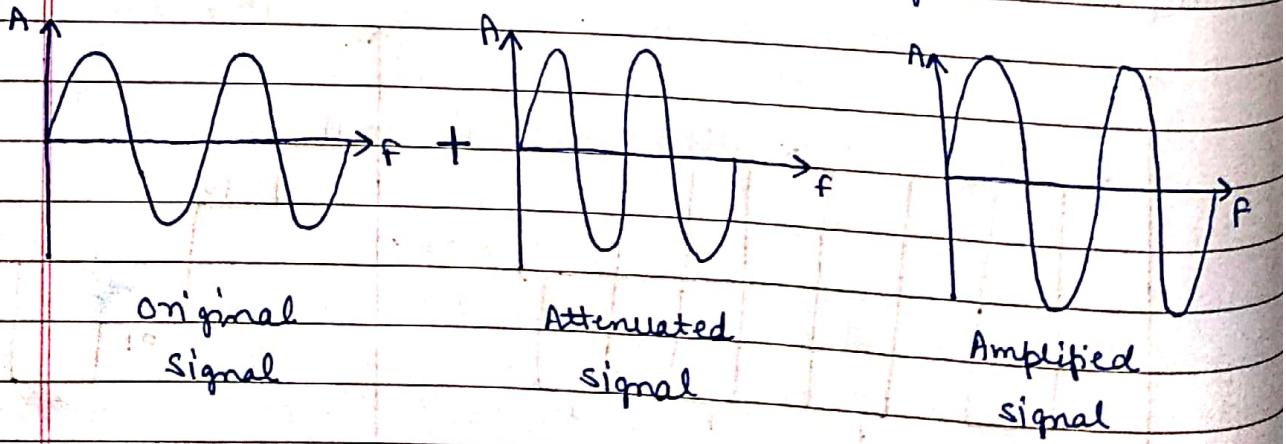
1) Attenuation 2) Distortion 3) Noise

Signal travels through transmission medium which are not not perfect. The imperfection cause impairment. This means that the signal in the beginning and at the end are not same, what is send is not what is receive.

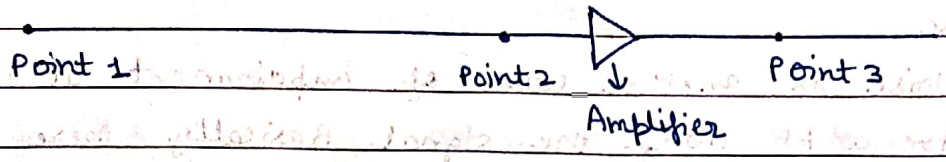
1) Attenuation

Attenuation means a loss of energy when a signal travels through a medium it loses some of its energy in the form of heat in overcoming the resistance of the medium that's why a wire carrying electric signal gets warm to compensate for this loss.

Amplifier are used to amplify the signal.



Original signal Attenuated signal Amplified signal



Attenuation has no external factor.

Attenuation is calculated by dB (decibel).

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

where P_2 is power of signal at point 2.

& P_1 is power of signal at point 1.

$$dB = 20 \log_{10} \frac{V_2}{V_1}$$

If dB is -ve then signal is attenuated. It means there is loss of energy in the signal.

If dB is +ve then signal is amplified. It means there is a gain of energy.

Q. A signal travels through a transmission medium and its power is reduced to half. Calculate the attenuation.

Sol $dB = 10 \log_{10} \frac{\frac{1}{2}P}{P} = 10 \log_{10} 0.5 = -3.0102.$

2) Distortion

It also has no external factor. It means signal changes its form or shape. This can occur in a composite signal made of different frequencies. Each signal component has its own propogation speed and therefore, its own delay arriving in final destination. Difference in delay may create a difference in phase. Signal components at the receiver have the phase different from that they had at sender. Therefore, the shape of the composite signal is not same.

3) Noise

Noise is another cause of impairment. It is an external factor which change the signal. Basically, there can be four types of noise:

a) Thermal Noise
b) Induced Noise
c) Cross talk noise
d) Impulse noise

a) Thermal Noise

is the random motion of electrons which creates an extra signal not originally send by the transmitter.

b) Induced Noise

It comes from sources such as motors, generators and appliance etc. These devices act as sending antenna and the transmission medium act as receiving antenna

c) Cross talk Noise

is the effect of one wire on other wire. One wire acts as a sending antenna & other acts as receiving antenna.

d) Impulse Noise

is a spike, a signal with a high energy for a short time that comes from power lines, lightening etc.

SNR (Signal to Noise Ratio)

$$SNR = \frac{\text{Average signal power}}{\text{Average noise power}} = \frac{S}{N}$$

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

1) If SNR is high, noise is less that means signal is less affected by noise.
2) If SNR is low, noise is high that means signal is more affected or corrupted by noise.

Data Rate Limits:

Data rate depends on three factors:
1) Available bandwidth of the channel
2) The number of levels
3) Noise present in transmission medium.

Two theoretical formulas are developed to calculate the data rate: 1) for Noiseless channel - Nyquist Theorem
2) for noisy channel - Shanon channel capacity

1) Nyquist Limit Theorem

If B is the bandwidth of the channel, L is the number of signal levels to represent the bits of the data then data rate is defined as $R = 2B \log_2 L$.

If we increase the number of levels, then reliability will decrease. So, there is a limit in number of levels.

2) Shanon channel Capacity Theorem

In reality, we can't have a noiseless channel. Therefore, claude shanon extended the work of the Nyquist and introduced a formula called shanon channel capacity formula.

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According to this, If B is the bandwidth of the channel and if signal to noise ratio is S/N, then theoretically highest data rate or channel capacity.

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

Q. Consider a noiseless channel with bandwidth of 3000 Hz. transmitting a signal with 4 signal levels. Calculate the maximum bit rate.

Sol. $$R = 6000 \frac{\log_{10} 4}{\log_{10} 2} = 12000 \text{ bps}$$

Q. We need to send 265 kbps over a noiseless channel with bandwidth of 20 kHz. How many signals levels are need?

Sol. $R = 265000$ bps

$$265000 = 2 \times 20000 \log_2 L$$

$$6.625 = \log_2 L$$

$$2^{6.625} = L$$

$$L = 98.70$$

The answer is not acceptable. So, we have to either increase the number of levels or decrease the baud rate.

Case 1: $R = 2 \times 20 \times 10^3 \log_2 128$

$= 280 \times 10^3$ bps

Case 2: $R = 2 \times 20 \times 10^3 \log_2 64$

$= 240 \times 10^3$ bps

As, no. of levels increase is not reliable. So, we take $L = 64$ to decrease rate $R = 240$ kbps.

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Q. A channel has a bandwidth of 5 KHz and signal to noise ratio is 63. Determine the bandwidth needed, if signal to noise ratio is reduced to 31.

Sol: $C = B \log_2 (1 + SNR)$

$= (5 \times 10^3) \log_2 (1 + 63)$

$= 5 \times 10^3 \times \log_2 2^6 = 30,000$ bps.

$C = B \log_2 (1+31)$

$30,000 = B \log_2 (1+32)$

$30,000 = B \log_2 2^5$

$B = 6,000$ Hz

Q. Calculate the maximum bit rate for the channel having bandwidth 1600 Hz.

(a) SNR = 0 dB

(b) SNR = 20 dB

Sol. (a) $SNR_{dB} = 10 \log_{10} SNR$

$0 = 10 \log_{10} SNR$

$SNR = 1$

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

$C = 1600 \log_2 (1+1)$

$C = 1600$ bps

(b) $20 = 10 \log_{10} SNR$

$SNR = 100$

$C = 1600 \log_2 (1+100)$

$C = 1600 \log_2 102$

$C = 10.653$ kbps

Performance: of a network depends on following four factor:

1) Bandwidth
2) Throughput
3) Delay
4) Jitter

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- Bandwidth is potential measures and it should be high.
- Throughput is actual output & it should be maximum.
- Delay should be minimum
- Jitter should be low.

Delay Analysis: Delay are of four types:
1) Propagation delay
2) Transmission delay
3) Queuing delay
4) Processing time

1) Propagation delay (T_p)

Propagation time measures the time required for a 1 bit to travel from source to destination

$$T_p = \frac{\text{Distance}}{\text{Propagation Speed}}$$

2) Transmission delay (T_{fs})

In communication, we don't send just one bit, we send an entire message. There is a time between the first bit leaving the sender and the last bit arriving at the link. So, the time required to transmit or push all the data bits into the link is known as transmission time.

$$(T_{fs}) = \frac{\text{Message Size}}{\text{Bandwidth}}$$

Q. What are propagation time and transmission time for 2.5 Kbytes message. If the bandwidth of the network is 1 Gbps. Assume that distance b/w sender and receiver is 12000 km & Signal travels at speed of light = 2.4×10^8 m/s.

Sol. Propagation

Transmissi

Q. what is t
and bandw

Sol. Transmissi

3) Queuing
The
hold the packet
It is not a fixed
on the network.

4) Processing
The
header contains th
The time requi
where to direct
The processing ti
as time requir

Latency: The su
or latenc

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Sol. Propogation delay (T_p) = $\frac{\text{Distance}}{\text{Propogation Speed}}$

$= \frac{1200 \times 1000}{2.4 \times 10^8} = 0.05$ sec.

Transmission delay (T_{tr}) = $\frac{\text{Message Size}}{\text{Bandwidth}}$

$= \frac{2.5 \times 10^3 \times 8}{1 \times 10^9} = 0.02$sec.

Q. what is transmission delay if size of message is 5 M bytes and bandwidth of the signal is 1 M bps?

Sol. Transmission delay (T_{tr}) = $\frac{5 \times 10^6 \times 8}{1 \times 10^6} = 40$ sec.

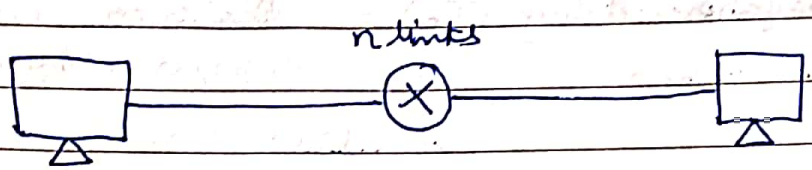
3) Queuing delay (T_q)

The time needed for each intermediate node to hold the packet or hold the message before it can be processed. It is not a fixed factor, it changes with the load imposed on the network.

4) Processing delay: (T_{pr})

The message consists of a header and a data, the header contains the destination address and other control information. The time required to examine the packet address and determine where to direct the packet, is the part of the processing time. The processing time may also include some other factors such as time required to check the errors.

Latency: The sum of all delays is called total nodal delay or latency.



$(n+1)\ T_p$ $(n+1)$ links.

$(n+1)\ T_{fr}$ (coz n intermediate nodes + 1 source)

$n\ T_q$ (coz n intermediate nodes)

$(n+1)\ T_{pr}$ (coz n intermediate node + 1 receiver)

$$L = (n+1)(T_p + T_{fr} + T_{pr}) + n T_q$$

Digital Transmission: representing digital data to digital signal

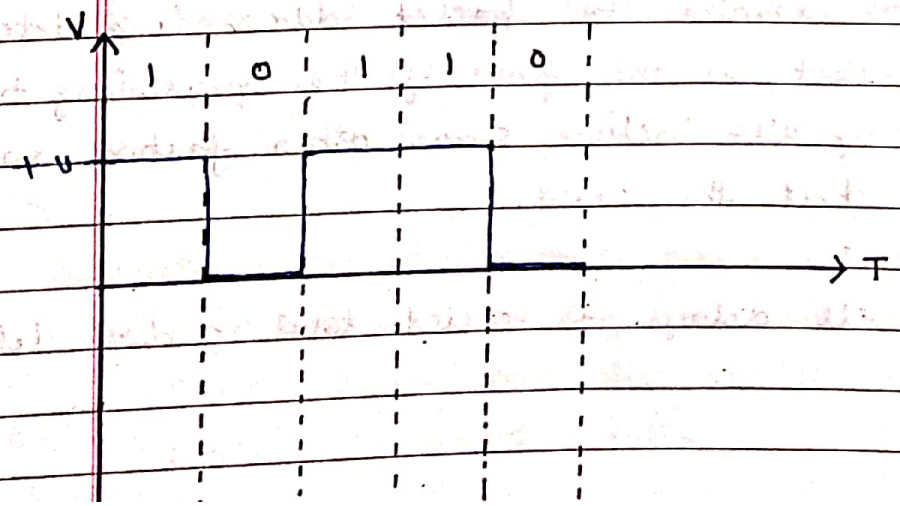
- Line coding
  - a) Unipolar
  - b) Polar
  - c) Bipolar
  - d) Multilevel
  - e) Multi transition

a) Unipolar

All the signals are on the one side of the time-axis either above or below.

NRZ: (Not Return to Zero)

Signal does not return to zero at the middle of the bit.



Assumption
+ve V - 1 bit
0 V - 0 bit

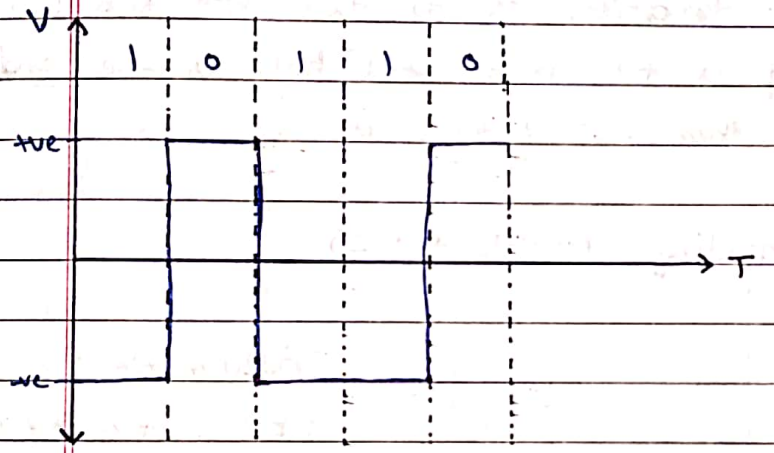
b) Polar: Voltage levels are on the both sides of the time-axis.

NRZ: It is of two types:

1) NRZ-L (level)

2) NRZ-I (Invert)

1) NRZ-L: The voltage level determines the value of bit.

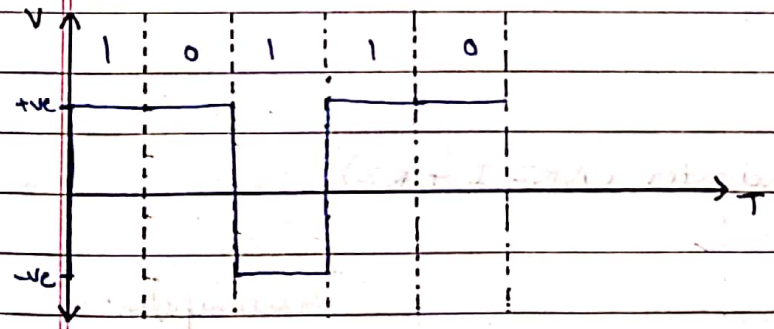


Assumption:

+ve V - 0 bit

-ve V - 1 bit

2) NRZ-I:



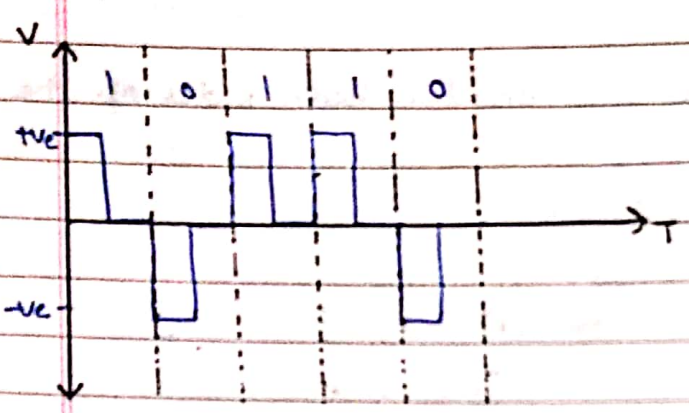
Assumption:

next bit is 0 - no inversion

next bit is 1 - inversion

RZ: (Return to zero)

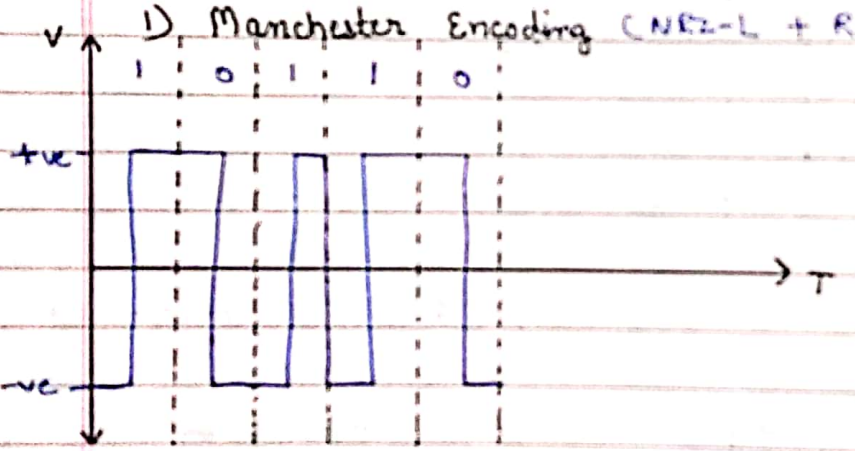
The signal level changes not between bits but during the bit. The signal goes to zero in the middle of the bit and it remains there until the beginning of the next bit.



Assumption:
-ve to 0 → 0 bit
+ve to 0 → 1 bit

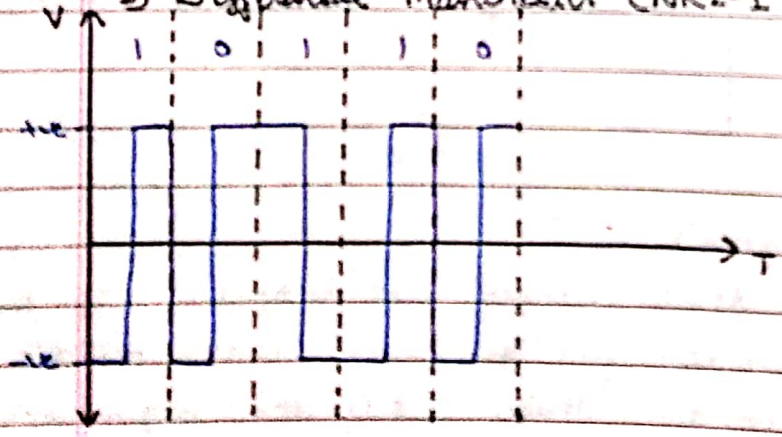
9) Bipolar: The bit duration is divided into two equal half, if first half is +ve then second half is -ve and if first half is -ve then second half is +ve.

1) Manchester Encoding (NRZ-L + RZ)



Assumption:
0 bit → +ve to -ve
1 bit → -ve to +ve

2) Differential Manchester (NRZ-I + RZ)



Assumption:
next bit is 0 - inversion
next bit is 1 - No inversion

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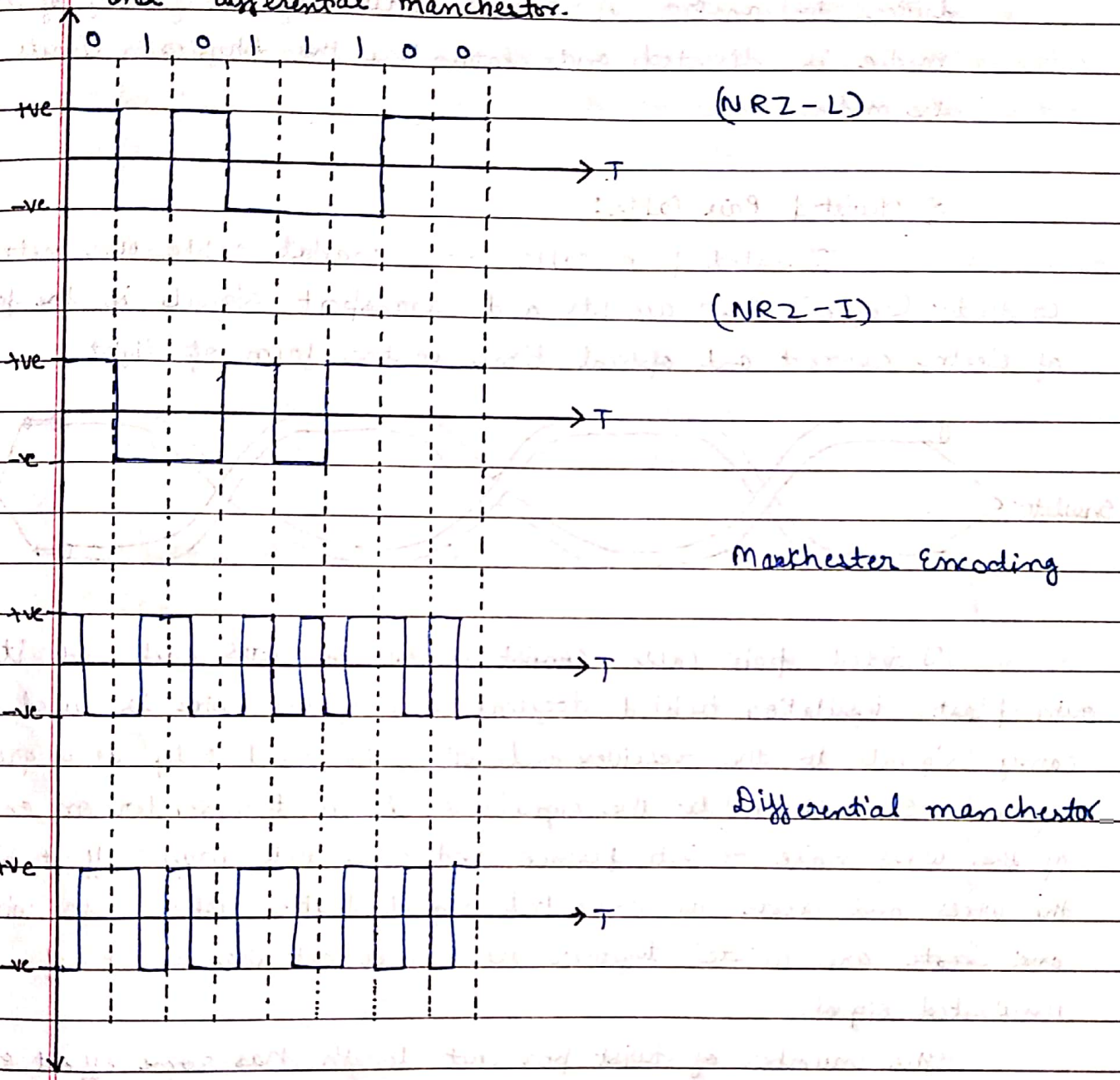
Q. Draw line coding for NRZ-L, NRZ-I & manchester encoding and differential manchester.



Transmission Media

1) Guided media (wired)
   a) Twisted pair cable
   b) Coaxial cable
   c) fibre optics cable
2) Unguided media (wireless)
   a) free space

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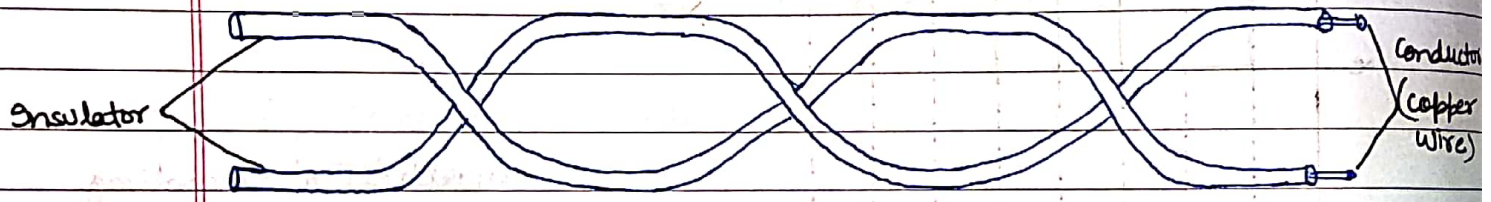
1) Guided media: are those that provide a conduire from one device to another. A signal travelling along any of these media is directed and contain by the physical limits of the media.

a) Twisted Pair Cable:

Twisted pair cable and coaxial cable use metallic conductor (copper) that accepts and transport signals in the form of electric current and optical fibre in the form of light.



Twisted pair cable consist of two conductors each with its own plastic insulation twisted together. One of the wire is used to carry signals to the receiver and other is used only as a ground reference. In addition to the signal, send by the sender on one of the wires noise or interference and cross talk may affect both the wires and create an unwanted signal that's why both wires ~~and create~~ are twisted together to cancel out the effect of unwanted signal.

The number of twist per unit length has some effect on the quality of the cable.

There are two types of cable:

i) UTP (Unshielded Twisted Pair Cable)
ii) STP (Shielded Twisted Pair Cable)

i) UTP:

ii) STP: IBM has produced a twisted pair cable for its use called STP. STP cable has a metallic foil or a braided mesh covering that in cases, each pair of insulated conductors. It improves the quality of cable but become bulkier and more expensive.

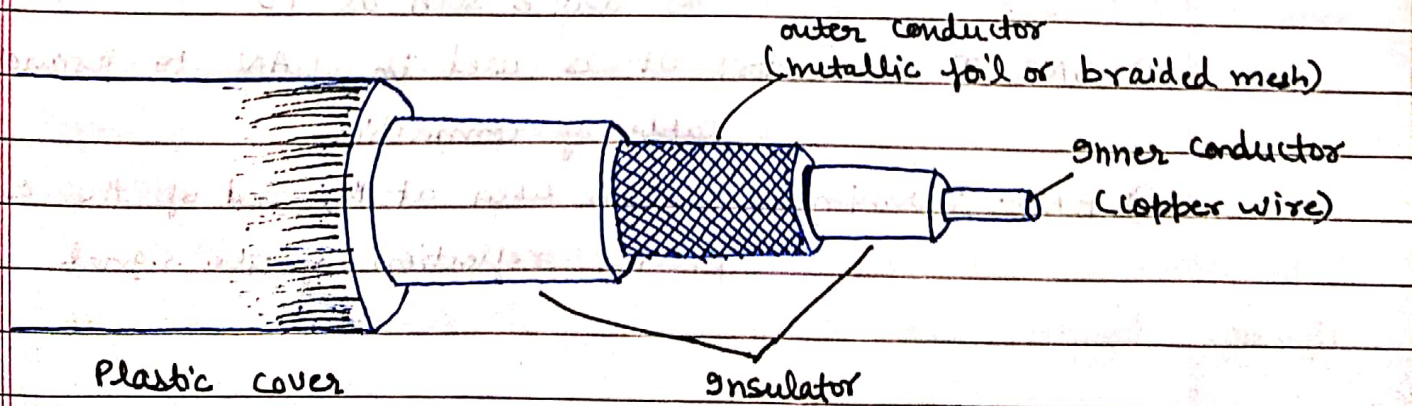
Connector: The most common connector is RJ-45 (Registered Jack). It is a keyed connector that is inserted only in one way. It is of two types:

- RJ-45 Male: It is used in wire.
- RJ-45 Female: It is used in devices.

Categories of UTP:

Category	Data Rate	Uses
1	Upto 1 Mbps	Analog telephony communication
2	Upto 2 Mbps	Analog & digital telephony
3	Upto 10 Mbps	LAN
4	Upto 20 Mbps	token ring LAN
5	Upto 100 Mbps	Ethernet LAN
5e	Upto 125 Mbps	LAN
6	Upto 200 Mbps	LAN
7	Upto 600 Mbps	LAN

b) Coaxial Cable:



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Coaxial cable carries signals of higher frequency ranges than twisted pair cable. Coaxial cable has a central core conductor of copper wire enclosed in an insulating sheath which is in turn in cased in outer conductor of metallic foil or braided mesh or the combination of two.

The outer metallic wrapping serve both as shield against noise and as the second conductor which completes the circuit. This outer conductor is also enclosed in an insulating sheath and the whole cable is protected by a plastic cover.

Coaxial Cable Standard: Coaxial cable are categorised by their radio government (RG) rating. Each RG number denotes a unit set of physical specification including the wire gauge of the inner conductors. The thickness and type of inner insulator, the construction of the shield i.e. outer conductor and size & type of outer casing.

Category	Impedance	Uses
RG-11	50 Ω	Thick Ethernet
RG-58	50Ω	Thin ethernet
RG-59	75 Ω	Cable TV

Coaxial Cable Connectors: To connect coaxial cable to devices, we use coaxial connector. The most common type of connector used is: BNC (Beyone Neil Concelman). It is of three types:

1) BNC connector: It is used to connect the end of wire to device such as TV.
2) BNC -T connector: It is used in LAN to branch out a cable of connection.
3) BNC- Terminator: It is used at the end of the cable to prevent reflection of the signal.

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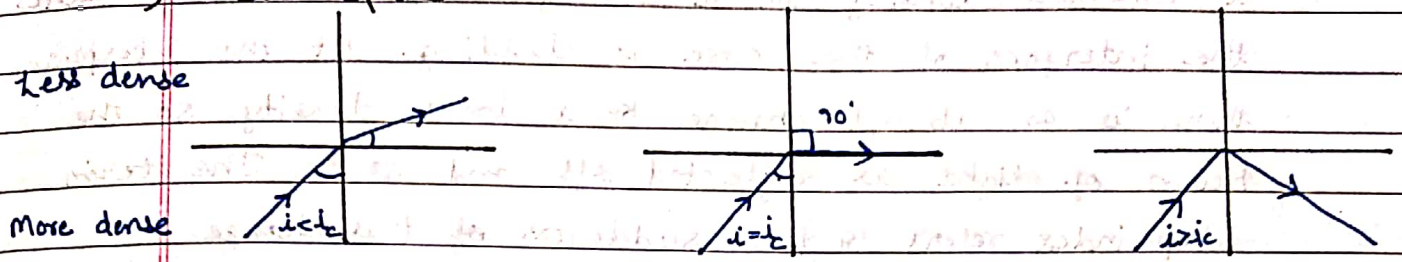
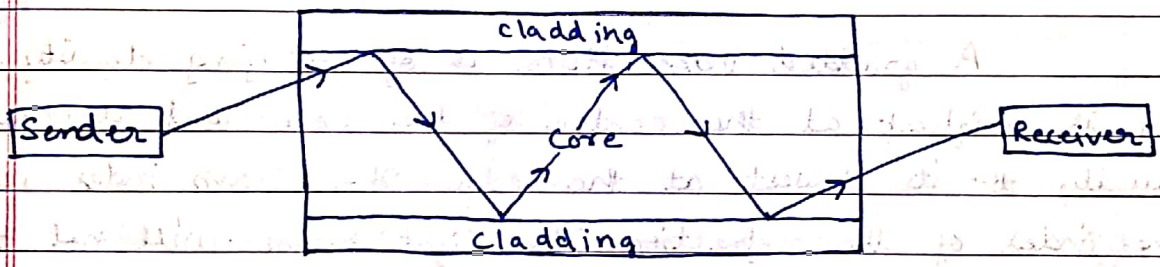
c) Fibre optics:



Refraction Reflection

A fibre optic cable is made up of glass or plastic and transmit signal in the form of light. Optical fibre uses reflection to guide light through a channel. A glass or plastic core is surrounded by cladding of less density.



The difference in the density of core & cladding must be such that a beam of light moving through the core is reflected off the cladding instead of being refractive into it.

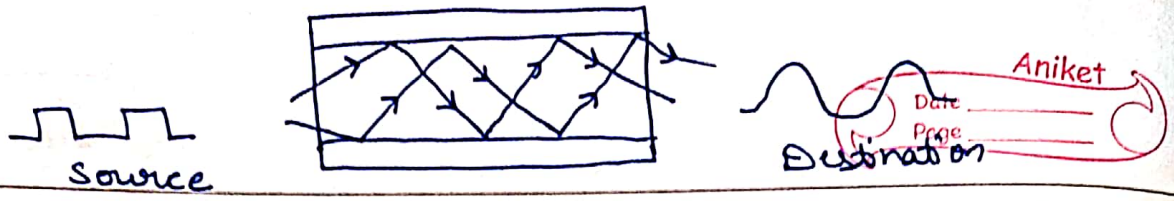
There are two types of propogation mode:

1) Multimode 2) Monomode

1) Multimode: In this, multiple beams from a light source move through the core in different paths. There are two types of multimode fibre:

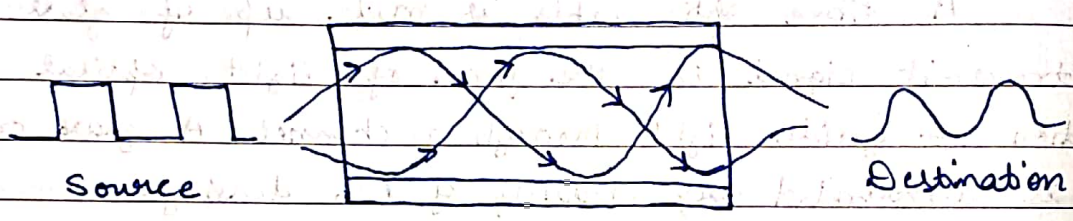
a) Step index:

In this, the density of the core remain constant from the centre to edge. A beam of light moved through



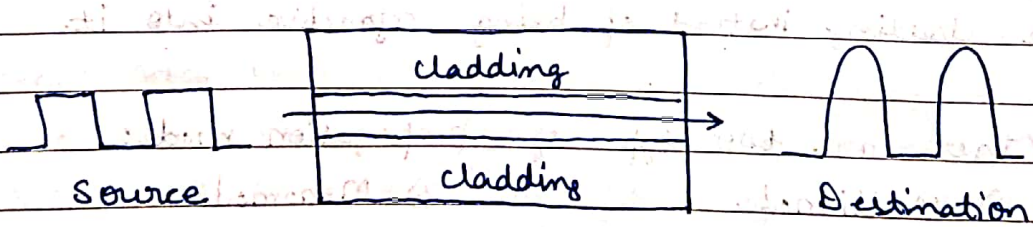
a constant density in a straight line untill it reaches the interface of the core & cladding. At the interface there is an abrupt change to a lower density. So the beam of light is reflected off and so on. The term step-index refers to the suddeness of this change.

b) Gradded Index:



A gradded index fibre is of varying density. The density is highest at the centre of the core and decreases gradually to its lowest at the edge. The term index refers to the index of the refraction. The light beam will not travel in a straight line within a core but it in gradient manner.

2) Monomode (Single Mode)



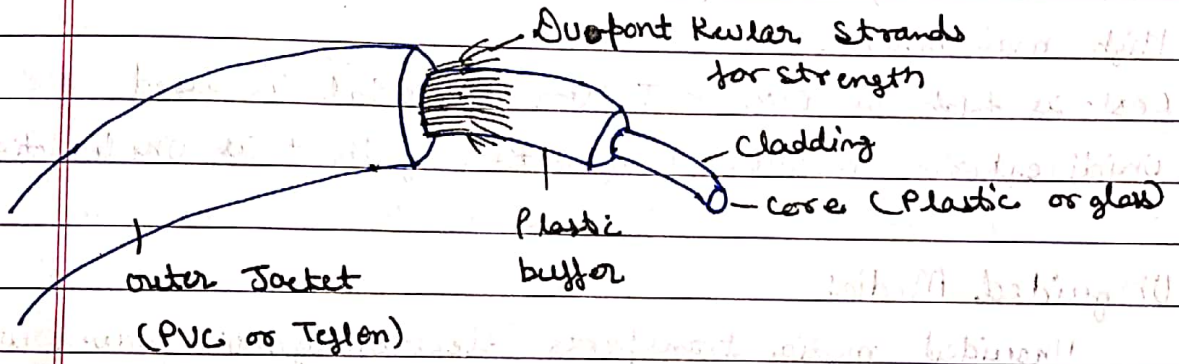
Density of core is less than multimode.

It uses a step-index fibre and a highly focused source of light. It is manufactured within much smaller diameter of core than multimode fibre and with substantially lower density. The decrease intensity results in a critical angle that is close enough to 90°. It makes the propagation of beam almost

horizontal and the propagation of different beam is almost identical.

fibre size:

Type	Core (um)	Cladding (um)	Mode
50/125	50	125	Multi-mode Gradded
62.5/125	62.5	125	Multi-mode gradded
100/125	100	125	Multi-mode gradded
7/125	7	125	Mono-mode - Step



The outer jacket is made of either PVC or Teflon. Inside the jacket are Kevlar strands to strengthen the cable. Kevlar is a strong material used in fabrication of bullet proof jacket. Below the Kevlar is another plastic coating to cushion the fibre, the fibre is at the centre of the cable & it consist of core and cladding.

Connector:

1) SC: (Subscriber channel): It is used in cable TV system.
2) ST: (Straight Tip) : used for connecting cable to the networking devices.
3) MT-RJ: (Mechanical Transfer - Register Jack): It is a new connector with the same size as RJ-45.

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Advantages of optical fibre:

1) Higher bandwidth of optical fibre & data rate
2) Less signal attenuation (as light wave is used)
3) No electromagnetic interfaces
4) Resistance to corrosive material
5) More immune to tapping

Disadvantages of optical fibre:

1) Installation - requires expert
2) High maintenance
3) Cost is high as PVC or Teflon material is used.
4) Unidirectional because propogation of light is unidirectional.

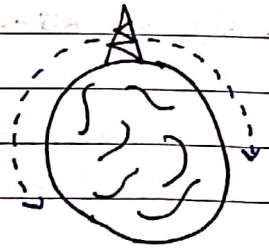
2) Unguided Media:

Unguided media transports electromagnetic waves without using physical conductor. It is also known as wireless communication. The signals are normally broadcast through air and available to anyone who has a device capable of receiving them.

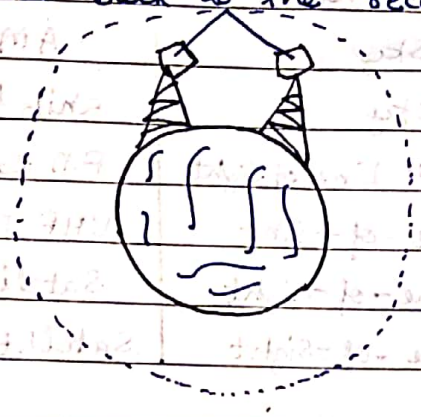
Propogation of electromagnetic waves in three ways:

1) Ground propogation
2) Sky propogation
3) Line-of-Sight

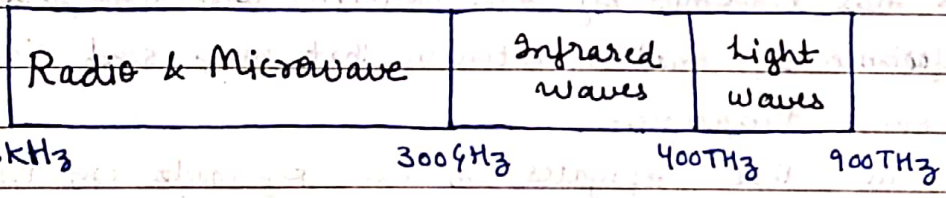
1) Ground propogation: Low frequency waves travels along the curvature of the earth, it is called ground propogation.



2) Sky propogation: High frequency waves propogates in upward direction and reach at a highest point to the ionsphere and then reflected back to the receiving antenna



3) Line-of-Sight: A line of sight propogation sending and receiving antenna's must be aligned facing each other. Antenna should be very high such that no obstacle in between them.



Electromagnetic spectrum for Wireless Communication

Band: The section of the electromagnetic spectrum that defines radio waves and microwaves is divided into 8 ranges is called band.

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Band	Range	Propogation	Use
VLF	3kHz - 30kHz	Ground	Long range radio navigation
LF	30kHz - 300kHz	Ground	Radio beacons & GPS
MF	300kHz - 3MHz	Sky	AM Radio
HF	3MHz - 30MHz	Sky	Ship & Aircraft communication
VHF	30MHz - 300MHz	Sky & Line of Sight	FM Radio & VHF TV
UHF	300MHz - 3GHz	Line-of-Sight	UHF TV & cellular phone
SHF	3GHz - 30GHz	Line-of-Sight	Satellite communication
EHF	30GHz - 300GHz	Line-of-Sight	Satellite communication & RADAR

(1) Radio waves: Electromagnetic waves having frequency between 3 kHz and 1 GHz are normally called radio waves.

a) Radio waves are omnidirectional, when an antenna transmits radio waves, they can propogate in all direction. This means that the sending antenna & receiving antenna don't need to be aligned.

b) Omnidirectional property has a disadvantage also that radio waves has transmit by one antenna are susceptible to interference by another antenna that may send signal using the same frequency.

c) Radio waves that propogates in the sky mode can travel long distance that's why these are a good candidate for long distance broadcasting.

d) Radio waves of low and medium frequencies can penetrate walls. It is an advantage because a radio can receive signal inside a building. It is disadvantage too because we cannot isolate a communication to just inside or outside a building.

e) This band is relatively narrow just under 1GHz. When this band is divided into sub-bands, the sub-bands are also narrow leading to a low data rate to a digital communication.

f) Almost the entire band is regulated by authority. Omni-directional antenna are used to send out radio waves as signals.

Uses: Radio waves are multicast communication such as radio, t.v., pairing system.

(2) Microwaves:

Electromagnetic waves having frequency between 1 GHz to 300 GHz are called microwaves. Microwaves are unidirectional this means that sending antenna and receiving antenna needs to be aligned.

a) Micro wave propogation is line-of-sight.

b) Very high frequency micro waves cannot penetrate walls. this characteristics can be disadvantage, if receiver is inside a building.

c) The microwave band is relatively wide almost 299 GHz. Therefore, wider subbands can be assign and a high data rate is possible.

d) Some or certain portion of the band requires permission from the authority. Micro wave need unidirectional antenna that send out signal in one direction.

Two types of antenna's are used for microwave communication

i) Parabolic Dish Antenna

ii) Horn Antenna

i) Parabolic Dish Antenna: This type of antenna is used to receive micro wave at a common point.

ii) Horn Antenna: Outgoing transmission are broadcast through a horn aimed at the dish.

Uses: Micro waves are used in unicast communication such as satellite, cellular-telephone, wireless LAN etc.

(c) Infrared waves:

Infrared signals with frequency 300GHz to 400THz can be used for short range communication.

a) Infrared signal having high frequency cannot penetrate walls. This advantageous characteristics prevent interference between one system and another.

b) We cannot use infrared waves outside the building because sun's ray contain infrared & ultraviolet rays that can interfere with the communication.

Uses: 1) Communication between remote & TV
2) Wireless keyboard, mouse & printer

Service Primitives:

A service is specified by a set of primitives available to a user process to access the service. These primitives tell the service to perform some action or report on an action taken by a peer entity. The primitives for connection-oriented service are different from the connectionless service.

The five different service primitives for implementing a simple connection-oriented service are:

a) Listen: The server executes LISTEN to indicate that it is prepared to accept the incoming connection.

b) Connect: The client executes a CONNECT call to establish the connection with the server and also specify the address.

c) Receive: The server executes RECEIVE to prepare the first request. This call blocks the server.

d) Send: The client executes SEND to transmit its request followed by the execution of RECEIVE to get the reply.

e) Disconnect: The client use DISCONNECT to end the connection.