3/01/25

UNIT - I

Network Models and Physical layer

* Data Communications

→ Communication - sharing of information (local or remote)
remote - communication over distance
local - Face to Face

→ Telecommunication - telephony, telegraphy, television
- communication at distance
- In Greek tele → far.

→ Information data - information presented in whatever form is agreed upon by parties creating and using data.

→ Data communication - exchange of data between two devices via transmission medium eg wire cable
- communication devices made up of h/w & s/w

→ Fundamental Characteristics of Data Communication

* Delivery - system deliver data to correct destination
* Accuracy - system deliver data accurately without alteration
- If altered & uncorrected then it is unreable
* Timeliness - Deliver data in timely manner else useless.
- Happens in real time audio & video transmission
* Jitter - Variation in packet arrival time
Eg). If video packets sent every 30 ms
But at receiver side if some packet arrives at 30 ms & other packets arrives at 40 ms.
it will lead to uneven video quality

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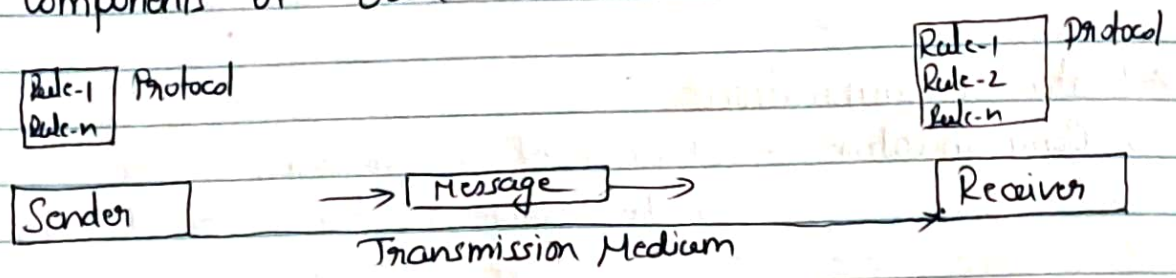
* Components of Data Communication



→ Message : information or data to be communicated
→ sender : Devices that sends data msg. eg) computer
→ Receiver : Devices that receives msg
→ Transmission Medium : physical path. eg) twisted pair wire
coaxial cable, fiber optic cable
→ Protocol : set of rule that govern data communication.

* Data Representation

① Text : in communication data represented as bit pattern 0 or 1

: Different bit pattern followed called coding or code

: Eg). Unicode → use 32 bit to represent symbol.
: ASCII - American Standard Code for Information Interchange
- use unicode for first 127 character.

② Number : Represented by bit pattern
: ASCII not used
: Directly converted to binary number.

③ Images : Represented by bit pattern
: Matrix of pixel - size of matrix depends on resolution of image

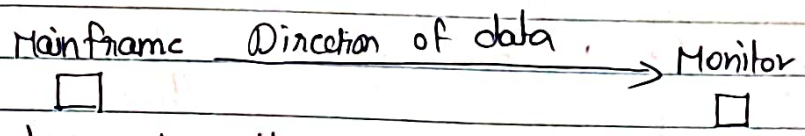
: Each pixel is assigned a bit pattern
: size & value of pattern depends on color of image
: Eg) only b/w image - 1 bit pattern
Gray scale image - 2 bit pattern
black → 00, dark gray → 01, light g → 10, white 11

RGB for color image
YMCM

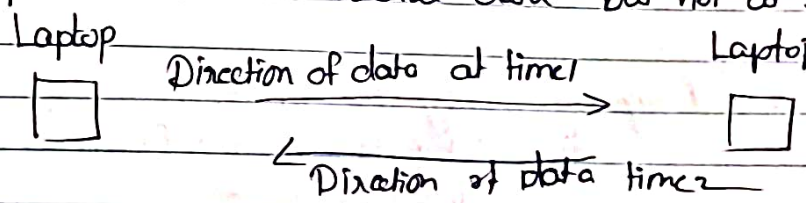
③ Audio :: sound or music
continuous data not discrete

④ Video : picture or movie
can be continuous (eg camera) or discrete (image).

* Data Flow
① Simplex - unidirection, eg) keyboard, monitor. entire capacity of channel for one way comm

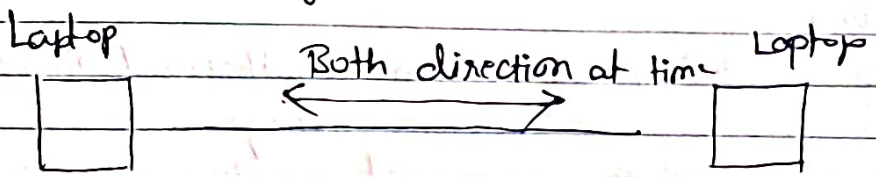


② Half Duplex - transmit & receive data but not at same time.



eg) walki talkies

③ Full Duplex : two way comm at same time. eg) telephone.



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* Networks

* Network → Interconnection of set of devices capable of communication.

Device
- → Host → computer, laptop, workstation, Mobile phone
- → connecting devices – router, – connect N/w to other N/w
  - switch – connect device together
  - Modem – changes form of data.

* Network criteria

→ Performance

Measurement metrics
- ↳ Transit time → time required for a msg to travel from one device to another
- ↳ Response time → elapsed time between inquiry and response

↳ other factors – number of users, type of transmission medium, capabilities of connected h/w

Evaluation metrics
- ↳ throughput
- ↳ Delay

} We need more throughput & less delay

→ Reliability

↳ measured by
- frequency of failure,
- time taken to recover from failure
- Network's robustness.

→ Security

↳ protecting data from unauthorized access

" " " from damage

↳ implementing policies and procedures for recovery from breaches.

* Physical Structure

→ Types of connection

↳ Point to Point connection

↳ dedicated link b/w two devices

↳ entire capacity of link is reserved for transmission b/w two devices.

↳ Eg). TV channel change using IR remote control device

↳ Multipoint. (or) Multidrop

↳ More than two devices share the single link

↳ capacity of link is shared (either spatially shared or temporally shared)

↳ spatial sharing → several device use the link simultaneously

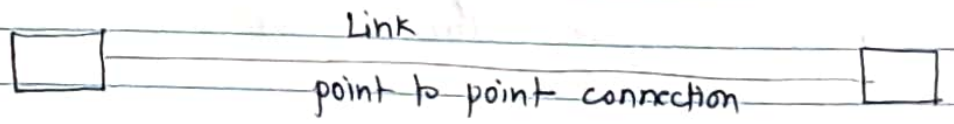
↳ Temporally shared → user or device take its own time turn to use the link.

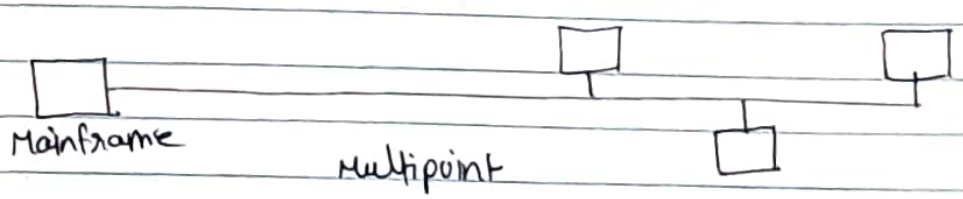
→ Physical Topology

↳ Refers to the way in which network is laid out physically

↳ Geometric representation of relationship of all the link and linking device to one another.

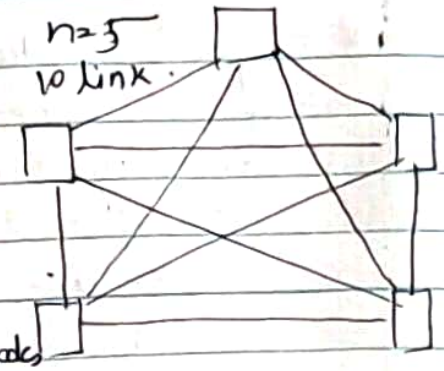
↳ 4 Types - 1) Mesh 2) Star 3) Bus 4) Ring.





→ 1) Mesh Topology (Fully connected)

↳ Dedicated point to point link to every other device



↳ To calculate no. of physical link with n-nodes.

Node 1 must be connected to n-1 nodes

Node n must be connected to n-1 nodes

So we need $n(n-1)$ physical link

If physical link allows communication in both way then divide no. of link by 2 (duplex mode)

So we need $n(n-1)/2$ duplex mode link

Also every device must have $(n-1)$ I/O ports

↳ Advantages

1) dedicated link : eliminate traffic problems

2) Robust : if one link fails, it will not affect other.

3). Privacy or security : only intended recipient can see msg

4) Easy fault identification & fault isolation.

↳ Disadvantage

1) Installation and reconnection are difficult

2). Bulk of ~~wire~~ wiring

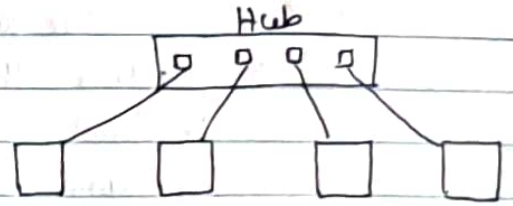
3). More expensive due to h/w requirement is high.

→ 2) Star Topology

↳ Each device has point to point link to only central controller HUB

↳ Devices not linked directly to each other

↳ Devices send msg to hub, which in turn forward to another device



↳ Advantages

1) Less expensive than mesh each devices needs only one link & I/O port.

2) Easy to install & reconfigure

3) Needs only less cabling.

4) Robustness → If one link fail, it will not affect other

↳ Disadvantages

1) Entire N/W depends on hub, if Hub fails, then N/W is dead.

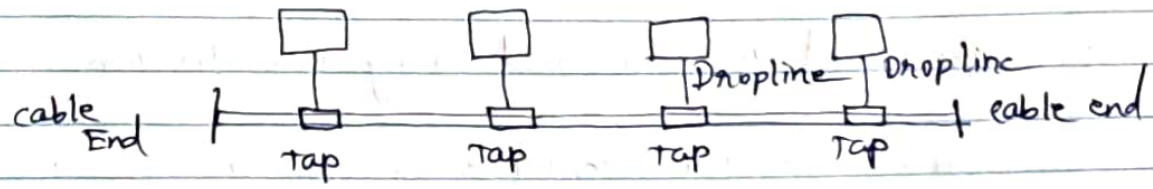
2) Requires more cabling than other Topology except Mesh.

↳ Mesh topology used to build LAN

3) Bus Topology

↳ Multipoint connection used in single cable

↳ one long cable act as a backbone to link all devices



↳ Drop line is connection running between devices & main cable.

↳ Tap is a connector that splices into the main cable

↳ Data signals becomes weaker when it travels long distance through backbone cable

↳ This is due to heat generated

↳ To reduce this

↳ limit the no. of taps

↳ limit the distance b/w taps.

↳ Bus topology used to build LAN in earlier day but not now

↳ Advantages

① Easy to install

② Requires less cabling when compared to Mesh & Star

↳ Disadvantage

① Difficult for reconnection & fault isolation

② Difficult to add new device later to bus

③ Data signal degradation.

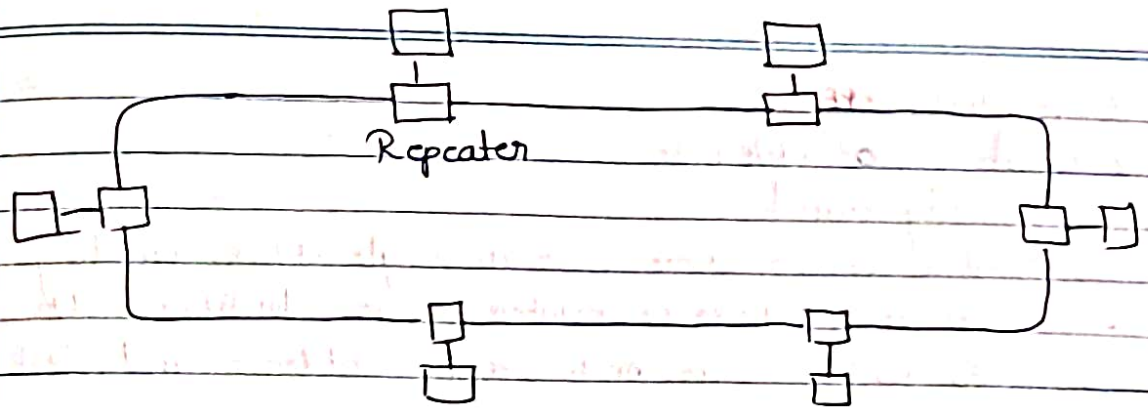
④ Fault in bus cables stops all data transmission

→ ④ ~~Star~~ Ring Topology

↳ Each device has dedicated point to point connection with only 2 devices on either side. of it.

↳ Data signal is transferred along one direction.

↳ Device other than intended ~~to~~ receiver will use its repeater to regenerate the bits & passes them along



↳ Advantages

1) Easy to install & reconfigure
2) Addition or deletion of devices requires only changing two connections
3) Fault isolation is simplified.
   ↳ Faulty devices will send alarm to N/w operator when it do not receive data signal within specific time

↳ Disadvantages.

1) Unidirectional traffic
2) Break in ring cable will disable entire N/w
   ↳ solved using dual ring or switch devices.

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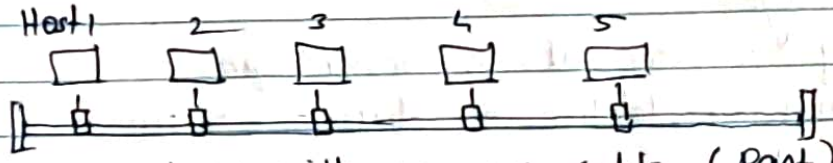
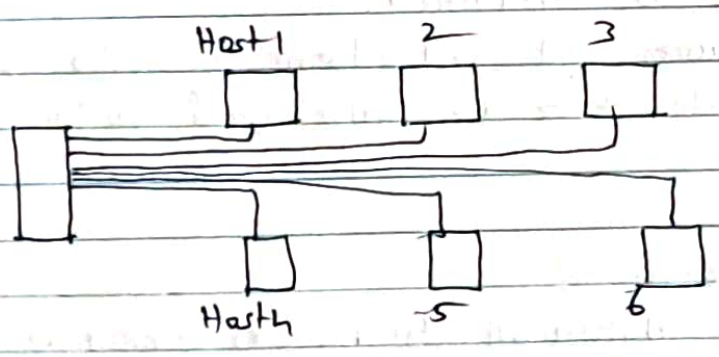
* NETWORK TYPES

* Local Area Network

→ Privately owned
→ Used to connect some host in single office, building or campus
→ Each host (system or printer) has identifier (address) unique
→ Data packet has both source address and destination address.



LAN with common cable (Past)



LAN with switch (today)

→ 2 types of LAN

① LAN with common cable (past)
↳ All connected host receive packets sent any ~~recei~~ one host.
↳ Only intended host kept packet, other drop

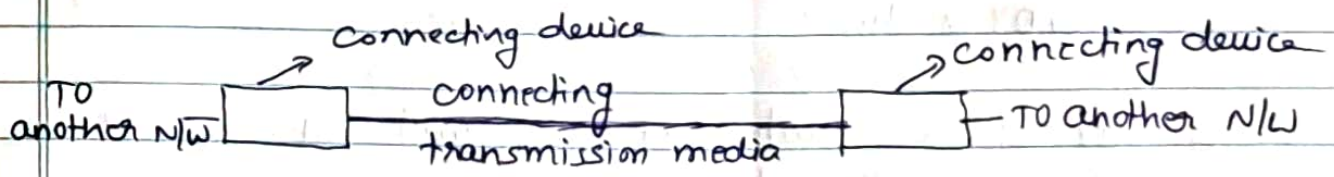
② LAN with switch (Today).
↳ smart connecting switch used
↳ Recognize the destination address of packet and guide it to be received to destination host.
↳ Reduce traffic in LAN
↳ Enable more than one pair of communication in parallel.

* Wide Area Network (WAN).
↳ Interconnection of devices for communication purpose.
↳ Difference b/w LAN & WAN

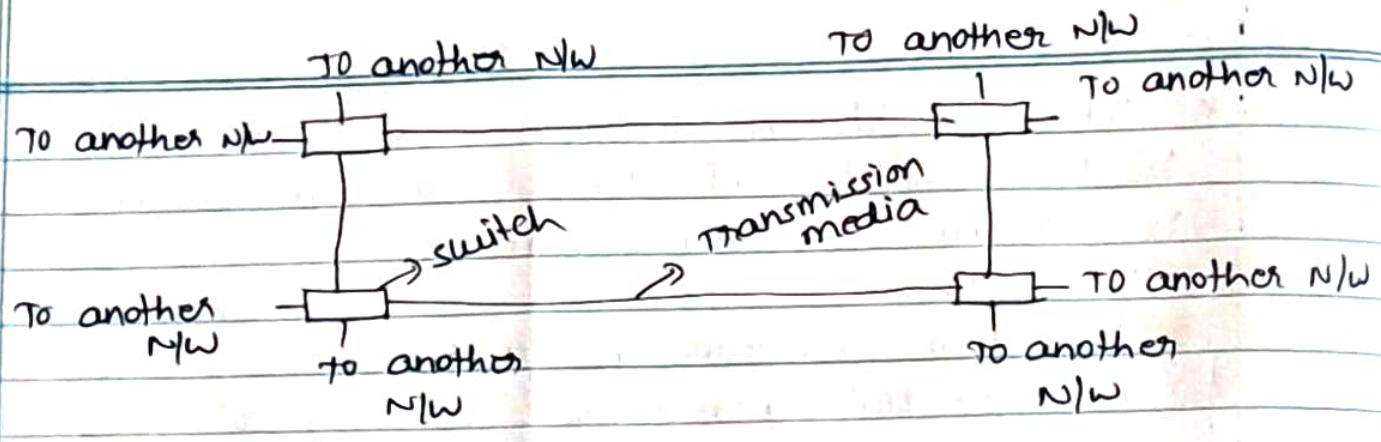
LAN	WAN
① Limited in size. spanning to office, building or campus	① Has wider geographical area spanning to town, state, country even world
② Interconnect hosts	② Interconnect connecting device such as switch, router, modem
③ Privately owned by organization	③ Created and run by communication ~~devices~~ companies & leased by organization that use it.

→ ~~Two~~ Three example for WAN or Three types of WAN

① Point to Point WAN
↳ N/W that connects two communicating devices through media (transmission medium) cable or air.

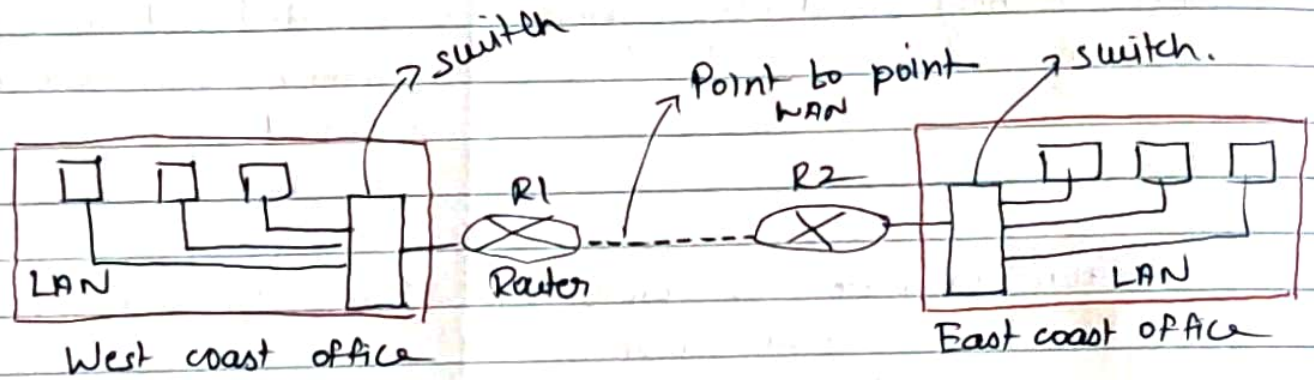


② Switched WAN
↳ N/W with more than two ends
↳ It is used in backbone of today's global communication
↳ It is combination of several point to point WAN that are connected by switch.



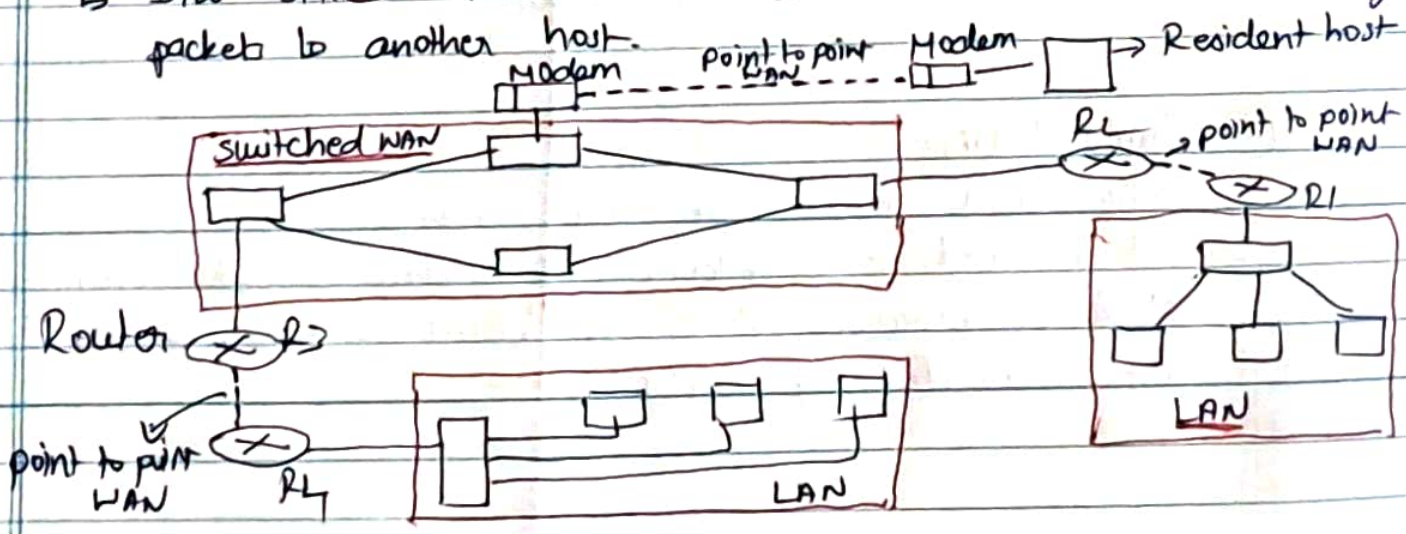
③ Internetwork (or internet).

↳ It is two or more N/W connected together.



↳ within office switches will take care of routing packets to another host

↳ B/W office Router (R1 & R2) will take care of routing packets to another host.



* SWITCHING

→ Internet is a switched N/W

→ Switch - forward data from a N/W to another N/W

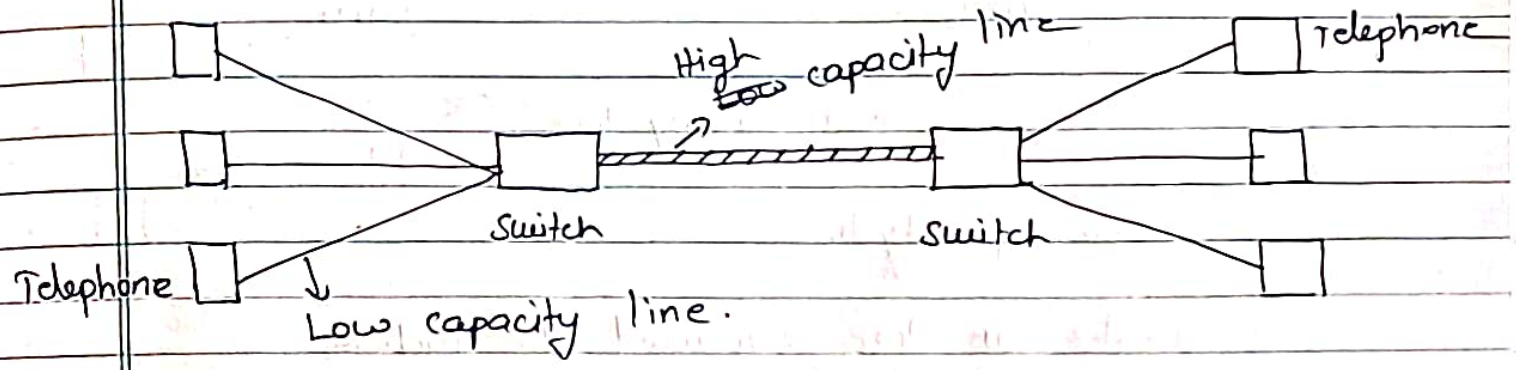
→ 2 types

1) Circuit switched
2) Packet switched.

1) Circuit Switched N/W

↳ ~~Del~~ Dedicated connection (called connection) available b/w two end system.

↳ Switch can make the circuit to active or inactive



↳ High capacity line can able to handle more than one communication parallely.

↳ Circuit switched N/W - inefficient when it is used partially. by only one communication pair

↳ Here, switches will not store any data, it will simply forward the data.

↳ ~~Here~~ Mostly used in telephone N/W, where communication is continuous.

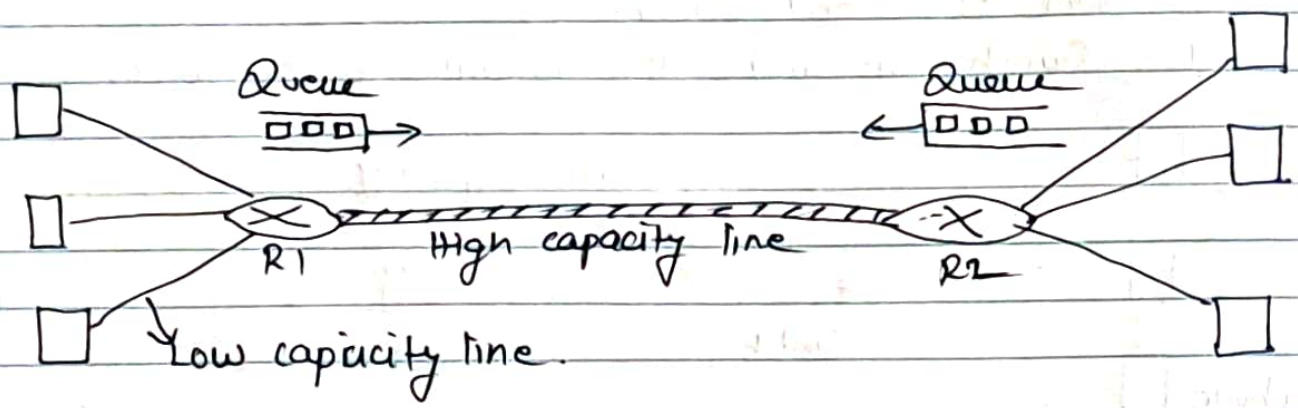
2) Packet Switched Network

↳ In Computer N/W

↳ communication b/w two host involves block of data called **Packet**

↳ Here switches can able to store and forward the data packets

↳ Because, packet is an independent entity that can be stored & sent.



↳ Router can store & forward the packet.

↳ When High capacity line is working at its full capacity, then new packets at router will be stored and sent later

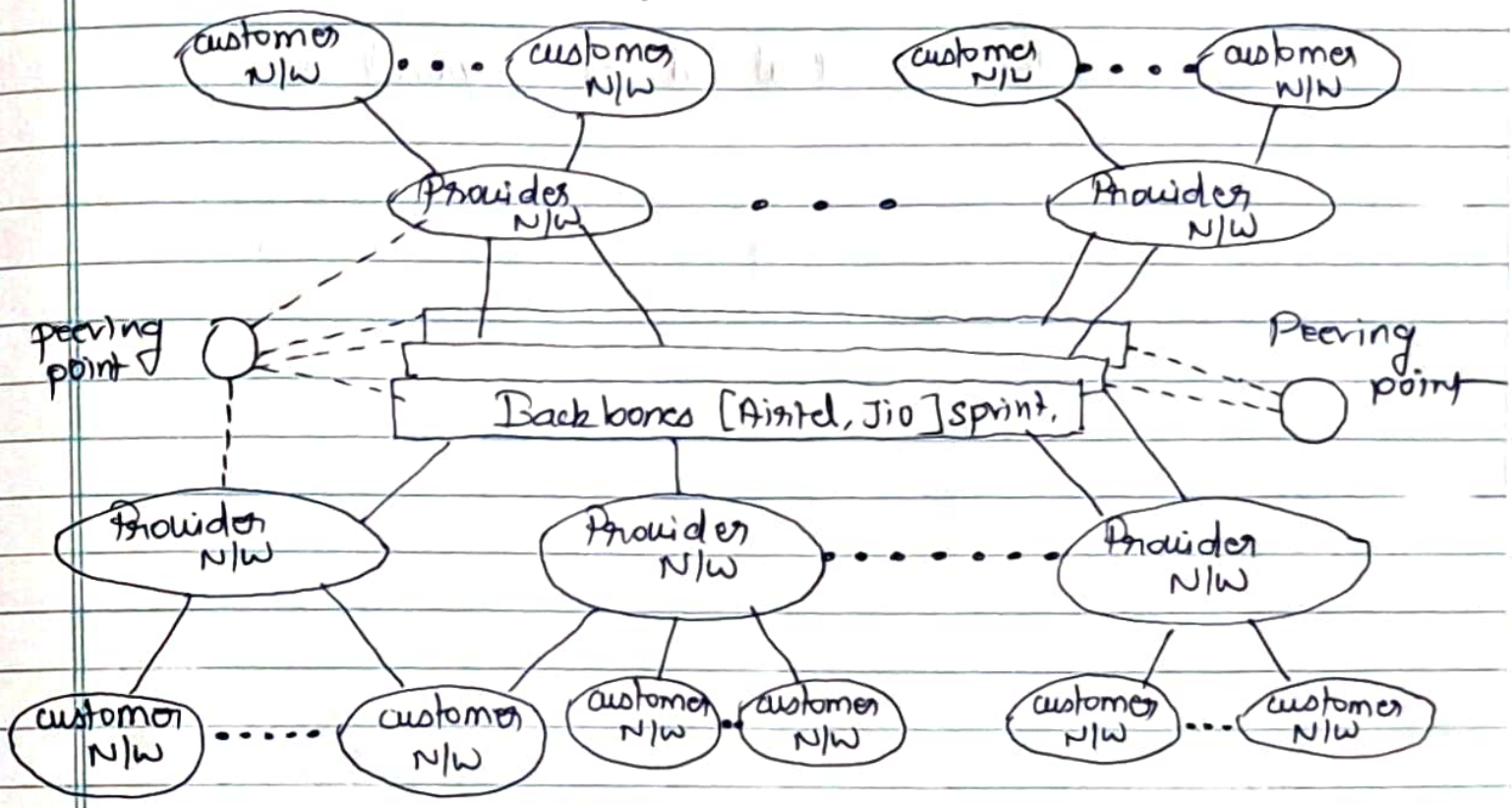
↳ Hence packets may encounter some delay.

* The Internet.

↳ Difference b/w internet & Internet.

↳ internet → connecting 2 or more n/w

↳ Internet → connecting thousands of N/W.



TOP LEVEL

→ Backbone → Large N/w owned by communication companies.

Eg). Sprint, Verizon, AT&T.

→ Peering Point → Backbone n/w connected through peering points.

SECOND LEVEL

Provider N/w → small & use services of backbones for fee.
→ connected to backbone & something to other provider.

Customer N/w → Edge user of internet
→ Pay fee to provider.

→ Backbone & Provider N/w also called Internet Service Provider. [ISP]

→ Backbone → International ISP

→ Provider → National or Regional ISP.

* Accessing the Internet.

→ To avail internet facility
- ↳ any user needs to physically connected to ISP.
- ↳ Normally done through point to point WAN.

→ 2 ways.

① Using Telephone N/W.
- ↳ User or business use internet by connecting to telephone line
- ↳ by converting voice line into point to point WAN.
- ↳ 2 ways

Ⓐ Dialup Service
- ↳ modem used to convert data to voice
- ↳ very slow
- ↳ when one line used for internet then it cannot be used for voice.

Ⓑ DSL Service
- ↳ High speed internet.
- ↳ Single line can be used simultaneously for internet & voice.

② Using Cable N/W.
- ↳ using cable TV service
- ↳ Cable service providers connect to internet (ISP)
  - ↳ upgrade their cable N/W
  - ↳ provid internet to cable user.
- ↳ High speed.

③ Using Wireless N/N.
↳ Use combination of wired & wireless connection to access internet.
↳ Wireless WAN used.

④ Direct connection to internet.
↳ Large organization or corporation use it
↳ Lease a high speed WAN from carrier provider & connect directly to ISP.
↳ Eg) Large ~~un~~ university with several campus.

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* TCP / IP Protocol Suite. (Transmission Control Protocol / Internet Protocol).

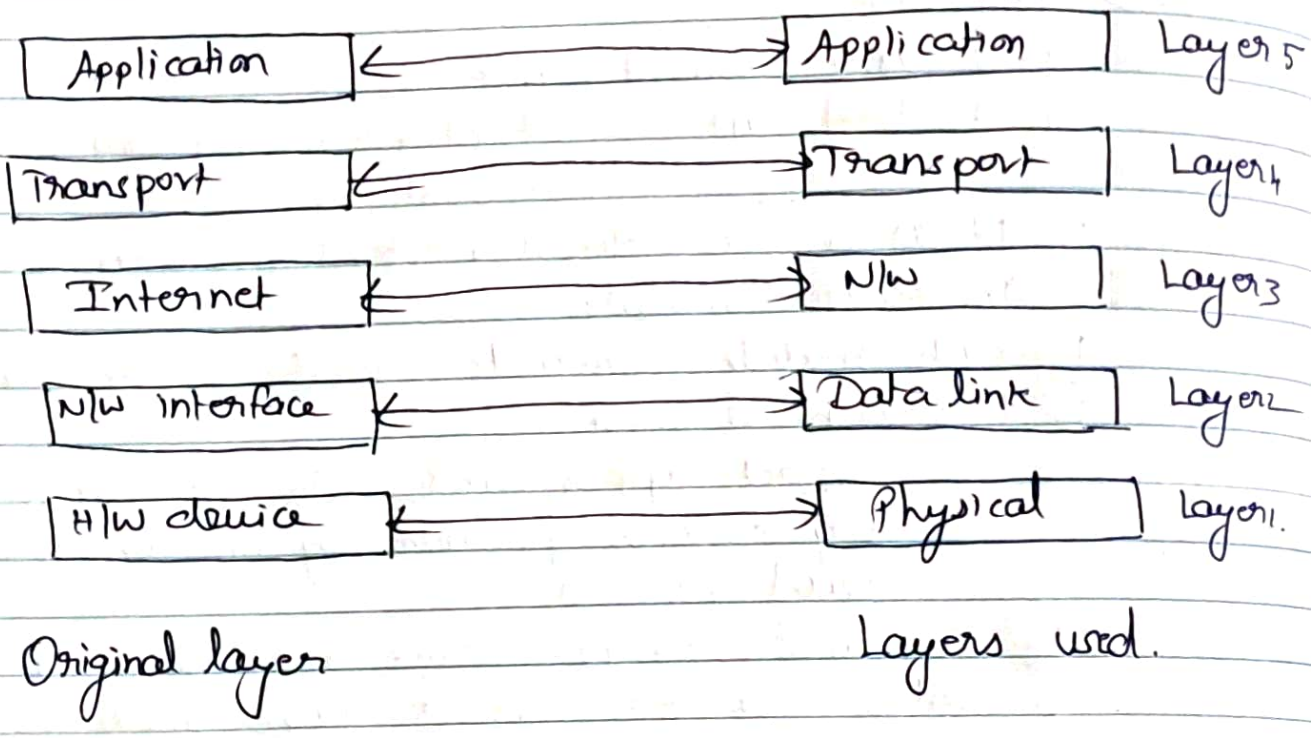
* Layered Architecture.

→ TCP / IP
- ↳ It is a protocol suite
- ↳ Protocol suite → set of protocols organized in different layers.
- ↳ It is a hierarchical protocol made up of interactive modules
- ↳ each module provide specific functionalities.
- ↳ Hierarchical mean
  - ↳ Each upper level protocol is supported by services provided by one or more lower level protocol.
- ↳ Original TCP / IP suite has 4 s/w layer
- ↳ Lates TCP / IP has 5 layer module.

* Layered

* Layered Architecture.

Figure: Layers in TCP/IP protocol suite.



→ Example

↳ A communicates with B in

↳ 5 communicating involved ~~between~~ A to B communi

① source host (A)

② Link layer switch (L1)

③ Router

④ Link layer switch (L2)

⑤ Destination host (B)

↳ Each devices involves set of layer
↳ based on its role & functionality.

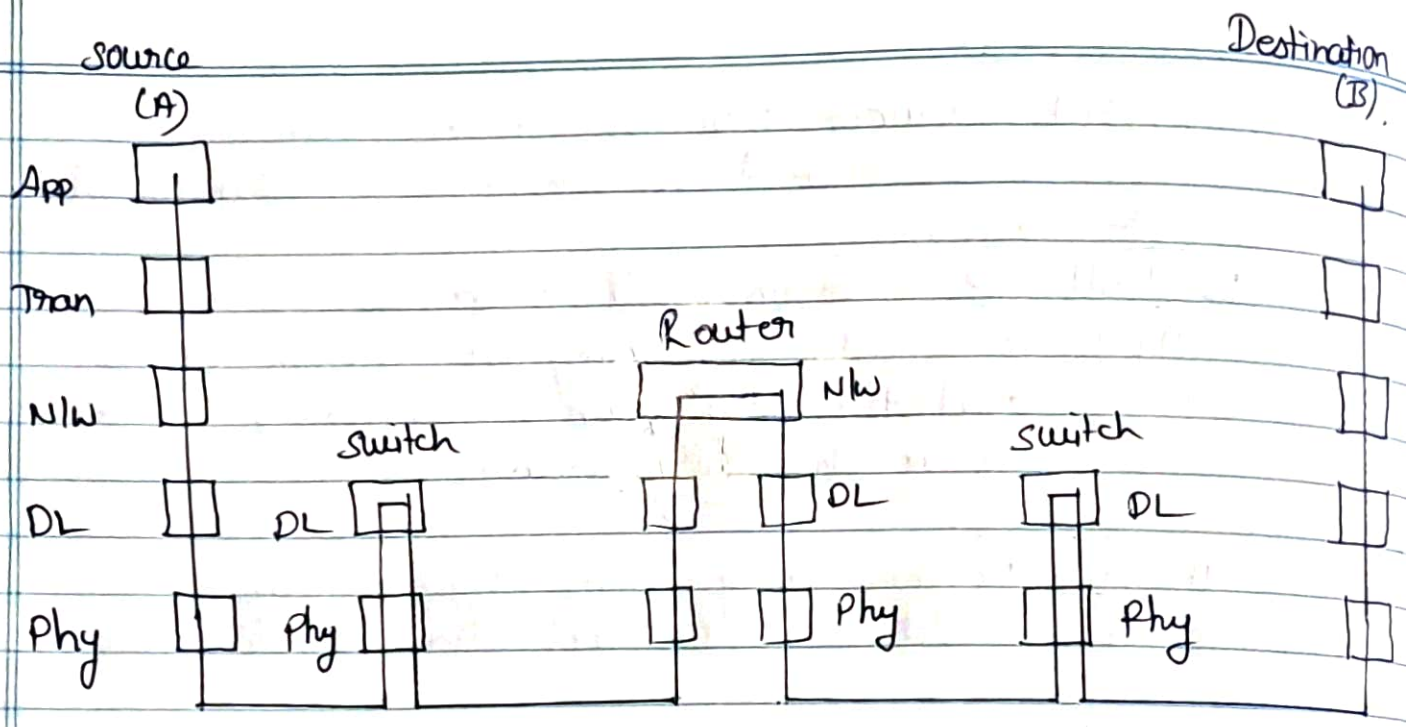
→ **Host** (H1 & H2).
↳ Both host involves all 5 layers
H1 ↳ It create msg using application layer
↳ send that msg down to remaining layer so that it is physically transferred to destination Host (H2).

H2 ↳ Receives msg from physical layer
↳ & deliver it to application layer throug remaining Layer.

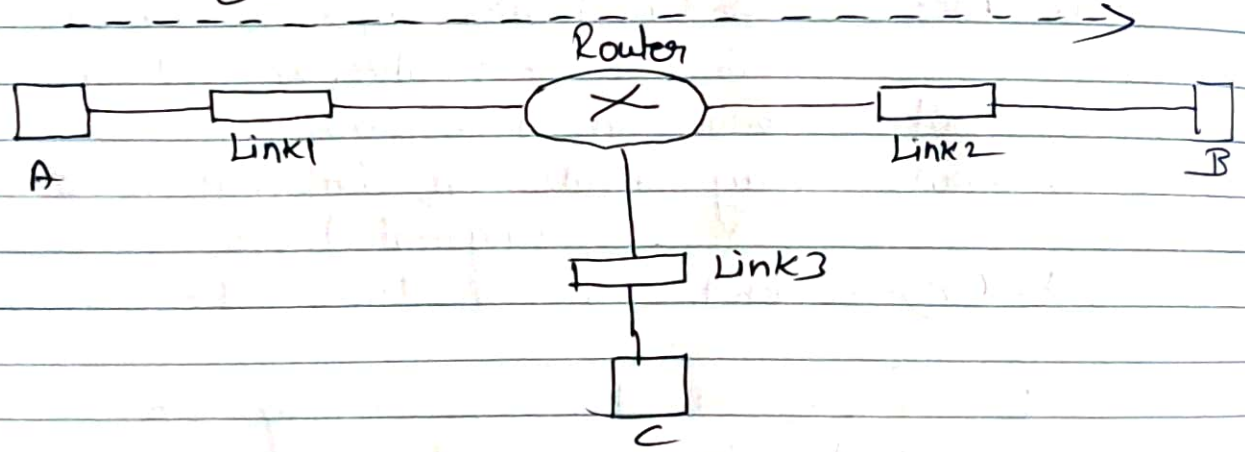
→ **Router**
↳ Involves only 3 layer (N/w, Data link, physical).
↳ Not use → Application layer & Transport layer
→ Because router is used only for routing purpose.
↳ Router involves one N/w layer.
↳ Router may involve (n) combination of Data link & physical layer.
↳ (n) → denotes no. of links the router is connected

↳ A to Router link } may use different
Router to B link } link layer & phy layer protocol.

→ **Link Layer switch**
↳ Involves datalink & Physical layer.
↳ switch link connection use only similar protocols
↳ Hence only one datalink & Physical layer are used.



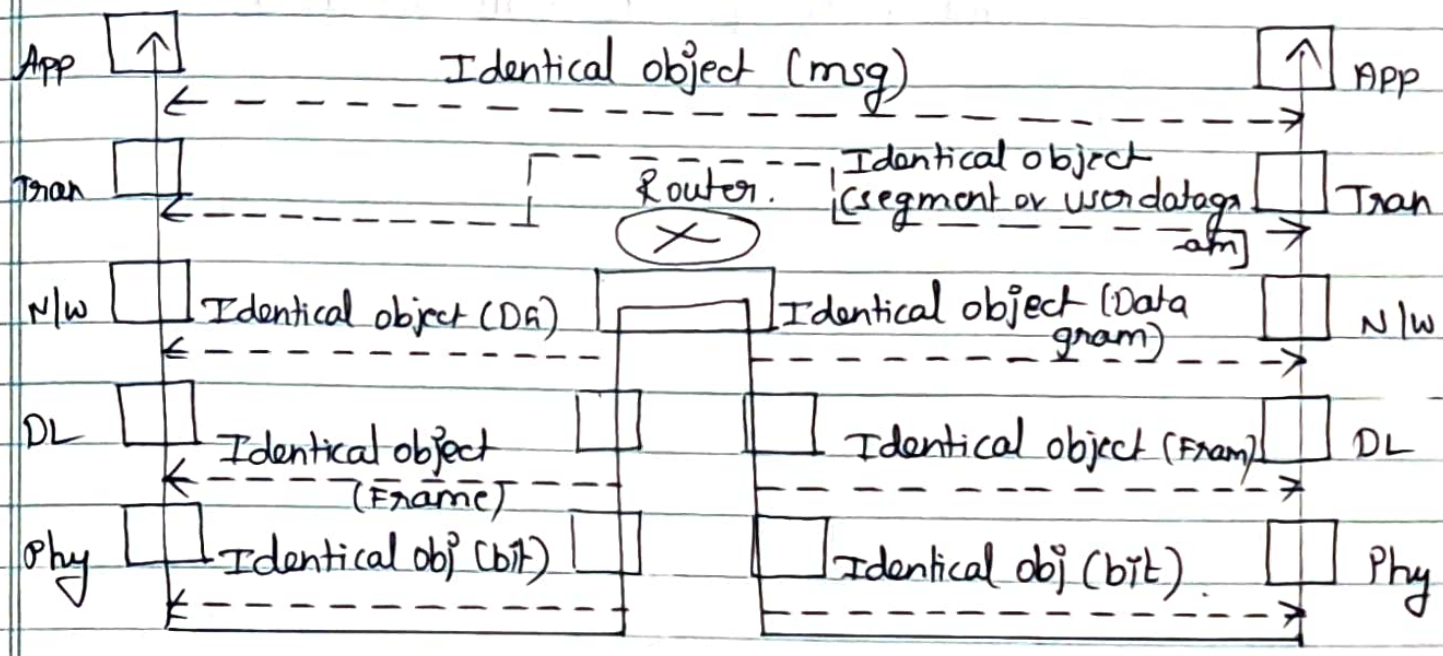
Communication from A to B



* Layers in TCP/IP Protocol suite.

→ Figure- Identical object in TCP/IP protocol suite.

→ Note : switches not shown because they don't change object.



→ Link or duty of application, transport & N/W layer are End to End

→ Link or duty of Data Link (DL), Physical layer are Hop to Hop Hop → Host or router

→ End to End
  ↳ Domain of duty is internet
  ↳ Data units (packets) will not be changed by router or link layer switch

→ Hop to Hop
  ↳ Domain of duty is link
  ↳ packets will be changed by router not by switch.

→ Note from figure :

↳ Although logical connection at N/w layer is b/w two host

↳ we can say identical object exist b/w two hop

↳ Because, router may fragment packets at N/w layer & send more packets than received.

* Description of Each Layer.

⇒ Physical layer.

↳ Responsible for carrying individual bits in frame accross link.

↳ Connection b/w two physical layer is logical

↳ Transmission media (cable or air) act as hidden layer in physical layer

↳ Transmission media → establish physical communication b/w host.

↳ Transmission medium do not carry bits, instead it carray electrical signal or optical signal.

↳ Logical unit b/w two physical layer is bit

↳ Protocols used to convert bits into signal.

⇒ Data Link Layer.

↳ Internet made of several link (LAN, WAN) connected by router

↳ overlapping link exist b/w source & destination.

↳ Router choose best link b/w source & destination.

↳ Next, Datalink layer takes datagram & move accross the best link b/w source & destination.

↳ Different protocol may be used with any link type (Wired LAN, Wireless LAN, Wired WAN, Wireless WAN)

↳ Data link layer takes datagram & encapsulate it in packet called Frame.

↳ Data link layer Protocol provides following services
1) Error correction & detection
2) Error correction only.

↳ No specific protocol. It support standard & proprietary protocol.

⇒ Network Layer.

↳ Responsible for creating connection b/w source & destination

↳ N/w layer communication is host to host

↳ It provides mechanism & protocol for routing & addressing

↳ Router device operates at the N/w layer
↳ uses the N/w mechanism to determine & forward packets ~~to~~ along best path.

↳ Why we need n/w layer? We may add the routing responsibility to transport layer & N/w layer can be dropped.
↳ seperation of different task b/w different layers
↳ Router do not need application & transport layer
↳ seperating task allows to use few protocols on router.

↳ Use mainly Internet Protocol (IP)

↳ IP defines format of packet called data ~~frame~~ gram

↳ IP also defines formats of structure of address used in N/W layer.

↳ IP also responsible for routing the packet from source to destination.
  ↳ achieved by each router in the path by forwarding datagram to next router.

↳ IP
① It is connection less protocol
  ↳ No flow control
  ↳ No Error control
  ↳ No congestion control

  } If any of these required by application, then it should rely on transport layer.

↳ N/W layer include
  ↳ unicast (~~point to point~~) (One to one) protocol
  ↳ multicast (one to many) protocol
  ↳ creates forwarding table for routers
    Helps in routing process of routers

↳ N/W layer also has auxiliary protocol
① Internet Control Message Protocol (ICMP)
  ↳ Help IP to report problem in routing

② Internet Group Management Protocol (IGMP)
  ↳ Help IP in multi tasking.

③ Dynamic Host Configuration Protocol (DHCP)
  ↳ Help IP to get N/W layer address for host

④ Address Resolution Protocol (ARP)
↳ Help IP to find link layer address of host or router when n/w layer address is given.

⇒ Transport Layer.
↳ Logical connection at transport layer is end to end

↳ Transport layer @ source host
↳ get msg from app layer
↳ encapsulate msg into datagram or segment
↳ Transport layer @ destination host
↳ Receives segment through logical connect from source transport layer

Why we need end to end transport layer when we already have end-to-end application layer?
↳ For seperation of task & duties.
↳ Transport layer should be independent of App layer

↳ Transport layer support more no. of protocols.

① Transmission Control Protocol (TCP)

↳ connection oriented protocol

↳ establish logical connection b/w transport layers at two host before transferring data

↳ provides Flow control

Normalize datarate b/w source & destination

↳ provides error control

Guarantee segment arrive at destination without error

↳ provide congestion control

Reduce loss of segment due to congestion in N/W

② User Datagram Protocol (UDP)

↳ connectionless protocol

↳ transmits user datagram without creating logical connection

↳ each datagram is independent

↳ Do not provide flow, error & congestion control.

↳ can not offer retransmission of packet

③ Stream Control Transmission Protocol (SCTP)

↳ used for multimedia

⇒ Application Layer
↳ end to end logical connection
↳ communication is b/w two process (two program running at this layer)
↳ Process to Process communication
↳ support many predefined protocols

① HyperText Transfer Protocol (HTTP)
↳ access WWW

② Simple Mail Transfer Protocol (SMTP)
↳ Electronic mail service

③ File Transfer Protocol (FTP)
↳ Transfer file from one host to another

④ Terminal N/W (TELNET) } to access site remotely
Secure Shell (SSH)

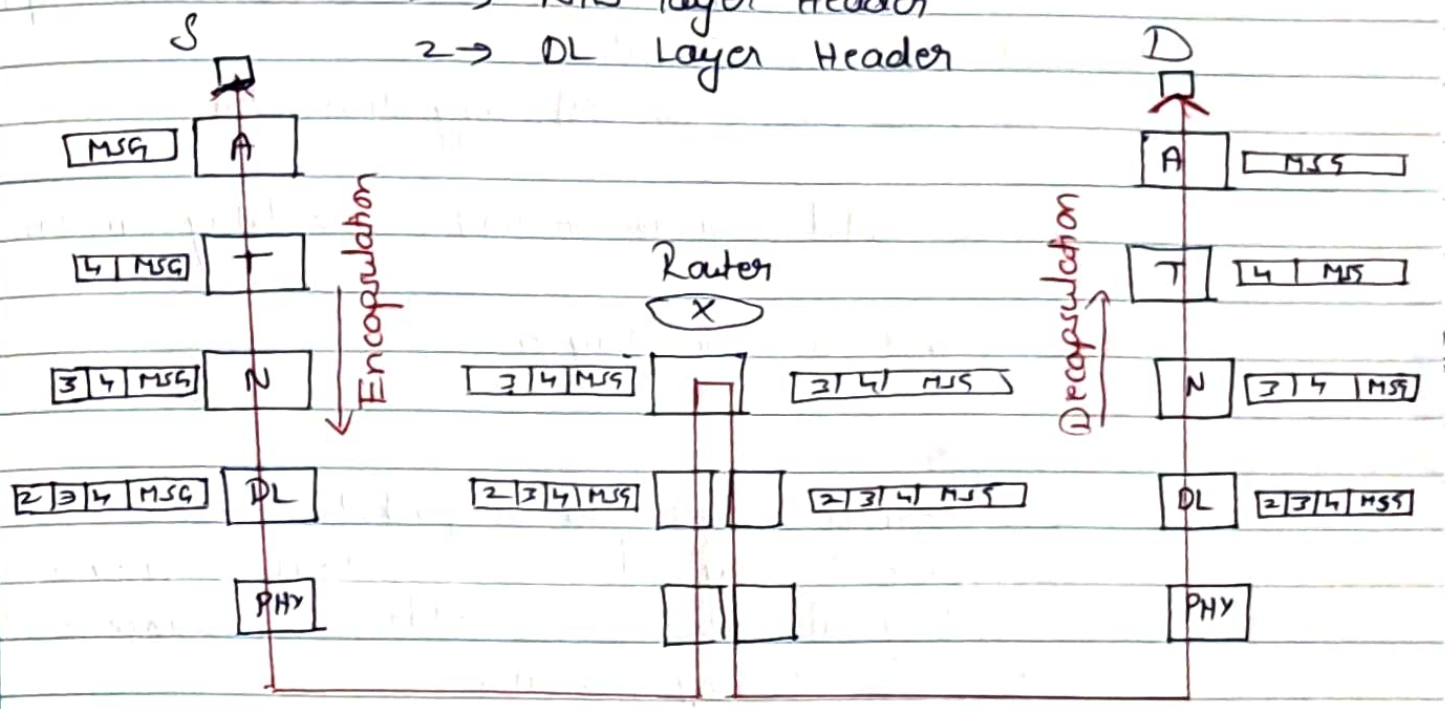
⑤ Simple N/W Mgmt Protocol (SNMP)
↳ used by admin to manage internet

⑥ Domain Name Sys (DNS)
↳ To find N/W layer address of computer.

⑦ Internet Group Mgmt Protocol (IGMP)
↳ to collect membership in group.

* Encapsulation & Decapsulation

4 → Header at Transport layer
3 → N/W layer Header
2 → DL Layer Header



Note : No encapsulation or decapsulation occur in link layer switch.

⇒ Encapsulation at Source Host

① Application Layer
- ↳ Data as message
- ↳ msg do not contain header or trailer
- ↳ msg passed to transport layer

② Transport layer
- ↳ take msg as payload (Load fat transport lay should take care)

↳ Add transport layer header (
↳ ~~Identitic~~
Identifier for source & destination app program
↳ Add additional information
↳ flow ctrl, error ctrl, congestion ctrl.

↳ o/p is called segment (in TCP), user datagram (in UDP)

↳ Pass packet to N/w Layer.

③ N/W Layer
↳ Takes transport layer data as packet
↳ Add Header to payload
↳ Logical addrs or IP addrs of source & destinati. → IPV4 or IPV6
↳ Error checking information
↳ Fragmentation information
↳ o/p is called Datagram

④ Datalink Layer
↳ Takes N/w layer data as payload
↳ Add header to payload
↳ Link layer addrs of host or next hop.
↳ Phy addrs or MAC address
(48 bit, represent as 6 Hexadecimal pair)
↳ o/p is called frames
↳ Frame passed to phy layer.

→ De capsulation & Encapsulation at Router

① Physical layer receives set of bits from its source physical layer & deliver it to Datalink layer as frame

② Datalink layer decapsulate datagram from frame & pass to N/w layer

③ N/w Layer
↳ inspect source and destination address in datagram header.
↳ consults its forwarding table to forward data to nxt hop.
↳ N/w layer ~~will~~ in router will not change data in datagram
↳ But, if datagram is too big to pass through nxt link
↳ Then fragment of datagram is done
↳ Datagram pass to datalink layer of nxt link.

④ Datalink layer (of nxt link)
↳ Encapsulate datagram into frame & pass to physical layer.

⇒ Decapsulation at Destination host
- ↳ Each layer only decapsulate packet received
- ↳ Removes the payload and deliver to nxt high layer
- ↳ Finally packet reach app layer.
- ↳ Error checking is involved at various step while doing decapsulation.

* Addressing
- ↳ Physical layer do not have any address
- ↳ 4 types of addrs used by remaining 4 layer.

↳ App layer - site name eg) Kongu.ac.in
or email addrs abc@gmail.com

↳ Transport layer
- port numer - local addrs tat distinguish b/w app layer program

↳ N/w Layer
- Global addrs, - Logic addrs

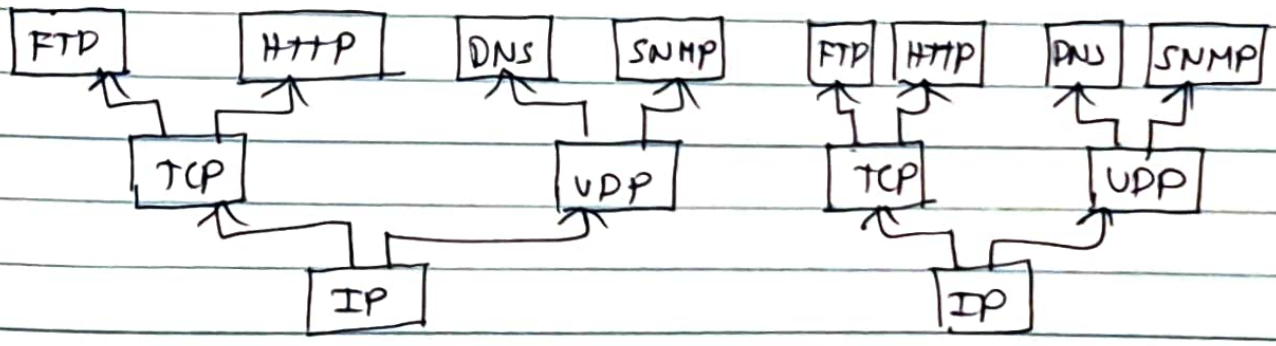
↳ DL Layer
- Phy addrs or MAC addrs

Packet Name		Addrs
Message	A	Name
segment / user datagram	T	Port numer
Datagram	N/W	Logical addrs
Frame	DL	Link layer addrs
Bits	PHY	

* Multiplexing & Demultiplexing (Protocol requires seperate field in header to identify encapsulted belong to which protocol).

→ Multiplexing
- ↳ involved at source host
- ↳ protocol at a layer can encapsulate packet from several higher layer protocolos (one at a time).

→ Decapsulate
- ↳ involed at destination host
- ↳ protocal at a layer can decapsulate packet & delivers to rxt higher layer protocols.

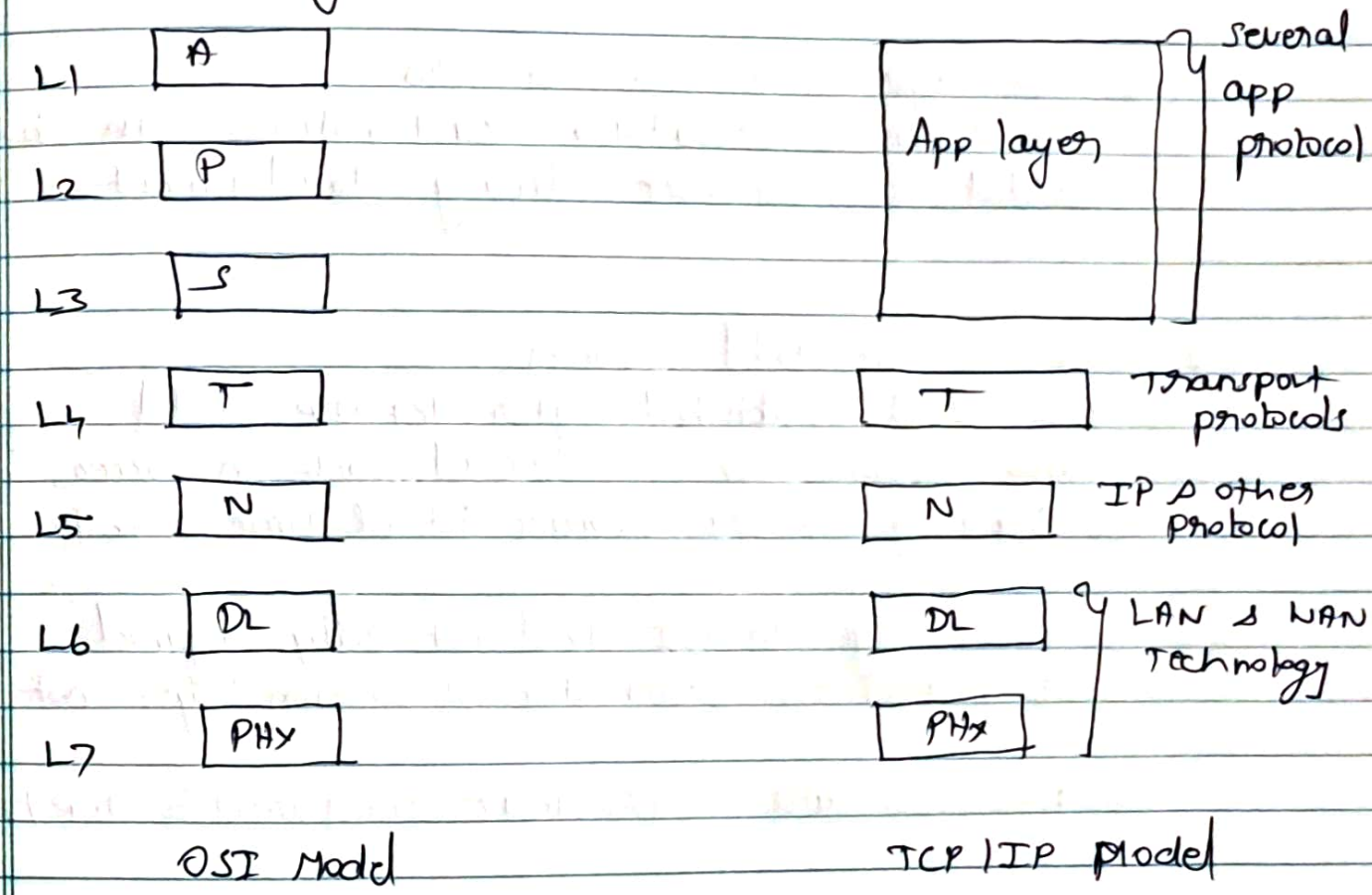


Multiplexing Demultiplexing.

4/1/25

* OSI Model (Open System Interconnection)

→ Introduced in 1970 By ISO
→ ISO → International Organization for standardization
→ ISO is organization
→ OSI is model.
→ OSI is layered framework for N/W sys design & allow communication b/w all types of computer sys.
→ seven layers present



OSI Model

TCP/IP model

* OSI Vs TCP/IP

→ Session & presentation layer not available in TCP/IP

→ App layer in TCP/IP is combination of 3 layer
App Layer, S Layer, P layer.

→ Reason for combining A, S, P in TCP/IP

① TCP/IP Transport layer has more no. of protocol which includes session layer protocols.

② App layer contain piece of s/w
If session & presentation functionalities can be added to software during development.

* Lack of OSI Model success

→ OSI Model established after TCP/IP Model

→ Major reasons for OSI Model Lack in success

① Replacing TCP/IP require lot of time & cost

② Some layer in OSI Model not fully defined
eg) protocol for presentation & session layer not specified

③ No performance improvement compared to TCP/IP.

* PHYSICAL LAYER : Digital to Digital Conversion

*

→ Representation of digital data to digital signal.

* LINE CODING

→ Process of converting digital data to digital signal

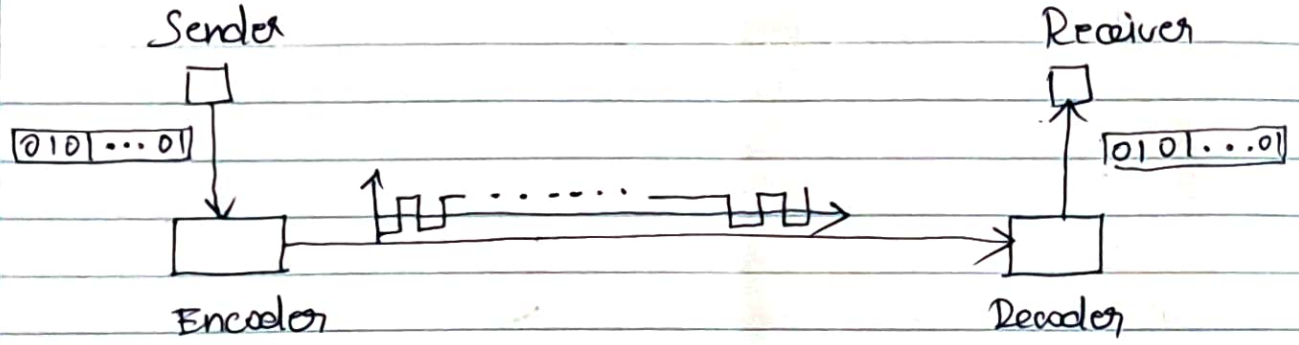
→ Computer data eg) Text, numbers, graphical image, audio, video

↳ stored as sequence of bits.

→ Line Coding

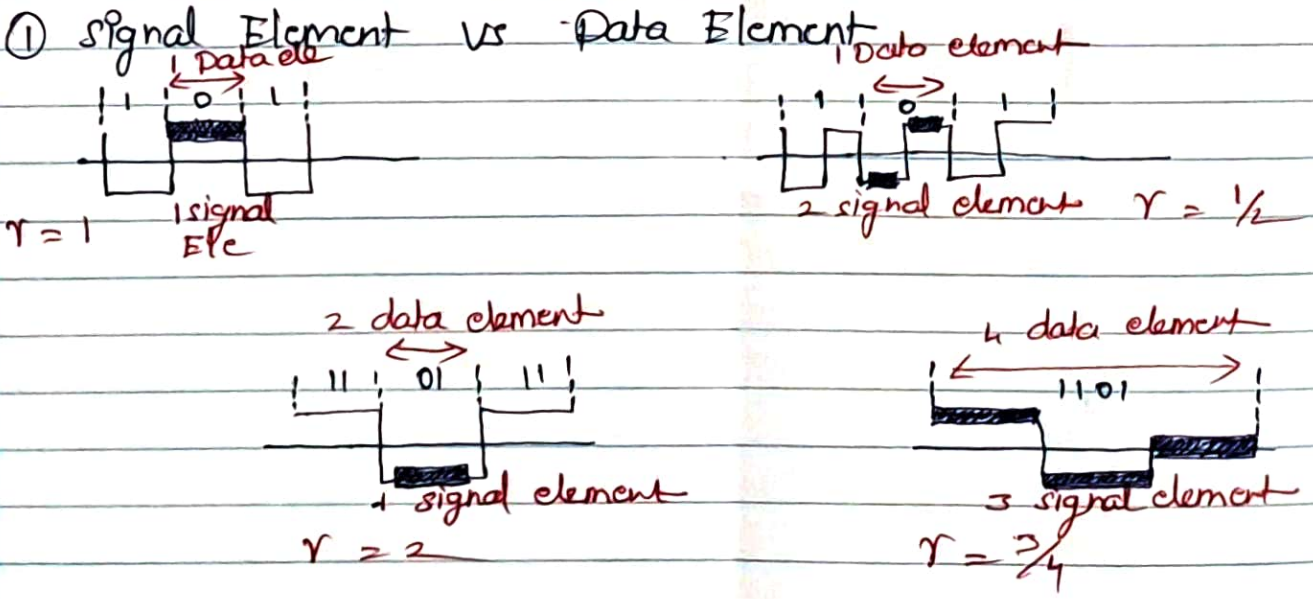
↳ At sender - digital data to digital signal (Encoder)

↳ At Receiver - digital signal to digital data (Decoder)



⇒ characteristics

① Signal Element vs Data Element



SIGNAL ELEMENT	DATA ELEMENT
① Used to carry data element shortest unit of digital signal	① smallest entity that represent piece of information (bit)
② What we can send	② What we need to send
③ Act as carriers	③ Data element are being carried

↳ Ratio (r) → No. of data element carried by signal element

② Data Rate Vs Signal Rate

↳ Data Rate → No. of data elements (bits) sent in 1s
→ unit is bits per second (bps).
→ Also called Bit Rate
→ Goal → Increase data Rate → increase speed of transmission

↳ Signal Rate → No. of signal elements sent in 1s
→ Unit is baud
→ Also called pulse rate, modulation rate, baud rate
→ Goal → Decrease signal rate → decrease bandwidth requirement

↳ Relationship b/w Data Rate (N) & Signal Rate (S)

$$S = N/r$$

↳ Define 3 cases
a) Worst → When we need max signal rate
b) Best → When we need min signal rate

Save = $c \times N \times (1/r)$ baud
N → data rate (bps)
c → case factor
S → No. of signal element per second
r → ratio

↳ Example problem: 4.1
Q1) A signal carrying data in which one data element is encoded as one signal element ($r=1$). If bit rate is 100 kbps, what is avg value of baud rate if c is b/w 0 & 1.

ANS:
assume: $c = 1/2$
$S = c \times N \times (1/r) = 1/2 \times 100{,}000 \times (1/1) = 50{,}000 = 50$ kbaud

③ Bandwidth.
↳ Bandwidth → Range of frequency that signal can occupy
→ Measured as difference b/w highest and lowest frequencies in a signal.
→ Expressed in unit of frequency Hz, KHz, MHz

↳ Theoretical vs Effective bandwidth
A) Theoritical bandwidth : refer to idea that digital signal can have infinite range of frequencies

B) Effective Bandwidth : refer to practical consideration that digital signal have finite range of frequencies

↳ Baud Rate (Signal Rate) determines the required bandwidth for digital signal

↳ Bandwidth is proportional to signal rate (Baud Rate)

↳ Minimum bandwidth can be calculated as

$$B_{min} = c \times N \times (1/r)$$

↳ To calculate max data rate, if bandwidth is given

$$N_{max} = (1/c) \times B \times r$$

$c \rightarrow$ case factor , $B \rightarrow$ Bandwidth, $r \rightarrow$ ratio.

↳ Example problem : 4.2

Q2) Max data rate of channel is $N_{max} = 2 \times B \times \log_2 L$
Does this agree with previous formula for N_{max} ?

ANS:

A signal with L level actually carry $\log_2 L$ bits per level
If each level correspond to one signal element &
we assume that avg case ($c = 1/2$) . then

$$N_{max} = (1/c) \times B \times r = 2 \times B \times \log_2 L$$

④ Baseline Wandering

↳ Baseline → Value calculated using running average of signal power (amplitude or voltage level of signal)

→ Act as threshold or reference point to decode the incoming data.

↳ Wandering → Problem occurs ~~when~~ due to long string 0's & 1's in digital signal

→ Long 0's & 1's will make calculated baseline value to drift (gradual change or shift in baseline value)

↳ Good line coding scheme

↳ ~~for~~ prevent baseline wandering

↳ Baseline Wandering problem will create error at receiver while decoding data signal.

⑤ DC Component (Direct Current)

↳ refer to very low frequency (around zero) in digital signal

↳ It is created due to constant voltage level in digital signal

↳ It lead to baseline wandering problem.

⑥ Self Synchronization

↳ Refer to ability of digital signal to provide timing information.

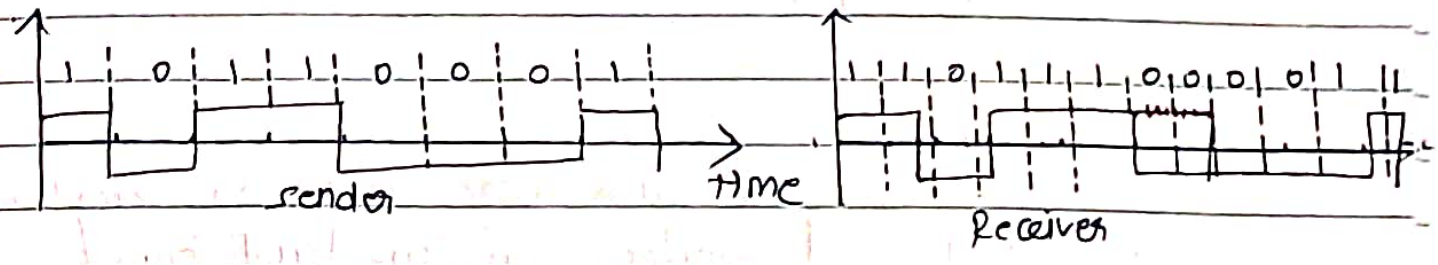
↳ This allows receiver to synchronize its clock with sender's clock.

↳ Clock mismatch will create misinterpretation of signal at receiver side

↳ Achieved by including transition in the signal that indicate beginning, middle or end of pulse

↳ Transition refer to chang in signal voltage level
Low to High (LH)
High to Low (HL)

Figure : Effect of lack of synchronization.



↳ From above fig, sender sends 10110001
Receiver receives 110111000011

↳ Example Problem 4.3

Q) In digital transmission receiver clock is 0.1 percent faster than sender clock, How many extra bits per second does receiver receives if data rate is 1 Kbps ?
If data rate is 1 Mbps).

Ans

At 1 Kbps, receiver receives 1001 bits instead of 1000 bps.
0.1% of 1 Kbps = 0.001 X 1000 = 1 bit per second.

For 1 Mbps
0.1% of 1 Mbps = 0.001 X 1000,000 = 1000 bits/sec
Hence receiver receives extra of 1000 bits/sec

⑦ Built in Error detection.

↳ Encoding scheme used ~~to~~ for error detection occur during transmission

⑧ Immunity to Noise and Interference

↳ Encoding scheme is immune or resistant to noise that corrupt signal.

⑨ Complexity

↳ Encoding scheme with more levels are complex

↳ 4 level signal complex than two level signal

* LINE CODING SCHEMES.

→ 5 categories

1) Unipolar 2) Polar 3) Bipolar 4) Multilevel 5) Multitransition.

1) UNIPOLAR SCHEME

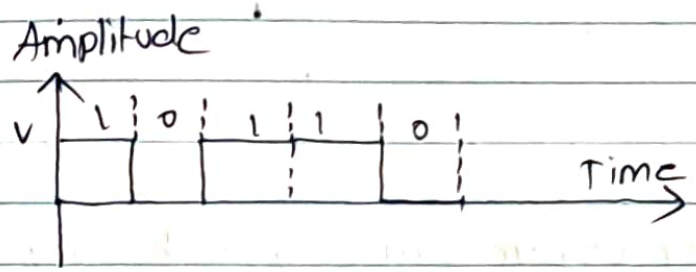
→ All signal level are on one side of time axis, (above / below)

A) NRZ (Non Return to zero).

↳ Positive voltage define bit 1

↳ Negative voltage define bit 0

↳ No signal will return to zero at middle of bit.



↳ costly when compared to Polar scheme because more power required

2) POLAR SCHEME

→ Voltage are on both side of time axis

→ voltage level 0 for positive

→ " " 1 for Negative

A) Non Return to zero (NRZ)

↳ 2 levels of voltage amplitude

↳ 2 version (NRZ-L, NRZ-I)

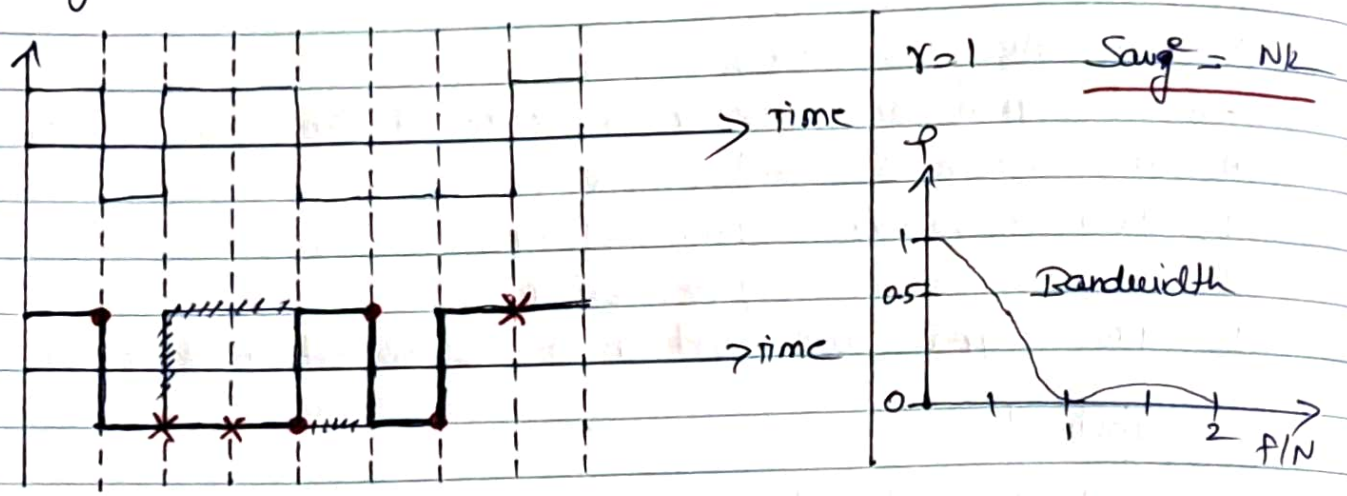
↳ NRZ-L : Level of voltage determine value of bit

~~↳ NRZ~~ NRZ-Level

↳ NRZ-I (Invert) : change or lack of change in voltage determine value of bits.

: If there is no change, bit is 0
If there is change bit is 1

Figure: Polar NRZ-L & NRZ-I



↳ NRZ-L
↳ Baseline Wandering problem occurs for both long sequence of 0's & 1's
↳ Synchronization problem also occurs
↳ Change in polarity of cable result in wrong interpretation of 0's & 1's

↳ NRZ-I
↳ Baseline Wandering problem occurs only for 0's
↳ Synchronization problem occurs only for long 0's
↳ No Polarity problem

↳ Average Signal Rate (Save) = N/2 (Both NRZ-L & NRZ-I)

↳ Both have DC Component problem.

Example Problem 4.4

Q1) System using NRZ-I to transfer 10 Mbps data. What are average signal rate & min bandwidth

ANS

Save = N/2 = 500 K baud

Min Bandwidth B_{min} = S = 500 KHz

B) Return to zero (ZR)

↳ NRZ encoding problem : Non synchronize clock

↳ Resolved by ZR

↳ ZR : 3 level of signal (Positive, Negative, zero)

: signal change not b/w bit but during the bit

: signal goes to zero in middle of bit

↳ Drawback

↳ Requires 2 signal change to encode one bit. It lead to more bandwidth.

↳ Change in cable polarity lead to ~~mis in~~ wrong interpretation of 0' & 1'

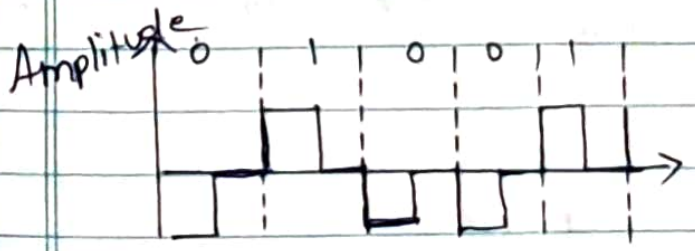
↳ More complex due to 3 level of voltage

↳ Advantage

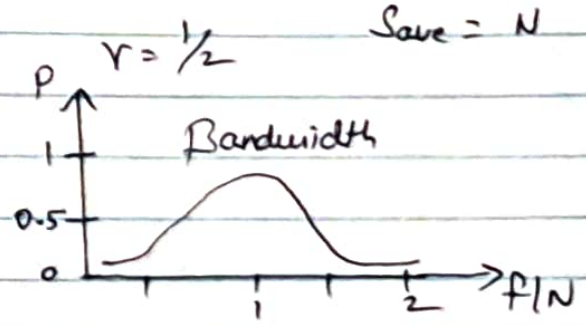
↳ No DC component problem

c) Biphase : Manchester & Differential Manchester

↳ Manchester

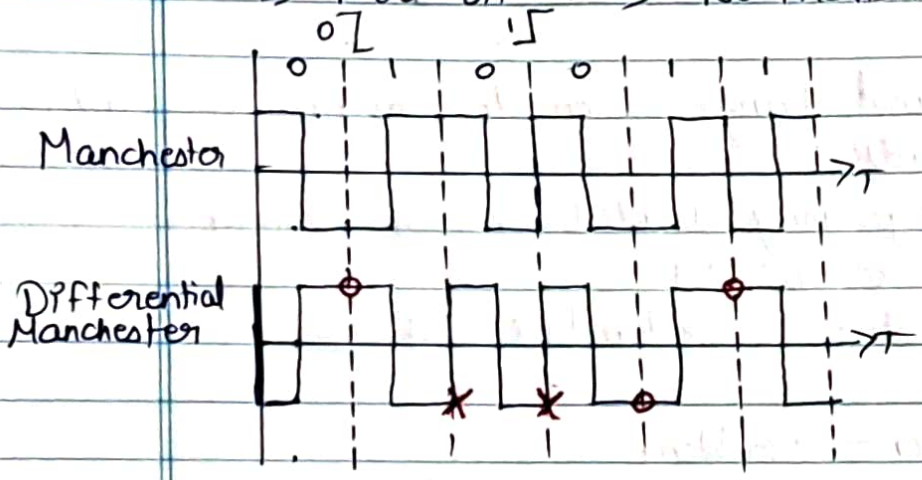


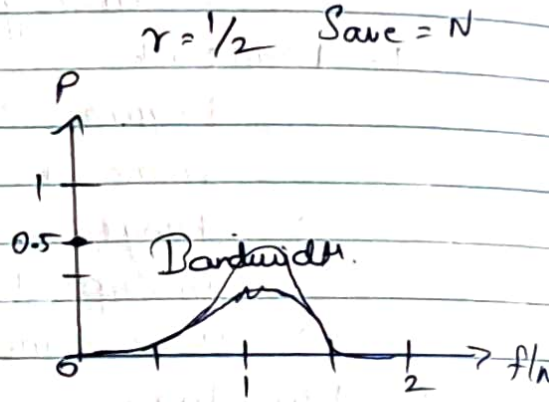
Save = N



↳ Manchester
- ↳ Combines RZ & NRZ-L
- ↳ duration of bit is divided in to a half
- ↳ Voltage remain at one level during first half & move to other level during second half
- ↳ Transition at middle of bit provide synchronization

↳ Differential Manchester
- ↳ combine RZ & NRZ-I
- ↳ Transition at middle of bit, but bit value determined at beginning of bit
- ↳ Next bit 0 → Transition
- ↳ Next bit 1 → No transition





o - No inverse. Next bit 1

x - Inverse. Next bit 0

↳ No baseline Wandering problem
↳ No DC component
↳ Easy Synchronization
} Both scheme

↳ Min bandwidth 2 times tat of NRZ

3) BIPOLAR SCHEME

→ Also called Multilevel binary

→ 3 voltage level used (positive, negative, zero)

→ AMI & Pseudoternary (2 types)

A) AMI

↳ Alternate Mark inversion (AMI)

↳ mark → comes from telegraphy (means 1)

↳ AMI mean alternate 1 inversion

↳ zero voltage represent binary '0'

↳ Alternative positive & negative voltage represent '1'

↳ used for long distance communication

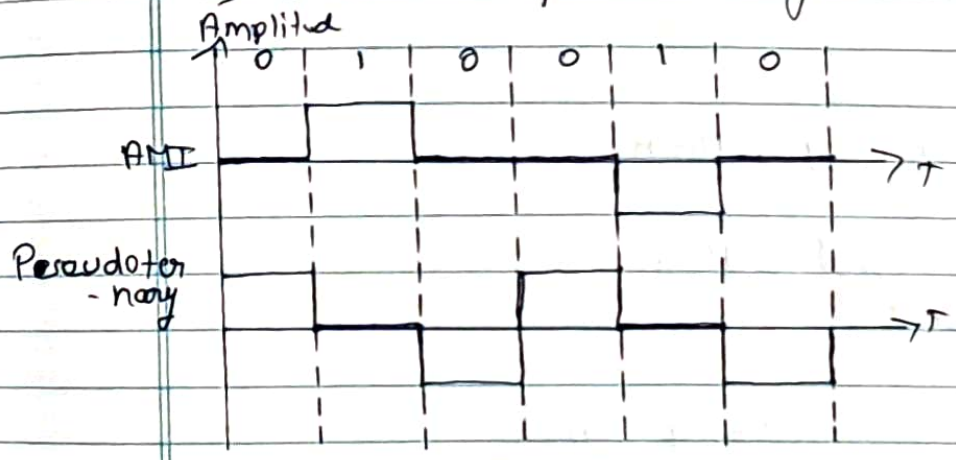
↳ Has Synchronization prolem for long seq of '0'

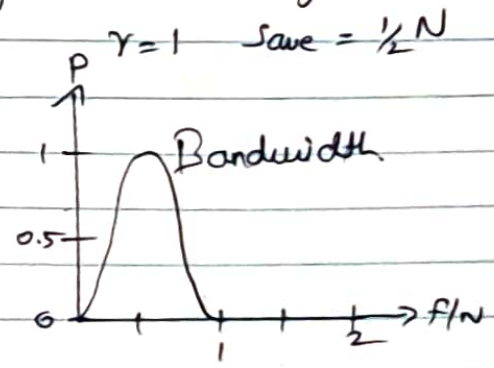
B) Pseudoternary

↳ variation of AMI

↳ zero voltage rep binar bit 1

↳ Alternative positive & negative voltage rep binary 0





→ Bipolar is alternate to NRZ

→ NO DC component problem in (Both scheme).

4) MULTILEVEL SCHEMES

→ Used to increase datarate or decrease bandwidth

→ By encoding m data elements in n signal elements

→ Data elements

↳ only two types '0' & '1'

↳ Produce 2^M data pattern

m → denotes no. of binary data elements (bits)

→ Signal Element

↳ multiple level of voltage

eg) binary - high and low voltage level

Ternary - 3 distinct voltage level

Quaternary - 4 " " "

↳ combination of n signal element with L levels produce L^n pattern

→ Encoding

↳ possible only $2^m \leq L^n$

Data pattern ↳ signal pattern

→ Classification : mBnL

m → length of binary pattern

B → binary data

n → length of Signal pattern

L → no. of level

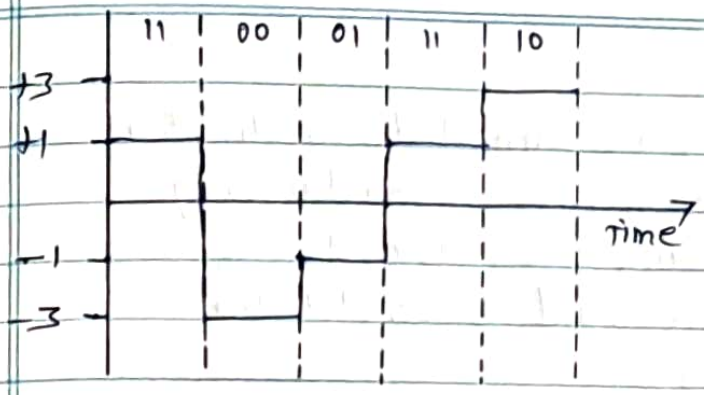
A) 2B1Q

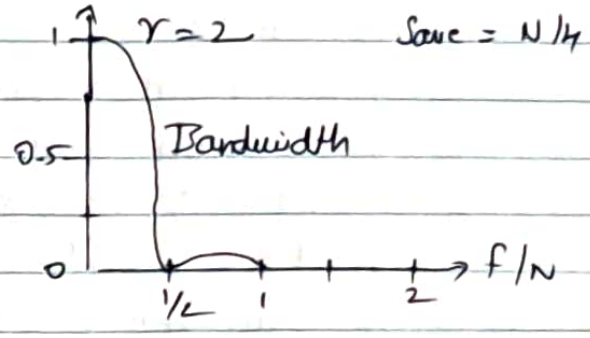
↳ 2 Binary digit 1 Quaternary signal

↳ m = 2, n = 1, L = 4.

$2^2 \leq 4^1 \Rightarrow 4 \leq 4$

↳ 2 bit pattern as one signal element with 4 level signal

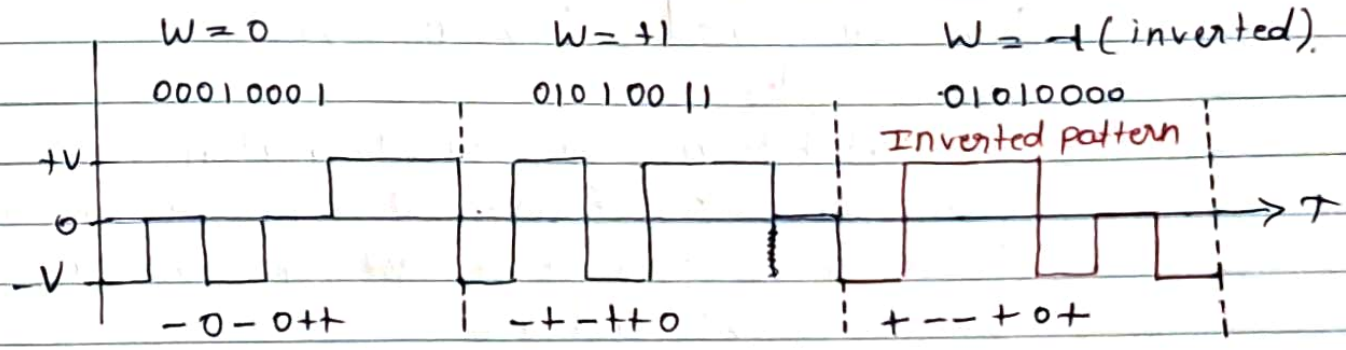




Rule: 00 → -3 01 → -1
10 → +3 11 → +1

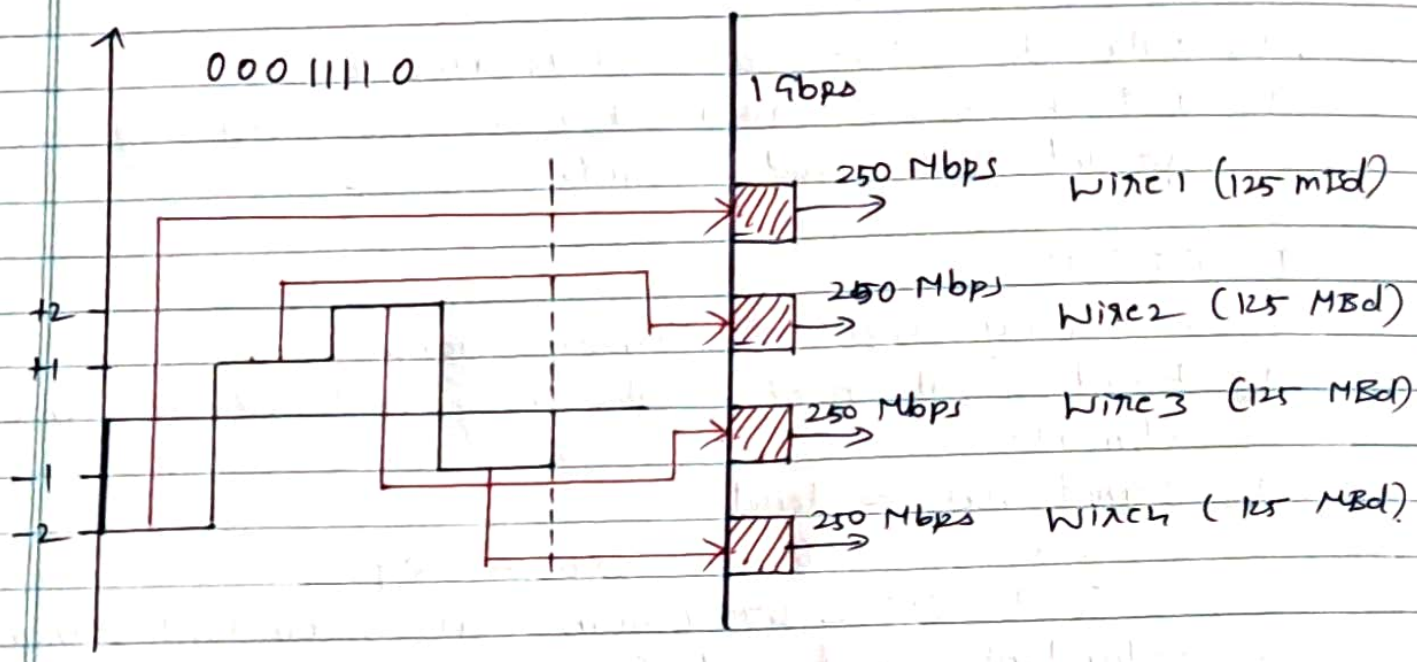
↳ Data rate 2 times faster than NRZ-L
↳ used in DSL (Digital Subscriber Line) technolog to provid high speed internet.

B) 8B6T
↳ 8 binary digit 6 ternary signal
↳ Encodes pattern of 8 bits using patter of six signal element.
↳ signal has 3 levels
$2^8 \leq 3^6 \Rightarrow 256 \leq 729$
$729 - 256 = 473$ (means 473 redundant signal)
↳ redundant signal used for synchronization & error detection.



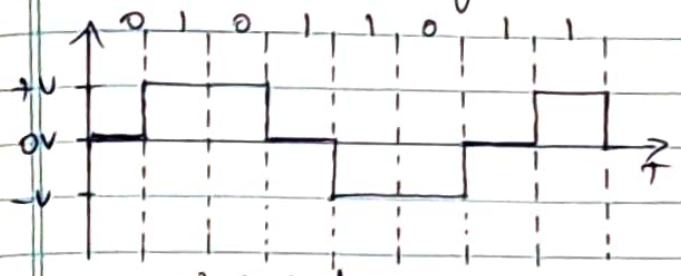
$Save = \frac{1}{2} \times N \times \frac{6}{8}$ min bandwidth close to 6N/8

c) 4D-PAM5
↳ 4 Dimension 5 level pulse amplitude modulation.
↳ 4D - Data sent over 4 wires simultaneously
↳ 5 level - 5 voltage level (-2, -1, 0, 1, 2).
↳ Level 0 - used for forward error detection.
↳ 1D equivalent : 8B4Q
8 bit translated using 4 level signal.

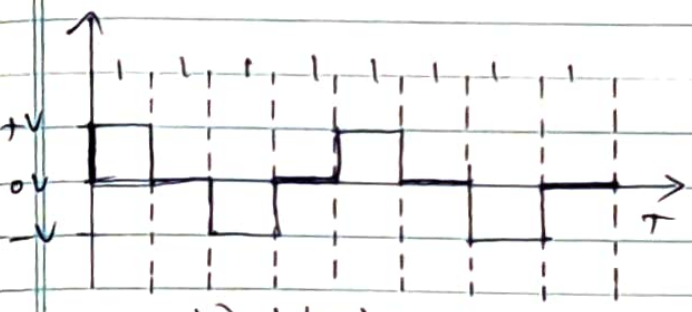


D) MULTITRANSITION : MLT-3
→ Multiline Transmission three level scheme
→ 3 voltage levels used. (+V, 0, -V)
→ 3 Transition Rules
↳ If nxt bit is zero, No Transition
↳ Transition to 0, if nxt bit is 1 & current level not 0
↳ Transition to opposite of last non-zero level for nxt bit 1 & current level is 0

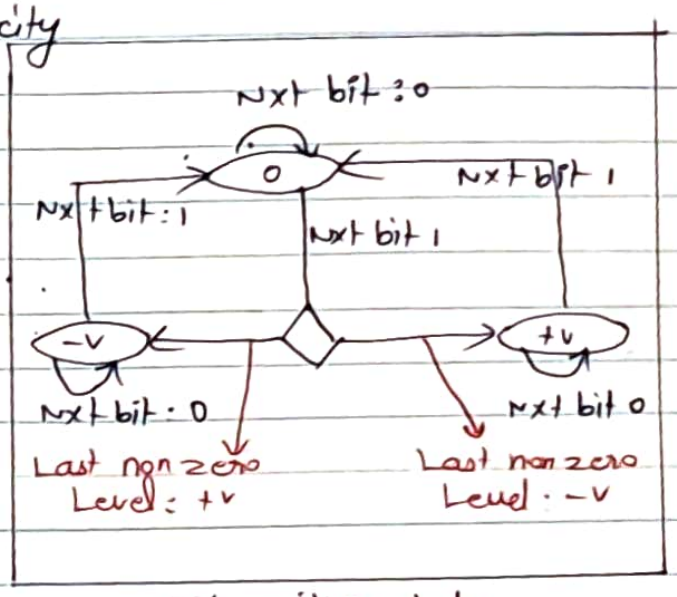
→ Reduce bandwidth
→ suitable for high speed data
→ used in LAN
→ Has similar signal rate to NRZ-I but with greater complexity



a) Typical case



b) Worst case



Transition states.

	Category	Scheme	Bandwidth	Characteristics
1)	Unipolar	NRZ	B = N/2	Costly, no-self synchronization if long 0 or 1, DC
2)	Polar	NRZ-L	B = N/2	No self sync, if long 0 or 1, DC
		NRZ-I	B = N/2	No " " " 0, DC
		BIPhase	B = N	self sync, no DC, high bandwidth
3)	Bipolar	AMI	B = N/2	No self sync for long 0, DC
4)	Multilevel	2B1Q	B = N/4	No self sync for long same double bit
		8B6T	B = 3N/4	self sync, no DC
		4D-PAM5	B = N/8	" "
5)	Multi transition	MLT-3	B = N/3	No self sync for long 0