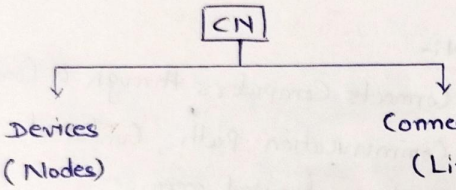
* Computer Network *

→ A Computer network is a Collection of two or more Computer systems that are linked together with Cables, switches, routers.

→ Used in data Transmission.



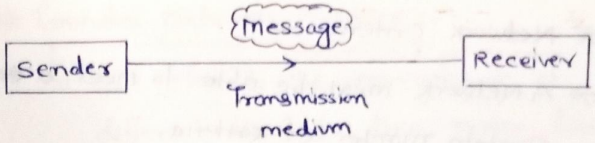
- The rules for how these Connections send information are Called Communication Protocols.
- The starting and ending Points of these Communications are often Called Ports.

→ Goals:
1) facilitating Communication
2) Resource sharing
3) Data storage and Access
4) Cost Efficiency
5) Reliability and Redundancy

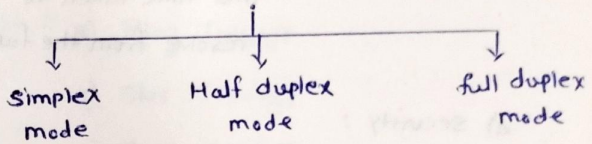
- Data Communication-
  ↳ Exchange of data between two devices via some transmission medium.

→ 5 Components-

A) message
B) sender
C) Receiver
D) Transmission medium
E) protocol
  ↳ set of Rules



- Transmission mode-
  ↳ Data flow b/w 2 systems Can be Categorised into 3 Types:



1) Simplex :
- The Communication is unidirectional.
- This mode Can use the entire Capacity of the channel to send data in one direction.

2) Half duplex :
- Each station Can both transmit and receive, but not at the same time.
- The entire Capacity of a Channel is taken over by whichever of the two devices is transmitting at the time.

Exa- Walkie - talkies

3) full duplex :
- Both station Can transmit and receive at the same time.
- It is two half duplex Communication.
- The Capacity of Channel must be divided b/w two directions.

* Network Criteria :-

→ A Network must be able to meet a certain number of criteria.

1) Delivery and Accuracy
2) Performance
3) Reliability : (measure of freq. of failure and time taken to resolve from the failure)
4) security :

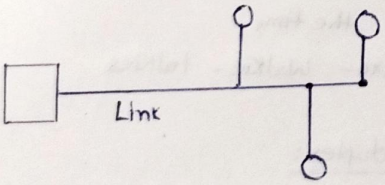
* Types of Communication :-

A) Point to Point

- This Connection provides a dedicated link between two devices.

B) multipoint :-

- A multipoint (Also called multidrop) Connection is one in which more than two specific devices share a single link.



* Types of Computer Network :-

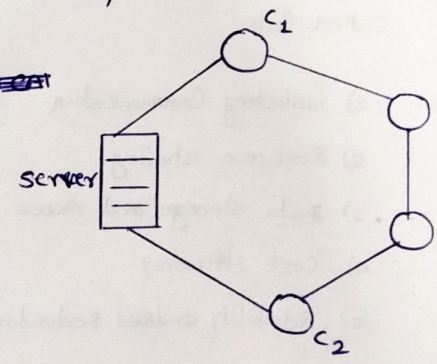
→ 1) LAN (Local Area Network)
→ 2) PAN (Personal Area Network)
→ 3) CAN (Compus Area Network)
→ 4) MAN (metropolitan Area Network)
→ 5) WAN (Wide Area Network)

1) PAN :-

- designed to Connect device within a short range.
- Exa- Bluetooth, IrDA, Zigbee
- Range- (1-10m)
- Transmission speed- very High

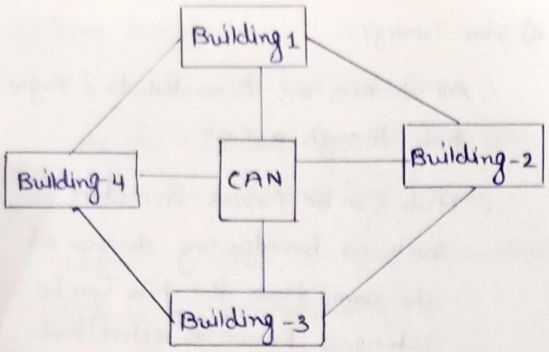
2) LAN :-

- Connects Computers through a Common Communication Path, Contained within a limited area.
- Exa- Ethernet, Wifi
- Range- up to 2Km
- Transmission speed- very high
- Easy maintainance and Low Cost



3) CAN :-

- LAN < CAN < MAN
- It spread across several buildings within the Campus.
- Range- (1-5 Km)
- Transmission speed- High
- moderate maintainance and moderate Cost
- Ex- Ethernet



4) MAN :-

- This Connects Computer over a geographical distance through a shared communication path over a city, town or metropolitan Area.
- Uses - FDDI, CDDI, ATM.
- Range - 5-50 Km
- Transmission speed - Average
- difficult to maintain, with high cost

5) WAN :-

- Connects Computers over a large geographical distance through a shared communication path.
- Also defined as group of LAN that Communicate with each other.
- Range - Above 50km.
- Used - Leased line, dial-up
- Transmission speed = very low

* Computer Networks Topology :-

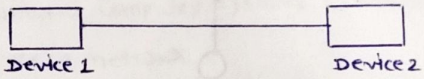
↳ This refers to the arrangement of different elements like nodes, links, or devices.

Types :-

1) Point to Point
2) Bus Topology
3) Ring Topology
4) Star Topology
5) Tree Topology
6) mesh Topology
7) Hybrid Topology

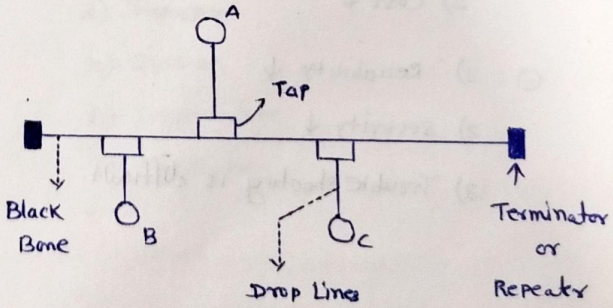
1) Point to Point :-

- This Works on the functionality of sender and receiver.
- This provides high band-width.



2) Bus Topology :-

- In this Every Computer and network device is Connected to a single Cable.
- It is bi-directional.



→ No. of Cables = n + 1

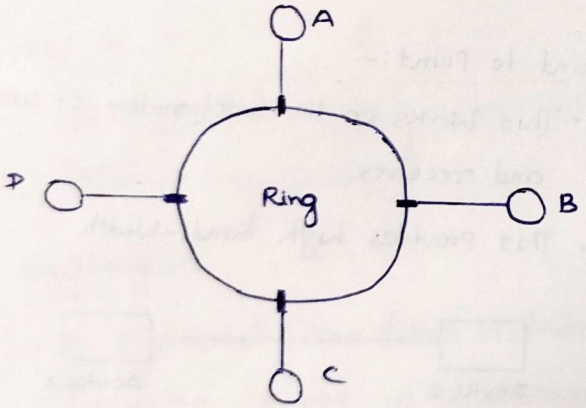
→ No. of Ports = 1 * n

⊕ : 1) Cost ↓

⊖ : 1) Reliability ↓
2) Security ↓
3) requires lot of Cabling

3) Ring Topology :-

- forms a ring Connecting devices With exactly two neighboring devices.
- Unidirectional
- Token Ring Passing Protocol is used by the WorkStation to transmit the data.



→ No. of Cables = n+1

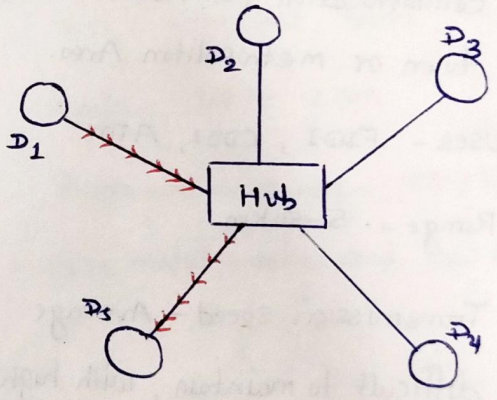
→ No. of Ports = 1*n

⊕ : 1) data Transmission speed ↑
2) Cost ↓

⊖ : 1) Reliability ↓
2) security ↓
3) Troubleshooting is difficult.

4) Star Topology :-

- All devices are Connected to a single hub through a Cable.
- Hub Can be passive in nature, Such as broadcasting devices at the same time the hub Can be intelligent known as active hub. Active hubs have repeaters.
- Ethernet LAN protocols are used as CD(Collision detection), CSMA(Carrier sense multiple Access)



→ No. of Cables = n

→ No of ports = 1*n

→ Reliability ↓

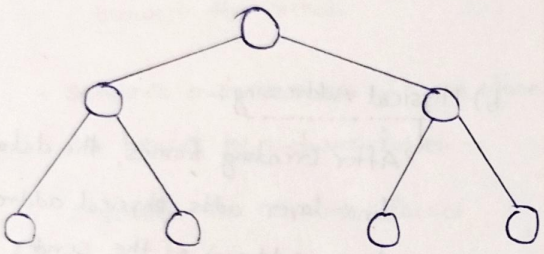
→ Cost ↑

→ security ↑↓

→ Point to point Communication

5) Tree Topology :-

- Combination of bus and star.
- All the Computers are connected with each other in hierarchical fashion.
- Point-to-point or point to multipoint links are frequently used.

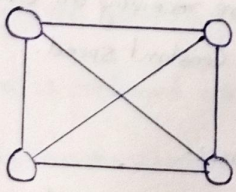


⊕ : 1) Can add new devices
2) Error detection and correction are very easy.

⊖ : 1) If the central hub fails then entire system fails.
2) Cost ↑
3) reconfiguration is difficult.

6) Mesh Topology :-

- Every device is connected with a another via a particular channel.
- Protocols – AHCP (Ad hoc Configuration)
DHCP (Dynamic Host Configuration)

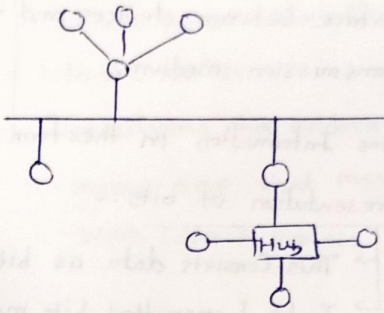


Point-to-point Communication

- No. of Cables :- $^{N}C_{2}$
- No. of ports – N x (N-1)
- Reliability is very high
- Cost ↑ · security ✓

7) Hybrid Topology :-

- Combination of all various topology.



⊕ : 1) flexible
2) Size of Network Can be Easily Expanded.

⊖ : Cost ↑

* OSI model :-

→ OSI (open systems Interconnection) model is a set of rules that explains how different Computer systems Communicate over a network.

→ This Consists 7 Layered Architecture–

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

1) Physical Layer :-

- Interface between devices and the transmission medium.
- Contains Information in the form of bits.

a) Representation of bits :-

→ This Consists data as bit stream
→ To be Transmitted, bits must be encoded into signal - Electric or optical.

b) Data Rate :-

→ Transmission rate - the number of bits sent each second is also defined by the physical Layer.

c) Line Configuration :-

→ Checks Connection of devices to the media.
(Point to Point or multipoint)

D) Handing Topologies

E) Handling Transmission mode.

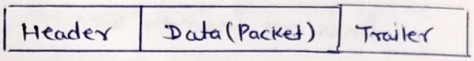
2) Data Link Layer :-

~~divides the stream of bits received from~~

- Responsible for node to node delivery of message.
- This Ensure data transfer is Error free.

a) Framing :-

→ divides the stream of bits received from the network Layer into manageable data units Called frames.



b) Physical Addressing :-

→ After creating frames, the data link layer adds physical address (MAC Address) of the sender or receiver in the header of Each frame.

c) Access Control :-

→ When a single Communication channel is shared by multiple devices, the MAC sub-Layer of the data link helps to determine which device has Control over the channel at a given time.

D) flow Control :-

→ flow Control Coordinates the amount of data that Can be sent before receiving an acknowledgement With Constant Speed.

e) Error-Control :-

→ It detects and retransmits damage or lost frames.

3) Network Layer :-

- Works on the transmission of data from one host to another ~~host~~ located in different networks.
- It takes care of packet Routing. ie. selection of the shortest path to transmit the packet.
- Sender's and receiver's IP are placed in header by network layer.
- segments in NL ⇒ Packet
- Implemented by routers or switches.

a) Logical Addressing :-

→ To identify each device in inter-network uniquely.
→ Place Ip's in Header

b) Routing :-

→ This protocols determine which route is suitable from source to destination.

4) Transport Layer :-

- This Layer Provides services to the application layer and takes services from the network Layer.
- data is referred as segments.
- It is responsible for the end-to-end delievery of the Complete message.
- Used Protocols - TCP, UDP, PPTP

a) Service-Point Addressing :-

→ At the sender's side this adds service point Address (Port Number) to the Headers.
→ specifying this Address, the T-L- makes sure that msg is delievered with correct process.

b) Segmentation and Reassembly

→ This accepts the msg and breaks it into smaller units.
→ Each segment has a header
→ At the destination T.L- reassembles the msg.

c) Connection Control :

d) Error and flow Control

5) Session Layer :-

- This is responsible for the establishment of Connections, management of Connections, terminations of sessions b/w two devices.
- Provides authentication and security.
- Protocol used - NetBios, PPTP.

a) dialog Controller :

→ This allows to start Communication in half-duplex or full-duplex.

b) synchronization :-

→ Add checkpoints or synchronization Points.

6) Presentation Layer:-

- Also called as " Translation Layer".
- This manipulate the format of' over the network.
- Protocols - TLS / SSL

a) Translation -

↳ different Computers use different encoding techniques, this layer is responsible for interoperability between these different Coding techniques.

b) Encryption:-

↳ sender transforms the original information to another form and sends resulting message out over the network.

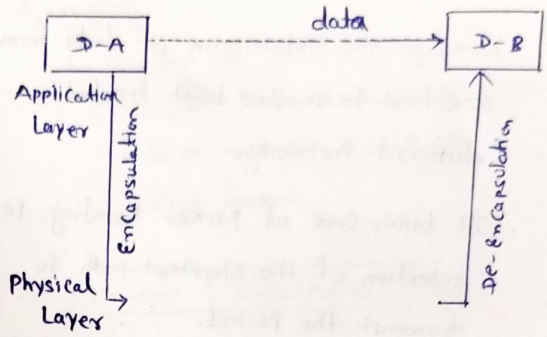
↳ At receiver - Decryption

c) Compression:-

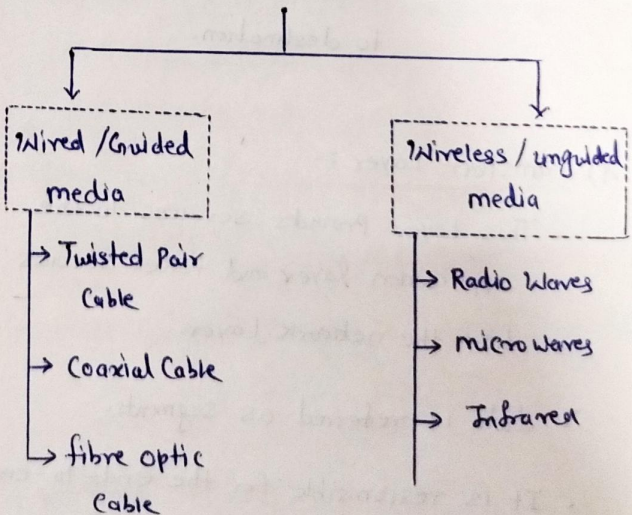
7) Application Layer:

↳ These application produce the data to be transferred over the Network.

↳ Provides User Interfaces and Support for the services such as electronic mail, remote file access and transfer,



* Transmission media :-

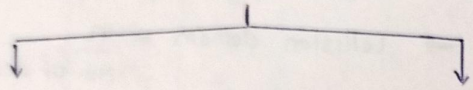


1) Guided media

- Provide a Connection from one device to another device.

A) Twisted pair Cable :-

↳ It Consists of 2 separately insulated Conductor Wires twisted about each other.



Unshielded Twisted Pair (UTP)

⊕ : Least Expensive
Easy to install

⊖ : Lower Capacity and performance
attenuation ↑

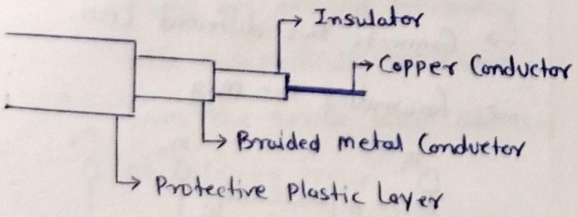
Shielded Twisted Pair (STP)

⊕ : Better performance
Eliminate Crosstalk
faster

⊖ : difficult to install
Expensive
Bulky

B) Co-axial Cable :-

↳ It has a central Core Conductor of solid wire enclosed in an insulating sheath, which in turn, encased in an outer Conductor of metal foil, braid or protective Plastic Layer.



→ transmits info in 2 modes -
Base band, Broadband

Exa - Cable tv, Analog tv Networks

⊕ : 1) These has high bandWidth
2) Easy to install
3) more Reliable and durable
4) Less affected by Noise, Cross talk
5) support multiple channels.

⊖ : 1) Expensive
2) bulky
3) Chance of breaking the coaxial cable and attaching a t-point by hacker.

c) optical fiber Cable :

↳ Uses Concepts of "Total ~~Re~~ Internal Reflection" of Light.

↳ A glass or plastic Core is surrounded by a less dense glass or plastic Covering Called Coating.

↳ Can be Unidirection or bidirectional.

⊕ : 1) Increased Capacity and bandwidth
2) Light weight
3) Less signal attenuation.

⊖ : 1) difficult to install
2) High Cost

Uses : 1) medical purpose
2) Defence purpose
3) Industrial purpose

2) unguided media :-

↳ No physical medium is required for the transmission of electronic signals.

→ features :

- broadcast through air
- Less secure
- used for longer distances

A) Radio Waves :- (omni direction)

↳ Easy to Generate and Can penetrate through buildings.

↳ frequency Range - 3KHZ - 1GHZ

↳ Exa - Am, fm

B) Micro Waves :- (uni-direction)

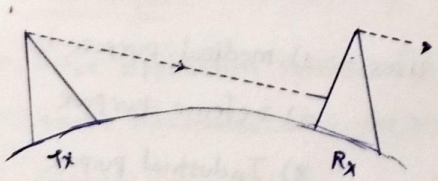
↳ It is a line of sight transmission

↳ Sending and Receiving Antennas need to be properly aligned with each other.

↳ distance Covered $\propto h$

↳ freq Range - 1GHZ - 300GHZ

↳ Majorly used in mobile phone Comm.



C) Infrared :- (unidirection)

↳ Used for very short distance Comm.

↳ Can not penetrate through obstacles.

↳ Prevents Interference b/w systems.

* Repeaters :-

→ It regenerates the signal over the same Network before the signal becomes too weak or Corrupted to extend the length.

→ It is a 2 port device

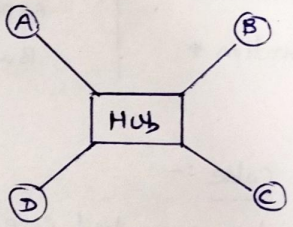
→ Physical Layer device

→ Collision domain = $\frac{n}{\text{No. of device}}$

* Hub :-

→ It is a multiport repeater

→ It Can't filter data. So data Packets are sent to all Connected devices.



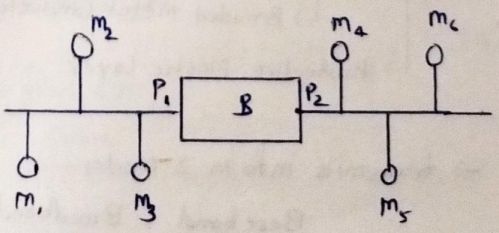
→ Collision domain $\leq n$

* Bridges :-

→ operates at data link layer.

→ Connects two different LAN.

→ forwarding the msg



→ filtering Content by reading the MAC Address.

→ It Can have multiple Ports.

MAC	Port
m_1	P_1
m_2	P_4
m_3	P_3
m_4	P_2
m_5	P_2
m_6	P_2

→ Types of bridges -

A) Static / Source Routing Bridges :-

↳ Routing operations is performed by the source station and frame specifies which route to follow.

A) Static Bridges :-

↳ This is manually configured by the network administrator.

↳ Bridge Table is fix.

B) dynamic Bridges :-

↳ A dynamic bridge builds and updates its ~~following~~ forwarding table automatically by learning from the source MAC addresses of incoming frames.

→ Bridges use store and forward method so No Collison

→ Use data unit protocol [for removing Loop]

* Switch :-

→ multiport ~~device~~ Bridge

→ data link layer device

→ Traffic is minimal

→ Collison domain is zero (0)

→ These Can perform error checking before forwarding data, which makes it very efficient as it does not forward packets that have errors and forward good packets selectively to the correct port only.

* Router :-

→ This is a device like a switch that routes data packets based on their ip address

→ Network Layer device.

→ This Uses routing table.

→ Normally Connets LANs and WANs

→ fitering ✓

→ Collison - No (Store and forward method)

* Analog & digital Data :-

- The Analog data refers to information that is Continuous.

  Exa :- Clock,
  Sound-Wave,
  Shaking of Hand

- Digital Data refers to information that has ~~disse~~ discrete states.

  Exa- Digital Clock

* Signals :-

1) Analog signal
2) Digital signal

→ Analog signals have infinitely many level of intensity over a period of time.

(It Includes Infinite Number of States/values)

→ Digital signals have limited Number of different states.

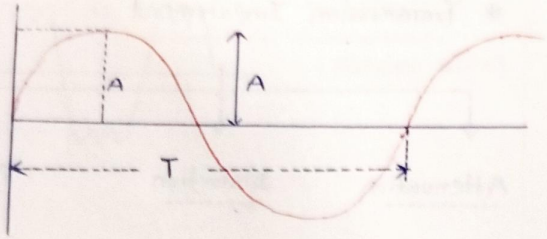
Analog signal

Periodic

A periodic signal completes a pattern within a measurable time frame, called period and repeats that pattern over subsequent identical periods.

Non-periodic

change without exhibiting a pattern



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

Periodic signal

1) Simple

- Single sine or Cosine Wave
- It has only 1 freq. Component

$$x(t) = A\sin(2\pi ft + \phi)$$

2) Composite

- Sum of 2 or more sine/Cosine Wave
- It has multiple freq. Component

- **Wave length** :- distance of a Simple ~~signal~~ signal can travel in one period.

$$\lambda = \frac{\text{Propogation speed}}{\text{frequency}}$$

- **Band-Width** :- The range of frequencies contained in a Composite signal is Band Width.

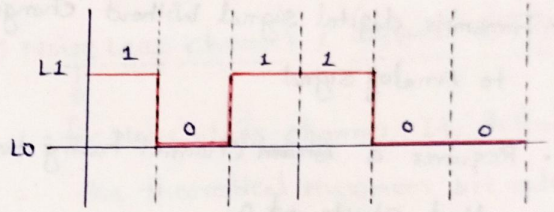
$$BW = f_{max} - f_{min}$$

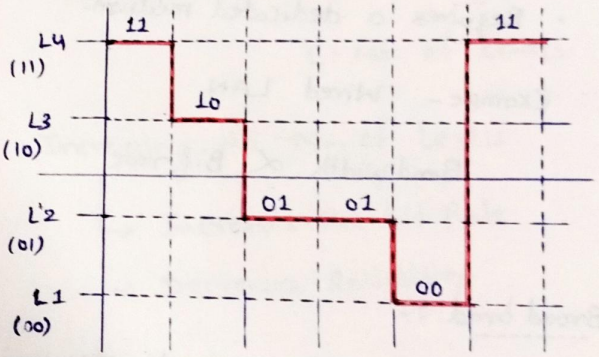
- **Digital signal** :-

1 : Positive voltage

0 : Negative voltage

→ Digital signal consists of Level, that represents information. (bits)





$$L = 2^n$$

- **Bit Rate** :- Number of bits sent per ~~Page~~ second

Unit - bps

- **Bit Length** :- Distance occupied by one bit on a transmission media.

= propogation speed x bit duration

* Digital signal Transmission :-

1) Baseband :-

- Transmits digital signal without changing it to Analog signal.
- Requires a ~~chan~~ channel having bandwidth that starts at 0.
- Requires a dedicated medium.

Example - Wired LAN

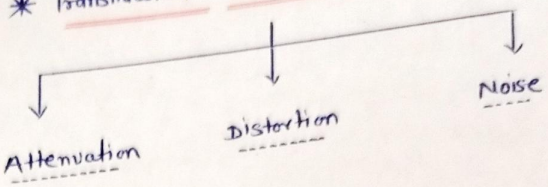
Bandwidth $\propto$ Bit rate

2) Broad band :-

- changes digital to Analog ~~transmission~~ signal for Transmission.
- Uses a channel with Bandwidth that not starting at 0.
- Does Not require a dedicated medium

Exa :- Sending Computer data through digital cellular telephone

* Transmission Impairment :-



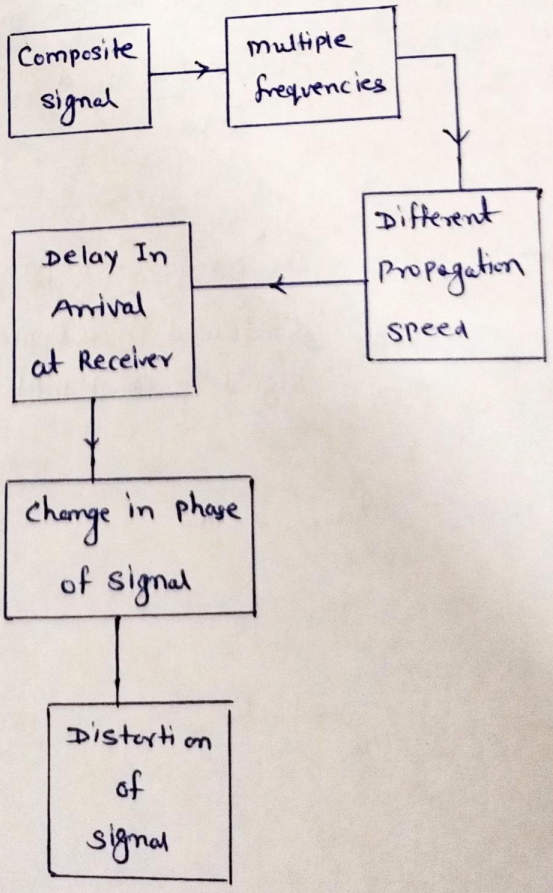
1) Attenuation :-

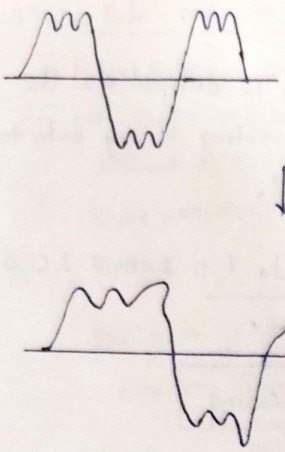
- Loss of energy of a signal during transmission.
- Use of Amplifieres to strengthen the signal again.
- Unit :- decibel (dB)

$$dB = 10 \log_{10}\left(P_2/P_1\right)$$

2) Distortion :-

- Change in the shape or form of a signal.





(Sender side)

(Receiver side)

3) Noise :-

Thermal Noise : Random motion of Electrons in a Wire

Induced Noise : Comes from External Sources like motors and appliances.

Crosstalk : Effect of one Wire on Another

Impulse Noise :- Spike in the signal.
↳ Lightening etc.

• Signal - to - Noise Ratio :- (SNR)

$$SNR = \frac{\text{Avg. signal power}}{\text{Avg. Noise power}}$$

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

$$\text{Data Transmission time} = \frac{\text{message size}}{\text{Bandwidth}}$$

* Data Rate Limits :-

• Data Rate : How fast we can send data (bps)
↳ depends : 1) Bandwidth
2) Levels
3) Noise

i) Noise Less channel : Nyquist Bit Rate
↓
• for Noise - Less channel, It defines the theoretical maximum bit rate -

$$\text{Bit Rate} = 2 \times B.W \times \log_2(L)$$

L : No. of Levels

Increasing the No. of Levels
↳ Increases the bit Rate
↳ Decreases Reliability

ii) Noisy channel : Shannon Capacity

$$\text{Capacity} = B.W \times \log_2(1+SNR)$$

SNR : No units

• This is Independent of No of Levels.

• Through Put :-
↳ Rate at which data is successfully transmitted from sender to receiver over a Network in a given time.

$$\text{Throughput} = \frac{\text{Total Data successfully Transferred}}{\text{Total Time taken}}$$

Latency :-

→ It is the time delay between when a sender transmits data and the receiver gets it.

→ Components :

1) Propagation Delay
   ↳ Time for signals to travel through the medium (fiber, copper)

$$P.D. = \frac{\text{Distance}}{\text{Signal speed}}$$

2) Transmission Delay :-
   ↳ Time to put all bits of a packet onto the link.

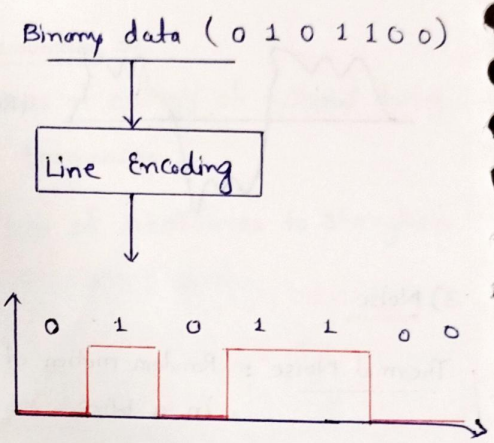
$$T.D. = \frac{\text{Packet size (bits)}}{\text{Bandwidth}}$$

3) Processing delay :-
   ↳ Time Routers / Switches take to examine packet headers and make decisions.

4) Queuing Delay :-
   ↳ Time spent waiting in queues when the Network is Congested.

Line Coding :-

→ The Line Coding is defined as the Process of Converting binary data to a digital signal.

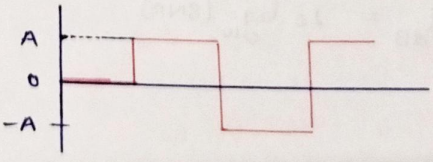


→ Characterstics :-

1) Signal level and Data level
2) Pulse Rate and bit Rate
3) DC Component
4) self synchronization

1) signal level and Data level

- The Number of values allowed in a Particular signal is defined as the Number of signal levels.
- The Number of values to represent data is called as the Number of data levels.



↳ for binary data levels = 2
↳ for this signal levels = 3

*2) Pulse Rate and Bit Rate :-

- Pulse Rate is defined as the Number of pulse per second and a pulse is defined as the minimum amount of time required to transmit a ~~signal~~ symbol.
- Bit Rate is defined as Number of bits per second

$$\text{Bit Rate} = \text{Pulse Rate} \times \log_2(L)$$

$L = 2^m$

m = No of bits per Sample

3) DC Component :-

- Over one cycle period of a Waveform, if all the (+)ive voltages are Cancelled by Negative voltages then DC Component of the Waveform is Zero.
- In Line Coding, the signal With the Non-Zero DC Component is treated as a distorted one and it Can Create Errors in received signal.
- The Signals With a DC Component Cannot Pass through a transformer Hence Zero DC Components Signals Prefered.

4) Self-Synchronization

- Clock freq. of T_x and R_x Should be Same
- $(\text{bit Interval})_{Tx} = (\text{bit Interval})_{Rx}$

* Data Element :-

→ A data element is the smallest unit of information to represent the the digital Information in binary bits.

→ In digital Communication, this usually refers to a bit (0 or 1)

Exa :- A = 01000001

↳ Each bit : data Element

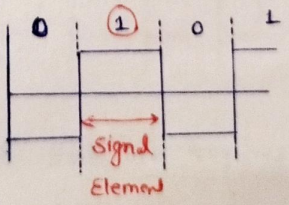
* Signal element :-

→ A signal Element is the smallest unit of signal that represents a data element in transmission.

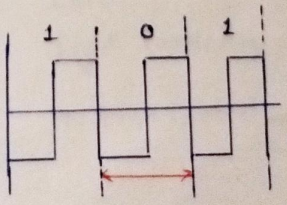
→ Part of transmitted Waveform that encodes data.

→ It may Carry one or more bit.

$$r = \frac{\text{No. of data element}}{\text{No. of signal element}}$$



$r = 1$



$r = \frac{1}{2}$

* Data Rate

- No. of data elements sent in one second
- Unit - bps
- Also called bit Rate

* Signal Rate

- No. of signal elements sent in one sec.
- Unit - Baud
- Also called pulse Rate, Baud Rate, Modulation Rate

$$S = C \times N \times \frac{1}{r}$$

Where: S = Signal Rate
C - Case factor
N - data Rate

$$BW_{min} = C \times N \times \frac{1}{r}$$

$$N_{max} = \frac{1}{C} \times BW \times r$$

* Baseline Wondering:-

→ This is a drift (shift) of the Average Voltage (baseline) away from it normal reference level.

* Types of Line-Coding:-

1) Unipolar - RZ, NRZ
2) Polar - RZ, NRZ, Bi-phase (↳ manchester)
3) Bipolar - AMI, Pseudo ternary
4) multi-Level - 2B1Q, 8B6T, 4D-PAM5
5) multi-Transition - MLT-3

1) Unipolar:- [Either +v or -v]

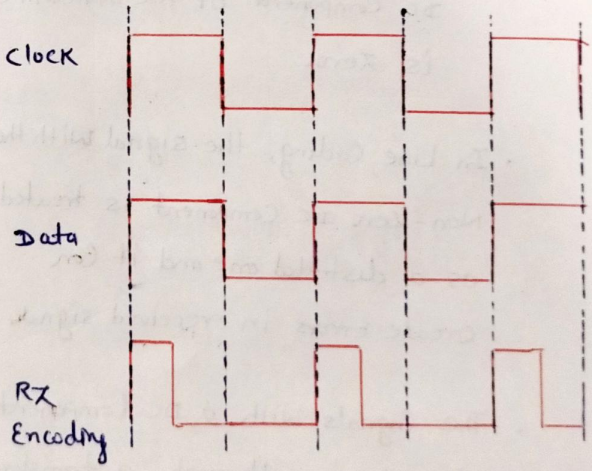
→ Also called on-off Keying (OOK)

→ presense of pulse : 1
Absense of pulse : 0

- RZ (Return to Zero)

0 (off-bit) → T_0

1 (on-bit) → $T_0/2$



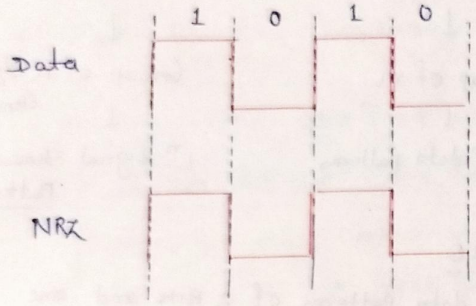
⊖ : 1) No Error Correction
2) occupies twice the BW as Unipolar NRZ.

• NRZ (Non Return to Zero)

→ 1 : Positive Voltage

0 : Zero voltage

→ duration is same as T_b (symbol bit duration).



⊕ : Lesser BW

⊖ : No Err Correction done

Loss of synchronization

2) Polar :-

→ Voltages are present on both sides of time axis.

• Polar NRZ :-

→ Uses 2 voltage levels (+V, -V)

→ Two Types -

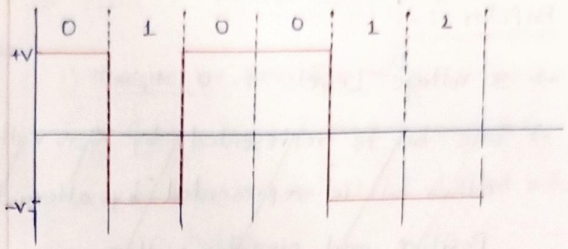
NRZ-Level : Level of voltage determines value of bit.

NRZ-Invert : change or Lack of change in the level of voltage determines the value of bit.

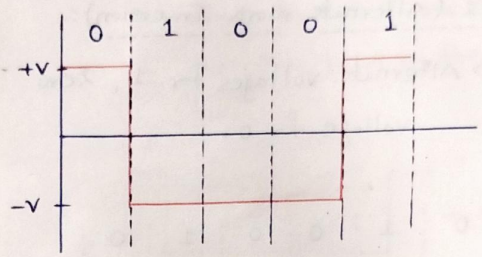
↓

No change in voltage : 0

change in voltage : 1



* NRZ-Level *



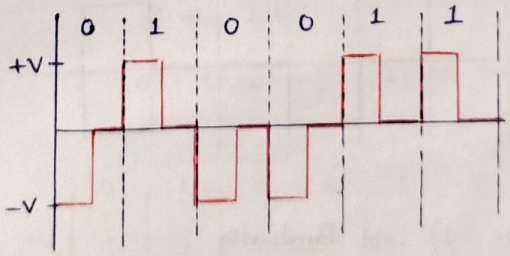
* NRZ-Invert *

• Polar - RZ

→ Uses 3 voltage Levels : +, -, 0

→ signal changes during the bit, Not between the bits.

→ Goes to zero in middle of each bit and Remains at 0 untill the beggining of Next bit.



⊖ : Each bit requires 2 changes in signal Level.

High Complexity

No Error Correction

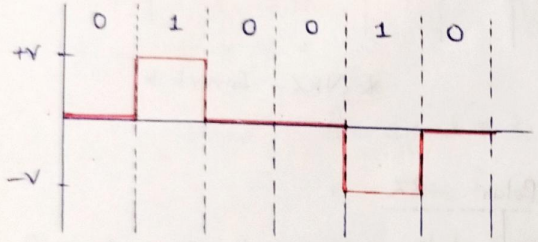
3) Bipolar :-

→ 3 voltage Levels : 0, +, −

→ one bit is represented by Zero voltage other bit is represented by alternating Positive and Negative voltage.

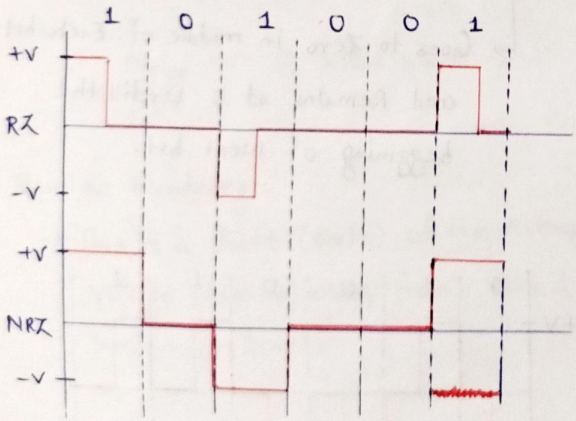
• AMI (Alternate mark Inversion):-

→ Alternate voltages for 1, Zero voltage for 0.



→ used for long distance Comm.

• RZ & NRZ



⊕: 1) Low Bandwidth

2) A Signal Err detection Capability

3) No low freq. Components are present

⊖: 1) NO clock

2) Long string of data Causes loss of synchronization

4) Multi-Level Line Coding :-

→ A pattern of m data elements into a pattern of n signal elements. → (mBnL)

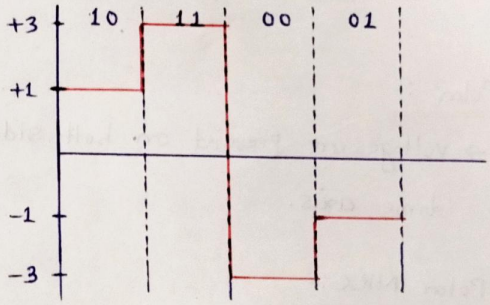
2 types of data elements → Group of m → 2^m data patterns

L types of signal elements → Group of n sig Element → L^n signal ~~Element~~ Pattern

• 2B1Q

→ data patterns of 2 Bits and one signal has 4 different Level

2 Binary + 1 Quaternary



⊕: 1) Bandwidth Efficient

2) Higher data Rate

⊖: 1) Complex Receiver Circuitry

• 8B6T :

8 Bits, 6 signal Elements Each having 3 different levels.

• 4D - PAM 5 :

→ four dimensional five level pulse Amplitude modulation.

→ Data is send over 4 wires (channels) simultaneously.

5) Multi- Transition Line Coding :-

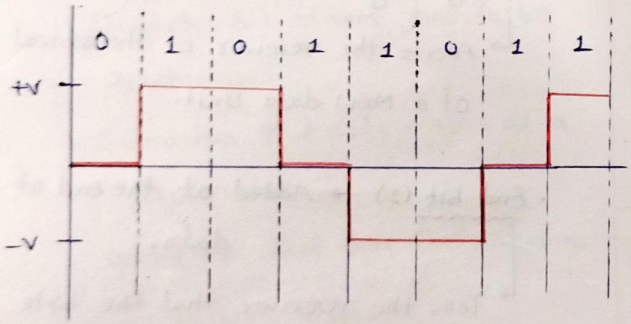
• MLT - 3 : (Multi-Line Transition using 3 Levels)

↳ If Next bit is 0 : No Transition

↳ Next bit = 1, Current Level ≠ 0
⇒ Next Level = 0

↳ Next bit = 1, Current Level = 0
⇒ Next Level is the opposite of Last Non Zero level

Data = 0 1 0 1 1 0 1 1



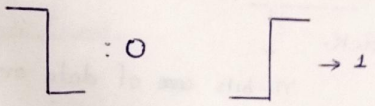
* Polar > Biphase Line Coding

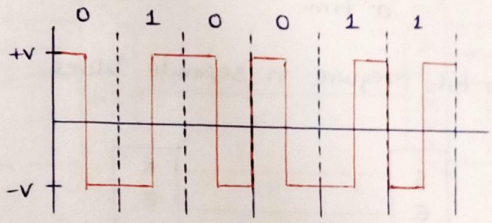
1) Manchester ~~Line~~ Scheme :

• Combination of NRZ-L and RZ

• Duration of a bit is divided into 2 halves.

↳ Voltage remains at one Level during first half and moves to the other Level in the second half.





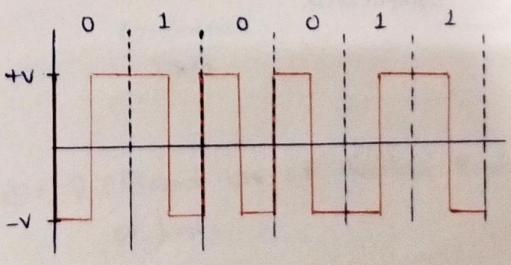
2) Diffrential manchester Scheme :.

• Combination of NRZ-I and RZ

• Signal changes in the middle of the bit.

• But valve is determined at the beggn. of the bit.

• 0 : transition, 1 : No transition



* Transmission Modes :-

1) Parallel

2) serial
   - A) synchronous
   - B) Asynchronous
   - C) Iso - synchronous

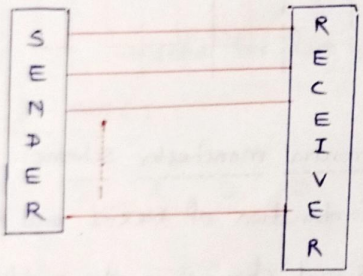
1) Parallel Transmission :-

→ multiple bits are sent with each clock tick.

↓

n - bits of data are sent at a time.

→ n bits require n separate wires.



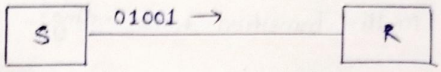
⊕: speed increased by n times

⊖: . Not cost Efficient
   . It is half - duplex
   . Transmission is unreliable and complicated.

2) Serial Transmission :-

→ one bit is sent with each clock tick.

→ Each bit follows the other on a single communication channel.



⊕: 1) Cost - Efficient
   2) used for long distance
   3) data flows in bi - direction. (full - duplex)
   4) Reliable and straight forward

a) Asynchronous :-

. Timing of a signal is not important

. start bit (0) is added at the beginning of data (8 bits as a unit)
   ↳ Alerts the receiver of the arrival of a new data unit.

. End bit (1) → Added at the end of data.
   ↳ Tells the receiver that the byte is finished.

. overhead of 2 bits.

. Can Contain gaps of varying duration
   ↓
   Represented by an idle channel or addition stop/ends bit

⊕ : cheap, effective

⊖ : Too many extra bits - slow

. used in Keyboard.

b) Synchronous:-

- Data is sent as a string of 0's and 1's → Called frames.
- frames may contain multiple bytes, sent without any gaps.
- No start bit or stop bit present.
- Receiver's responsibility to separate string of 0-1s into bytes
- Timing is very crucial for Synchronisation.

⊕: [Uneven gaps may exist between.
Faster transmission

F1	F2
1 0 0 1 1 1	0 1 0 1 0 1

c) Isochronous Transmission:-

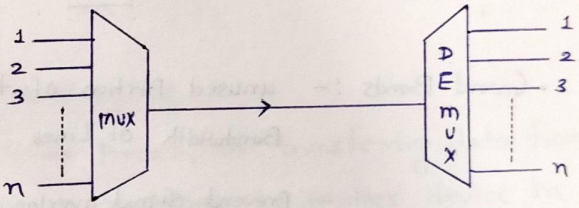
- Ensures No delays between frames.
- Complete bit stream has to be synchronised.
- Guarantees that data arrives at a fixed rate.
- Useful for Real time Communication.

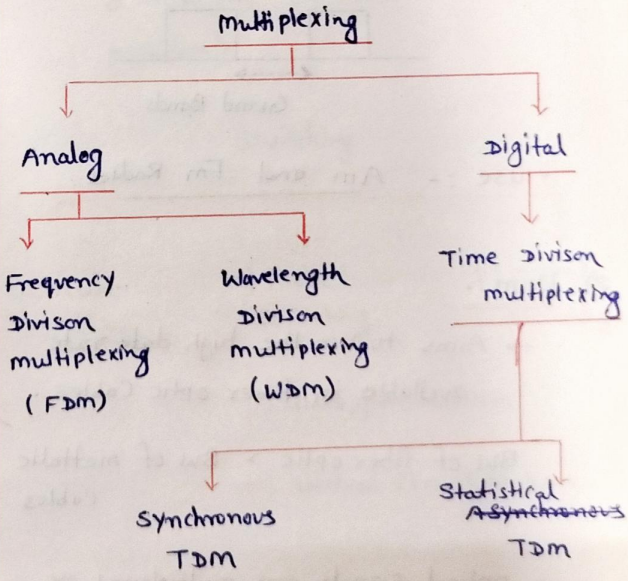
Exa- Audio, Videos

* Multiplexing:-

→ Multiplexing is the process of Combining multiple signals into one signal, over a shared medium.

→ The process of multiplexing divides a Communication channel into several Number of logical channels, alloting Each one for a different message signal or a data stream to be transferred.



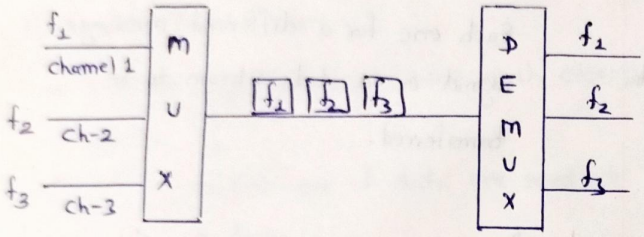


⊕: 1) Efficient use of Available Bandwidth of Link.

1) FDM :-

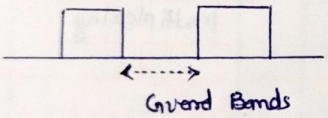
→ ~~mostly~~ multiple Carrier frequencies are used for modulating signals generated by different senders.

→ modulated signals are Combined into a single Composite signal.



• Guard Bands :- unused portion of the Bandwidth of Lines.

→ Prevent signal overlapping



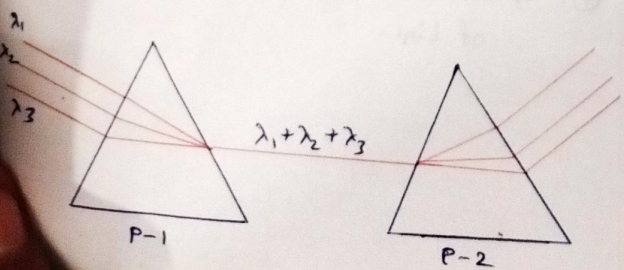
- use :- Am and Fm Radios

2) WDM :-

→ Aims to use the high data rate available in fiber optic Cables.

BW of fiber optic > BW of mettalic Cables

→ optical signals are multiplexed or demultiplexed.



Application-

Synchronous optical Networking (SONET)

• Dense WDM (~~DWDM~~ DWDM):

multiplexes a large No. of channels by spacing them very close to each other.

*3) TDM :-

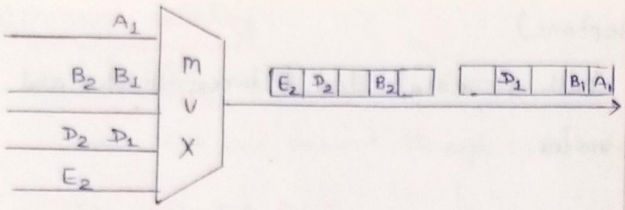
→ In this Each sender is given the entire possession of the Whole Bandwidth of the channel for a fixed duration of time, After this Control is moved to next sender, and the process Continues on the round basis.

A) Synchronous TDM :-

→ Each time slot is pre Assigned to a Constant source.

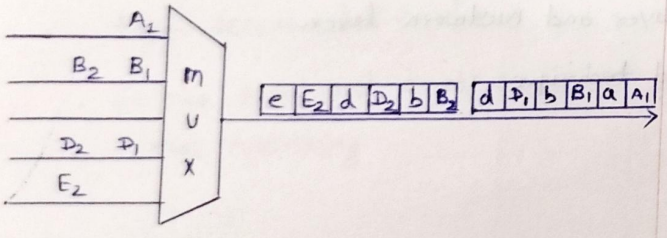
→ The time slots are sent irrespective of Wheather the sources have a few records ~~or~~ to share or not.

→ TDM devices Can manage the source of various data rates. This is Completed by authorising fewer slots per cycle to the passive input devices than the rapid device



B) Statistical TDm :-

- This is a method of multiplexing where time slots are dynamically ~~allocated~~ allocated to active input ~~lines~~ channels based on demands, instead of assigning fixed slots like in synchronous TDm.
- Each slots must include an address to indicate which source the data belongs to, since slots are Not fixed → overhead.



∵ In TDm :-

Size of Time slot = $T_t + T_p$

T_t: Transmission delay
Constant for all

T_p: propagation delay
↳ Take max so that all stations will get sufficient time to propagate their data.

- Efficiency (η) = $\frac{\text{Useful time}}{\text{Total time}}$

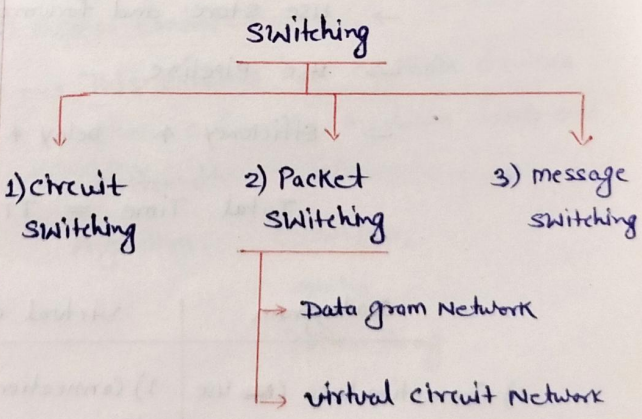
$$\eta = \frac{T_t}{T_t + T_p}$$

$$\boxed{\eta = \frac{1}{1+a}}, \quad a = \frac{T_p}{T_t}$$

- Effective BW / Throughput = $\eta \times$ BW
- Max Available Effective Bandwidth = (Total No. of Stations) x (B.W. requirement of 1 station)

* Switching :-

→ Process of transferring data from one device to another device in a network. (or from one to another Network)



1) circuit switching (Exa- Telephone)

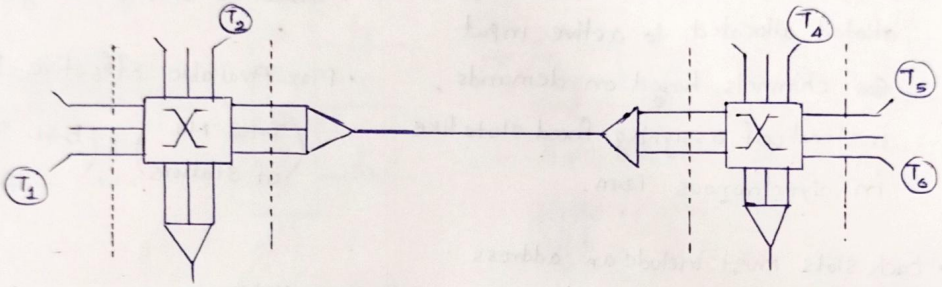
→ A dedicated Communication Path is established between sender and receiver before data transfer.

→ Works on physical Layer

→ Contiguous flow of data, No Need of headers

→ Efficiency ↓ Delay ↓

Total time = Setup time + TT + PT + Tear Downtime



2) Packet switching:- (Exa- Internet)

→ Data is divided into packets and transmitted independently over shared paths.

→ Works on Data link layer and Network layer.

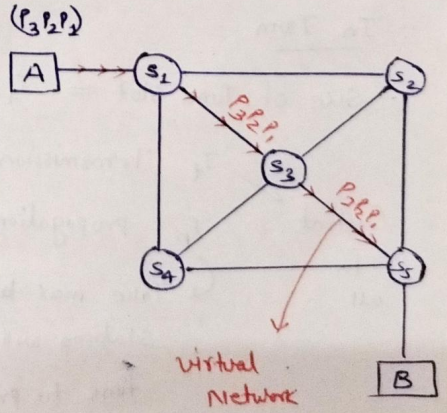
→ use store and forward technique

→ use pipeline

→ Efficiency ↑ Delay ↑

Total Time = TT + PD

Datagram	virtual circuit
1) Connection Less (~~use~~ Use Resources on demand)	1) Connection oriented (use pre defined Resources)
2) No Reservation	2) Reservation
3) out of order	3) Same order
4) Packet Loss ↑	4) Packet Loss ↓
5) Eff ↑	5) Eff ↓
6) Cost ↓	6) Cost ↑
(Internet)	(X-25, ATm)



3) message switching :-

→ Entire msg is treated as one unit and store and forward through Nodes.

→ No dedicated path

→ delay ↑

* Data - Link Layer :

- Services :-

1) framing :-

- When the ~~data~~ Network Layer gives datagram, to data link layers, It needs to be encapsulate it inside a frame

- frame = Header + Data + Trailer

- At the received side, data link layer decapsulates the frame

- defines start and end and mac Addressing

2) flow - Control :-

- This is like Producer - Consumer Problem.

  Sender : producer

  Receiver : Consumer

- Problems : If senden is faster than receiver then receiver's buffer may overflow.

- Solutions : 1) Receiver drop extra frames
  2) Receiver tells sender to pause or slow down

- Algorithm : 1) Stop & Wait
  2) Go back N
  3) Selective Repeat

3) Error Control :-

- Data travels as em signals, which can get corrupted due to Noise, Interference etc.

- Data - Link Layer must ensure:

  a) Error - detection (using CRC)

  b) Error Correction or Retransmission

  - ~~Sender~~ reqvest sender to resend the frame.

4) Hop to Hop :

- Goes data from one Node to another Node (Not destination directly)

5) Access Control :-

- This ensures how multiple devices share a Common medium fairly and efficiently.

- Algorithm : CSMA/CD,
  Aloha
  Token Ring

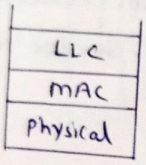
* Two Sublayers

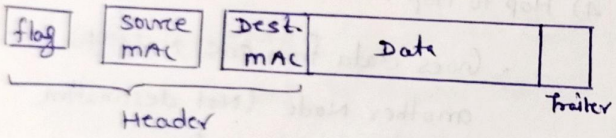
A) MAC (media Access Control)

- It defines the specific Access method for each LAN
- Avoids Collisons

B) LLC (Logical Link Control)

- Responsible for flow and Error Control





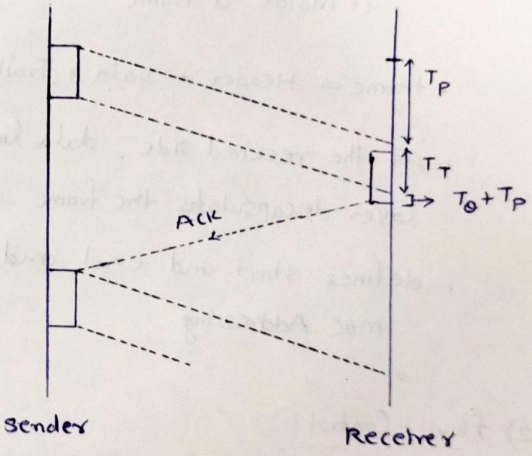
1) flow Control :-

for Noiseless channel → Stop & Wait

for Noisy channel → Sliding Window Protocol

- Stop & Wait ARQ
- Go back N ARQ
- Selective Repeat ARQ

- Stop and Wait Protocol :-
  - Used in Connection-oriented Communication.
  - Provides uni-direction data transmission with flow Control facilities without error Control.
  - After transmitting one frame, the Sender Waits for an acknowledgement before transmitting the next frame.
  - Send one data at a time.
  - Receiver Consume the data Packet then ACK send.



$$\text{Total Time} = (T_P + T_T + T_Q + T_P)_{\text{frame}} + (T_P + T_T + T_Q + T_P)_{\text{ACK}}$$

Assuming :-

1) $T_P + T_Q = 0$

2) $(T_T)_{ACK} = 0$

3) $(T_P)_{ACK} = (T_P)_{frame}$

Efficiency (η) = $\frac{\text{useful time}}{\text{Total Time}}$

$$\eta = \frac{T_T}{T_T + 2T_P}$$

$$\eta = \frac{1}{1 + 2\left(\frac{T_P}{T_T}\right)}$$

$$\boxed{\eta = \frac{1}{1+2a}} \quad \because \left(a = \frac{T_P}{T_T}\right)$$

$$\eta \propto \frac{1}{a}$$

$$\boxed{\text{Throughput} = \eta \times BW}$$

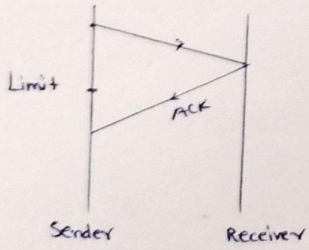
- Problems :-

1) Lost data packet

- Sender wait for ACK for an Infinite amount of time.
- Receiver also wait for Infinite.

2) Lost ACK

3) Delay ACK



- Stop and Wait ARQ :-

→ Provides Error Control and flow Control

→ Error Control in stop & Wait ARQ is done by keeping a copy of sent frame untill it receives an ACK.

→ Sender start a timer when it send a frame. If ACK is not received with in Allocated time period, then resends it.

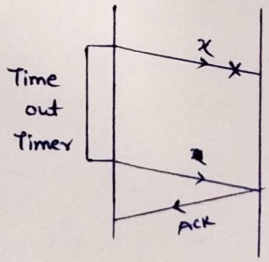
→ Receiver send a ACK.

→ ACK Number always define the Number of Next Expected frame.

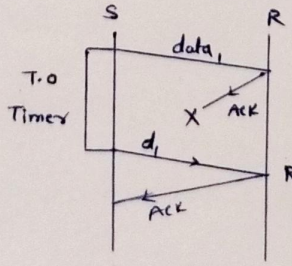
Stop and Wait ARQ = Stop & Wait + Time out + Sequence Number (data) + seq. Number (ACK)

Problems and Soln :-

1) Lost data packet :-

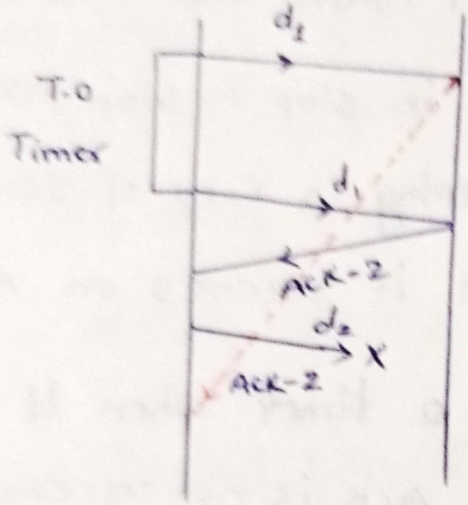


2) Lost ACK :-



Receiver Receive duplicate Packet + discard it and send ACK

5.) Delay Ack :



→ We Solve this Problem by assigning Next Expected frame Number With ACK.

$$\eta = \frac{T_T}{T_T + 2T_p}$$

⇒ Total Waiting time = Stop & Wait Time + Sender time out + Receiver time out

$$\eta = \frac{1}{1 + 2a}$$

Throughput = $\eta \times BW$