Date - 08.09.23 Ch-1

1) What is computer network?

fns → It is an interconnection of computers with a given technology

interconnected → information exchange is possible

* Interconnect / Connections :-

Wired medium
- (i) Copper wires - electrical signals
- (ii) Fiber optic cable - optic light signal
- (iii) Microwaves - emw
- (iv) Satellite link - emw

* Network :-

→ Classification on the basis of size and coverage :-

(1) PAN < 5m
(2) LAN < few hundreds of meters
(3) MAN
(4) WAN
(5) Internet - network of networks

Voyager - 1, 2 - man-made objects travelling in space → non-editable

2) How distributed system is different from a computer network?

→ editable

fns →

CN - direct access to physical system

DS - we have a middleware software (WWW) which helps in visualizing the information

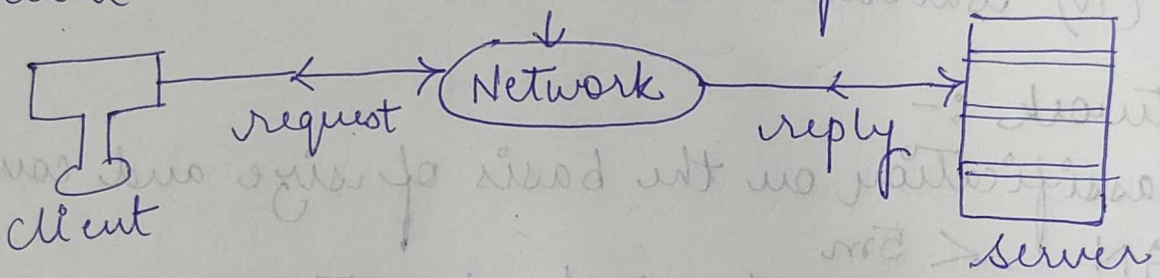
① ∴ distributed system is a middle-level software (i.e referred as middleware) that is built on top of the computer network.

However, computer network doesn't have this middle level software.

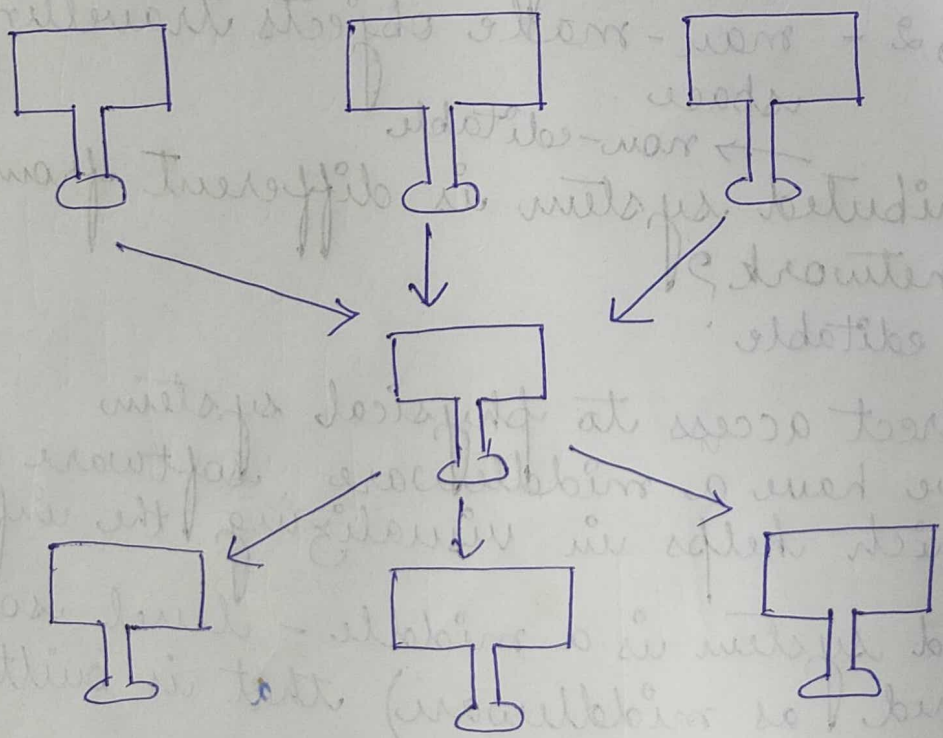
* Application Of Computer Network :-
(i) Access to remote information
(ii) In the field of entertainment
(iii) e-commerce

Date - 09.09.23

* Access to remote information :-
→ Client - Server Model (Mostly used in Internet)




→ Peer - to - Peer Communication :-
(Hacking)
⇒ No clients or server exists



B2C
B2B
G2B
G2C
} e-commerce

B → business
C → consumer
G → government

* Types Of Computer Networks :-

(a) Broadband Access N/w
(b) Mobile and Wireless Access N/w
(c) Content Provider N/w
(d) Transit N/w
(e) Enterprise N/w

} How to access internet?

⊙ Broadband Access Network :-
→ static (disadvantage)
→ Broadband N/w providers are BSNL (Telephone companies)
→ Copper lines
→ BW (Bandwidth) = very limited
→ Data rate (kbps) = few Mbps
↓
Co-axial lines
↓
Fiber optic cable
(Data rate > 1 Gbps) Fiber-to-the-home

⊙ Mobile and Wireless Access N/w :-
↓ ↓ not wired
⊙ mobility
⊙ tendency to move or dynamic
→ N/w providers are telephone companies.
→ Both fixed wireless n/w and mobile wireless
⊙ Mobile hotspot – fixed wireless n/w

⊙ Content Provider Network :-

This particular N/W is based on cloud computing environment.

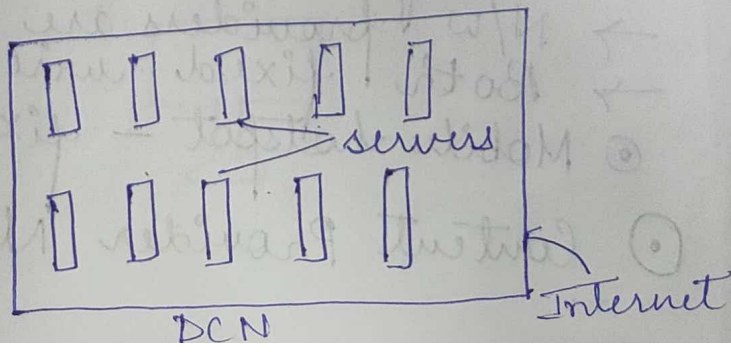
→ Cloud computing environment
  ↳ users ($10^6 - 10^9$)

$2^{10}$ - 1 kB
$2^{20}$ - 1 MB
$2^{30}$ - 1 GB
$2^{40}$ - 1 TB
$2^{50}$ - 1 PB

⊙ 2 types of content provider n/w :-
① Data Center N/W (DCN)
② Content Delivery N/W (CDN)

1) Data Centre N/W :-
(i) Data centre network are the collection of thousands and millions of servers in a single location.
(ii) These data centre network server network serves the increasing demand of cloud computing.
(iii) These DCN servers are designed to handle data b/w server to server and b/w data centre n/w and rest of the internet.

⊙ -ve points in DCN :-
① energy usage issue
② scale of computing
③ N/W throughput (↓)
  ↳ efficiency



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① Data Center Network - mostly handles cloud computing (T-flops) - $2^{50}$ Tera floating point operations.

→ Drawback Of DCN
1. increase in scale of computing (↑)
2. increase in energy usage (↑)
3. N/w throughput (↓) decreases.

To mitigate these -ve issues, content delivery network (CDN) evolves.

② CDN :-

(i) CDN is a large collection of servers which are geographically distributed in such a way that the content is placed as close as possible to the end users those who are requesting it.

(ii) CDN replicates the much demanded/downloaded files and store it in many locations across a single CDN.

(iii) Thus, when a demand comes from a user CDN decides which replica is to be delivered to the user.

Depends on -
(a) distance from each replica to the intented user.
(b) load on each CDN server
(c) traffic load/data traffic (no. of users)
(d) congestion in the network (accumulation at a point)

(iv) few companies like facebook, Google, Netflix, have their own CDN to operate data smoothly

⊙ Cloudfare & AKAMAI.

* Transit Network :-

Content - webpage (broadly)

ISP = Internet Servic Provider

Content

CDN

→ The content provider network & internet provider network are not connected directly.

→ They rely on a third network which is called as transit network or backbone network.

→ Direct connections between large ISPs and large Content providers like Facebook, Google and Netflix has their own transit n/w. They built & maintain own transit n/w for facilitating direct connection regardless of geographical area.

* Enterprise Network :-

→ This sort of networks are widely used in companies that does business & University.

→ This n/w supports :-

(i) physical resource sharing.
(ii) information sharing.
(iii) communication
(iv) E-commerce

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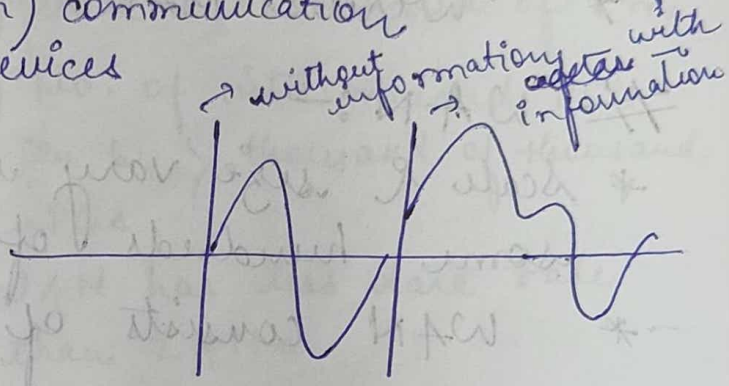
## * Network Technology :-

⊙ Based on n/w technology used; n/w's are as follows:-

→ PAN (Personal Area Network)
→ LAN (Local Area Network)
→ MAN (Metropolitan Area Network)
→ WAN (Wide Area Network)
→ Internet

### # PAN :-

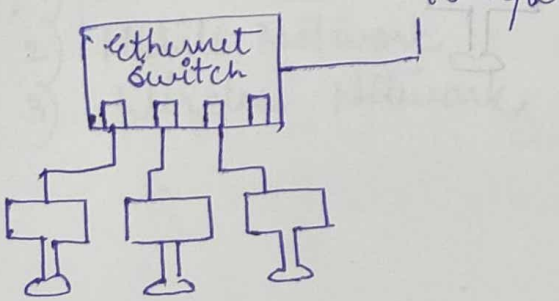
* Bluetooth - (non-standard) ← 2.4 GHz, 5 GHz } carrier frequency
* highly short range (<10m) communication
* limited to max^m 5-10 devices

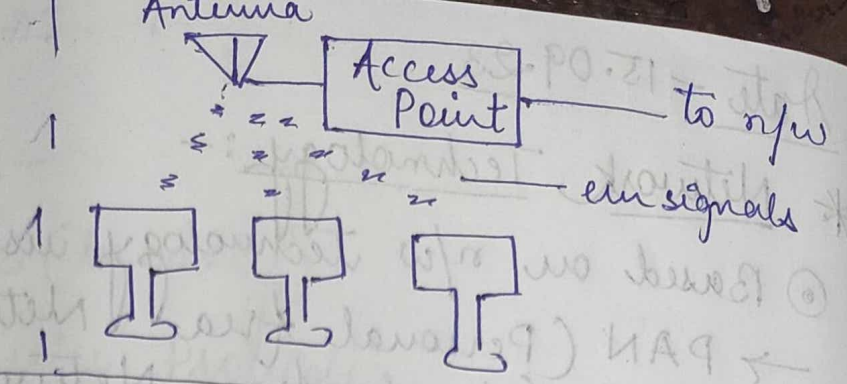



### # LAN :-

* Scale and size of LAN can be in the range of few metres to few kms.
* LAN resource sharing
* Wired LAN (IEEE 802.3)
  - 1Mbps • copper wire / twisted pair
  - 100Mbps • Co-axial cable
  - ≥1Gbps • fiber-optic cable
* Wireless LAN (IEEE 802.11) → (WiFi)
  - RF-link
  - Access point (transmitter as well as receptor)
  - IEEE 802.11b - 11 Mbps
  - IEEE 802.11ad - 7 Gbps

1 kbps - 1024 bits per second
Memory size (in bytes)
→ Info (Data rate - bits)
Memory chips (in bits)





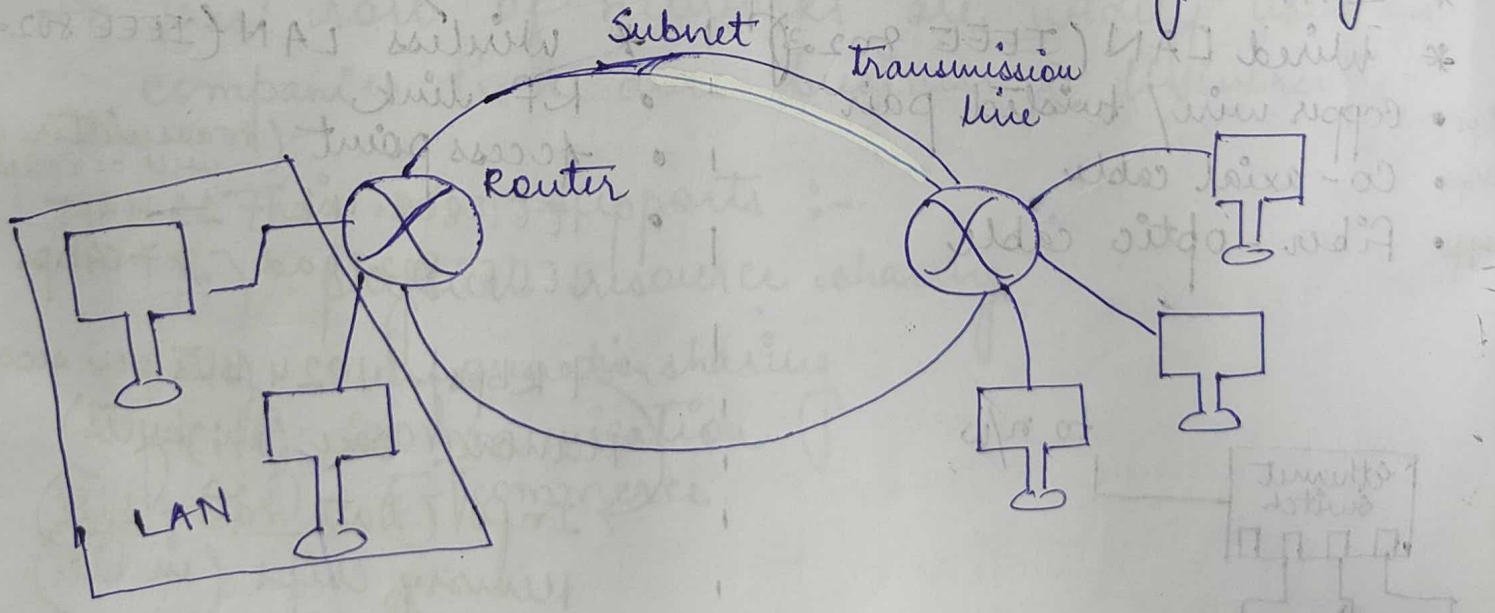

## # MAN :-

* Scale and size of MAN can be a longer geographical area covering a city (few kms)
* eg - Cable Tv N/w
* Wireless MAN - WiMax.

## # WAN :-

* Scale & size vary in terms of few kms to some hundreds of kms.
* WAN consists of host computers & subnets

WAN → Host / Host Computers
→ SubNet → transmission line technology
→ switching/routing elements



* WAN has many n/w operators unlike in LAN where it belongs to a single owner/company.
* Transmission line
  → copper wire

Date - 16.09.23

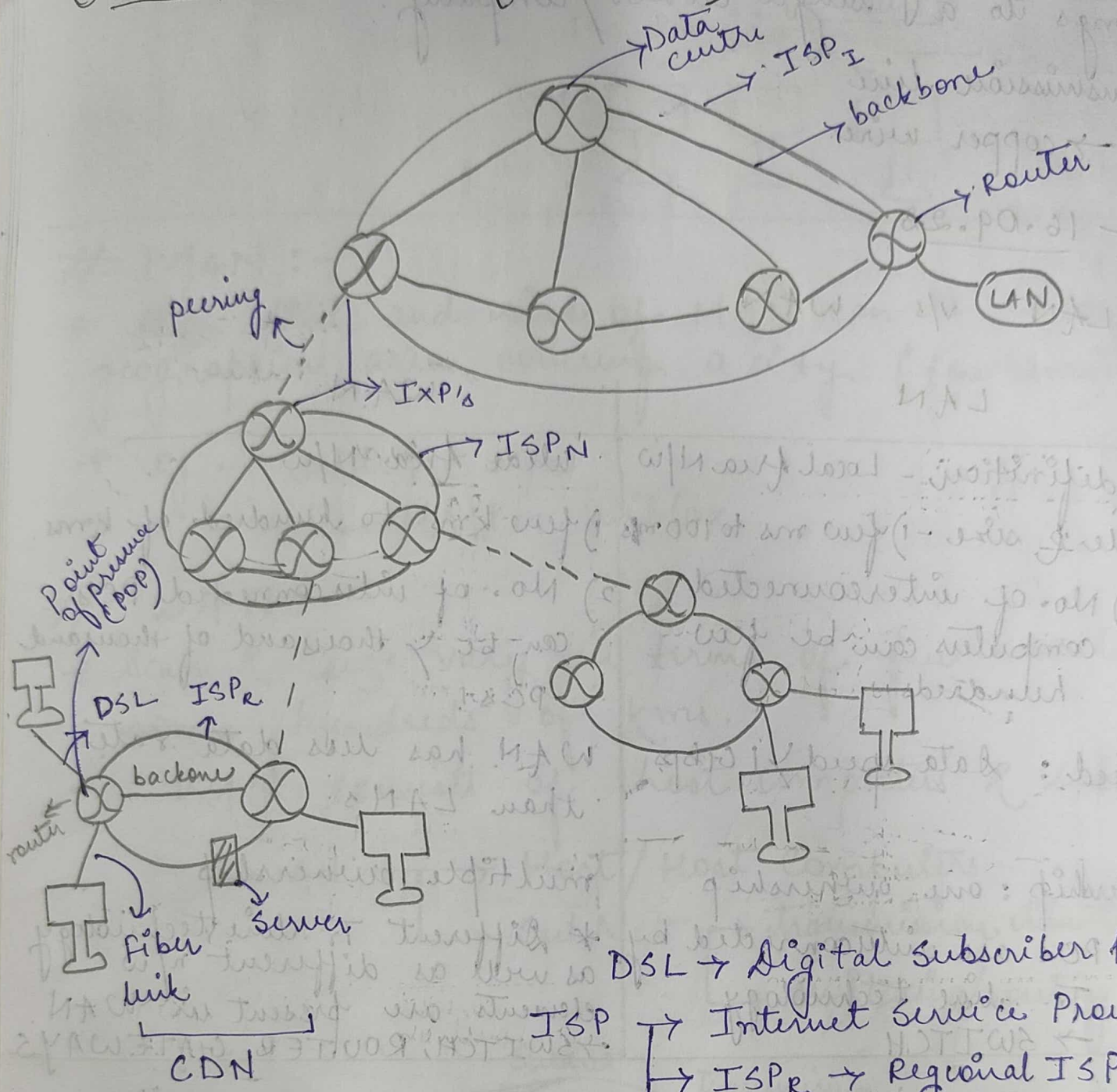
* LAN v/s WAN.

| LAN | WAN |
|---|---|
| * By definition - Local area N/w | Wide area N/w |
| * Scale & size - 1) few ms to 100 ms | 1) few kms to hundred of kms. |
| * 2) No. of interconnected computers can be few hundreds | 2) No. of interconnected PC's can be 1000s of thousand of thousand PCs. |
| * Speed: Data speed > 1 Gbps | WAN has less data rate than LANs. |
| * Ownership: one ownership | multiple ownership. |
| * All PCs are interconnected by single Tr. line technology → SWITCH | * Different Tr. line technology as well as different n/w elements are present in WAN. → SWITCH, ROUTER, GATEWAYS |

* The Internet :-
  * Interconnection of many LANs, WANs, and individual host PCs.

⊙ Network, Examples (1.4) :-
1) Internet
2) Mobile Network
3) Wireless Network

## ⊙ 1.4.1. (Internet Architecture) :-




DSL → Digital Subscriber link

ISP → Internet Service Provider
- → ISP R → Regional ISP
- → ISP N → National ISP
- → ISP I → International ISP

FTTH → Fiber to the Home

→ interconnection (router to router) within the same ISP.

← Backbone -
Router -
Peering -
CDN - Content Delivery Network

* Once the data comes to ISP, it becomes data packets and get transmitted as digital form.
Traverses as pkt-switch n/w.

* peering - communication b/w two ISPs.
* ISPs connect their network as IXP, where IXP stands for Internet exchange point, to exchange data packets. Thus, two connected ISPs are said to be in peer with each other.

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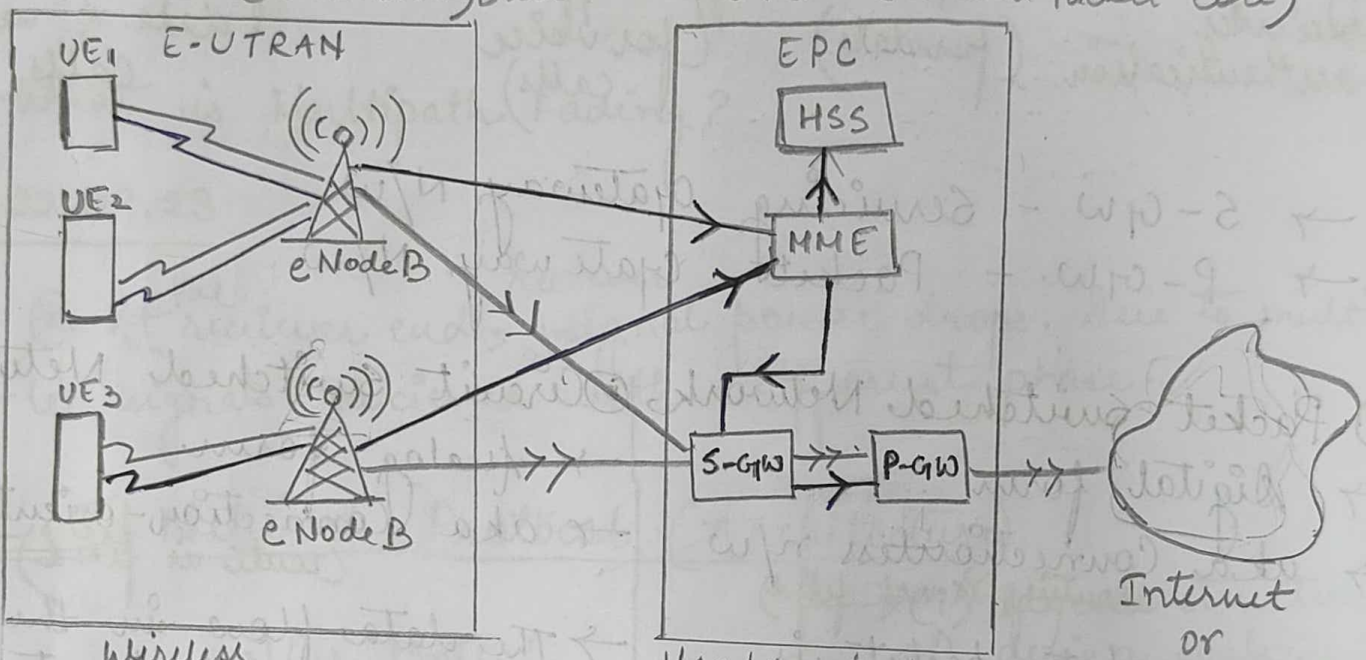
⊙ 1.4.2 (Mobile Network) :-

1) 4G LTE (Long Term Evolution) → mostly for data communication

E-UTRAN - (Evolved UTRAN) Data  EPC - (Evolved Packet Core)




→→ data signal

→ control signal

UE – User equipment

eNodeB – Base station (evolved)

HSS – Home Subscriber Server

MME – Mobile Management Entity

→ ⊙ E-UTRAN → Evolved UMTS Terrestial Radio Access N/w (4G)

⊙ UMTS → Universal Mobile Telecommunical System (3G)

→ E-UTRAN is a radio communication protocol used over the air b/w mobile equipment and the base station (i.e ENodeB)

→ EPC stands for Evolved Packet Core

In 3G → UMPS

- Control signals & used for reciever authentication
- Pkt switch N/W (for data)
- Ckt switch N/W (for voice calls)

In 4G - EPC

- digital
- for both data & voice calls

→ S-GW - Servicing Gateway N/W
→ P-GW - Packett Gateway N/W

⊙ Packet Switched Network

→ Digital form
→ aka Connectionless n/w (routing is not fixed)
→ every data packet is routed independently of other packets.
→ Due to over-crowding of data packets at any node may result a loss of data packets. Thus, the sender can be acknowledged for re-sending the data packet.
→ Channel utilization can be achieved with 100% theoretically. (Channel utilization is max^m)

⊙ Circuit Switched Network

→ Analog form
→ aka Connection-oriented n/w (route is fixed)
→ The data flow in the same dedicated path / route.
→ If the line or route gets down then the voice call or data is lost.
→ Channel utilization can't be achieved upto 100% theoretically.

⊙ 1.4.3 (Wireless Network) :- → Data rate 11.b - 11 Mbps
11.g - 54 Mbps
11.ac - 3.5 Gbps
11.ad - 7 Gbps

1) IEEE 802.11 - → Licensed N/w

2) Unlicensed Wireless N/w

ISM (Industrial, Social, Medical) / Lower power transmission.

902 MHz
2.4 GHz } Bluetooth
5.8 GHz }.

3) Wireless N/w (WiFi) is inherently a broadcast type of network, and it suffers from multipath fading.

Q. What is Multipath Fading?

Date - 22.09.23

Ans → ⊛ At the reciever end, reciever signal power drops. Due to multiple signals recieved with different phase.

*. 1.5.1 Network Protocol (Architecture)

N/w Protcol.

OSI
n/w model
protcol
• 7 n/w layers

TCP/IP
n/w model
• 4 n/w protcol layers

→ (i) Layerd structure
(ii) design goals: (benefits)
→ a. Reliability
↓
It is the ability to recover data packets or error or faulty data packets.

→ b. Resource Allocation
↓
Sharing access to common & limited resources.
(flow control)
(congestion)

flow of data packets

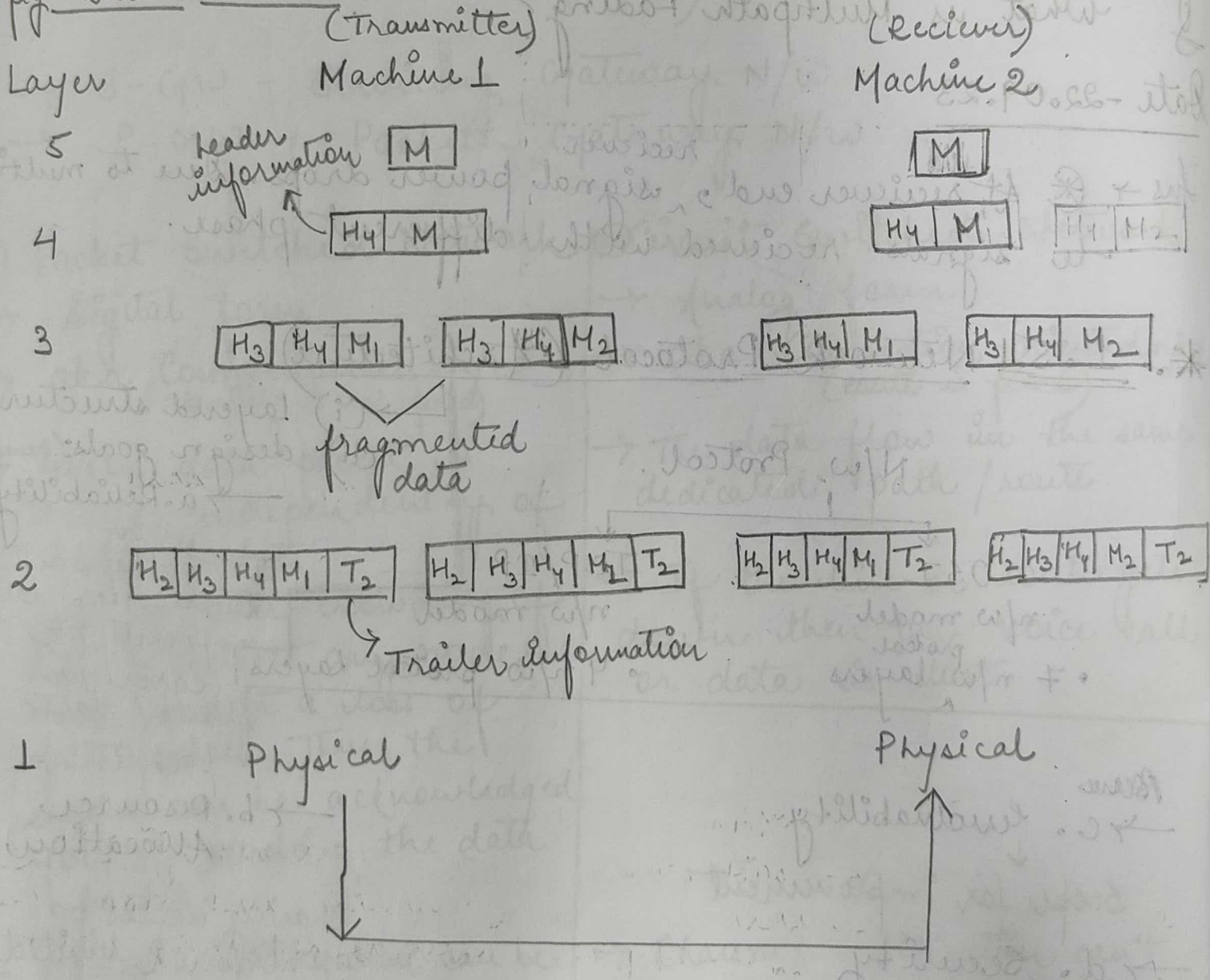
Because
→ c. Evolvability
↓
Scope for improvement

→ d. Security

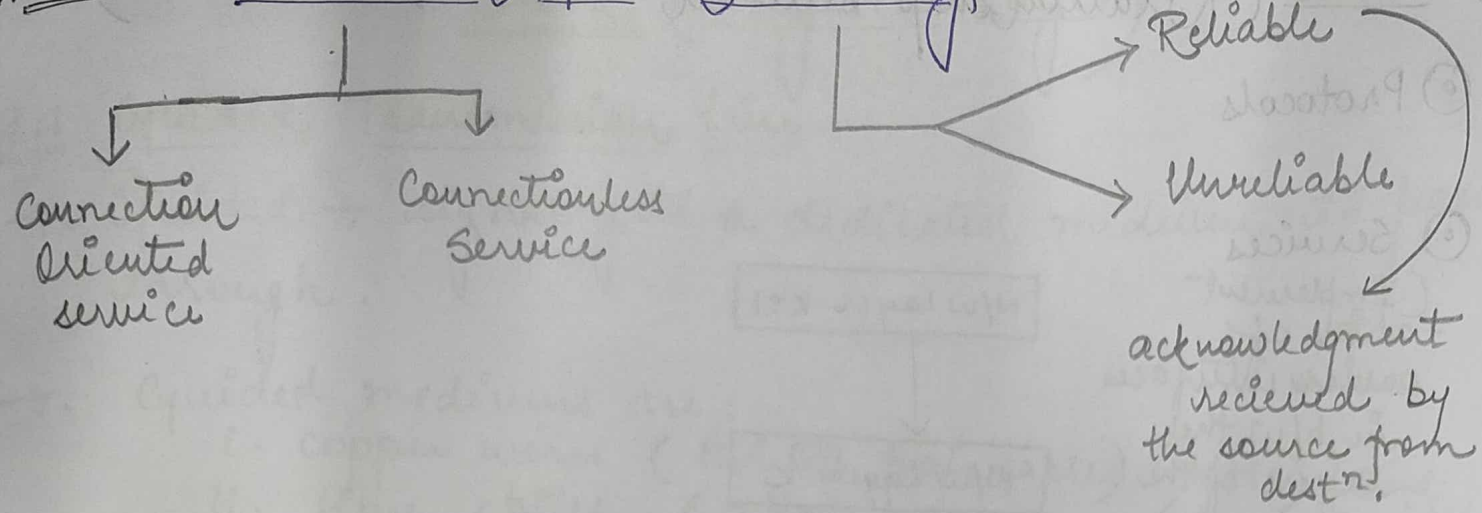
## * 1.5.2 Protocol Layering

→ N/w protocol architecture is a layer structure.
→ Data flows through different layers.
→ Protcol def$^{n}$ - Set of rules for communication of different devices in b/w the same layers.
→ Interface def$^{n}$ - Set of rules to communicate b/w adjacent layers of a single route machine.
→ Protcol + Interface → N/w protocol architecture

fig - Data Movement :-



## *1.5.3 Connection And Reliability




| | Services | Examples |
|---|---|---|
| Connection Oriented | Reliable | Byte string → Video downloading<br>Message sequence → Book downloading (single page is downloaded as a whole) |
| | Unreliable | |
| Connection - less | Reliable | → Text Messages |
| | Unreliable | → Spam Mails |
| | Request-reply | → client-server Model |

Date - 23.09.23

### 1.5.4 Service Primitives :- (Operations & Functions)

* Connection Oriented Service / Connectionless service
* Service primitive is a set of functions/operations.
* The following are the list of service primitives that provide a connection oriented services. These service primitives are :-

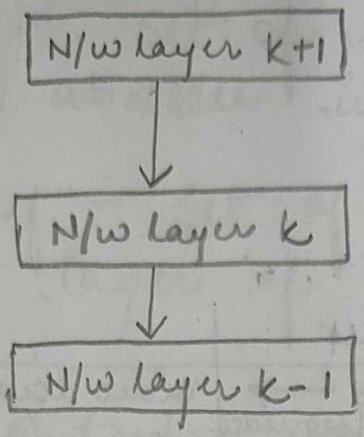
Request-reply of connection oriented service

(i) LISTEN → waits for an incoming connection.
(ii) CONNECT → establishes a connection with a waiting peer (host)
(iii) ACCEPT → accepts an incoming connection request from a peer.
(iv) RECEIVE → waiting for an incoming acknowledgement message.
(v) SEND → sends a message to the peer (server)
(vi) DISCONNECT → finally terminates the connection.

# 1.5.5 (Relationship between Services And Protocols):-

⊙ Protocols

⊙ Services (Implement-ation of services interfaces in b/w the layers of the same node)




# 1.6 (Reference Network Model):-

* OSI reference n/w model (7 layers) → theoretical
* TCP/IP n/w model. (4 layers) → practical

| OSI Model | TCP/IP |
|---|---|
| 1) Open System Interconnection | 1) Transmission Control Protocol/ Internet protocol |
| 2) 7 layers | 2) 4 layers. |
| 3) Reference Model | 3) Practical implementable model |
| 4) Application layer, Presentation layer and Session layer are present as separate entities in the hierarchy | 4) Application layer, Presentation layer and Session layer are clubbed together in Application layer. |
| 5) Data link layer & Physical layer are also present separately | 5) Host-to-network layer contains both the data link layer and physical layer |

# Ch-2 (Physical Layer)

## 2.1 Guided Transmission line :-

→. Guided → signal gets a dedicated medium to pass-through.

→. Guided mediums are :-
   i. copper wires (twisted pair cable) (MHz)
   ii. fibre optics (THz)
   iii. co-axial cable (GHz)

} Bandwidths MHz - $10^6$ Hz, GHz - $10^9$ Hz, THz - $10^{12}$ Hz

→. Bandwidth :-
Bandwidth is a measure of carrying capacity of a medium usually it is specified in Hertz. (KHz)
Audio :- 20Hz - 20KHz
Power line :- 50Hz
Central - 4KHz

Bandwidth & Data rate

### ⊙ Twisted Pair Cable :-
(UTP) - Unshielded twisted pair

1. Conventional way of data transmission & reception.
2. UTP cable supports both analog and digital signal communication.
3. { Cat 2, 3, 4, 5, 6, 7, 8 } Categories
   (2, 3, 4 → obsolete; 5, 6, 7, 8 → present categories)

| | Bandwidth | Data rate |
|---|---|---|
| Cat 5 - | 100MHz | 100Mbps |

Date - 28/09/23

⊙ Unshield Twisted Pair

→ Advantages Of Shielding -

Cat 7,8
- → Mechanically, it is more strong & robust
- → Less prone to interference
- → Avoid Crosstalk

→ Cat 7, 8 → Higher Data rates (> 1 Gbps)
in Cat 7 & in Cat 8 > 10 Gbps

⊙ Co-Axial Cable :-

- Supports shielding
- supports higher data rate of 1 Gbps and beyond
- BW can be about 6 GHz.
- More the bandwidth of the medium more the data rate

- There are two varieties of co-axial cable :-
  (i) impedance of 50 Ω & supports digital signal transmission & reception.
  (ii) impedance of 75 Ω & supports analog transmission & reception

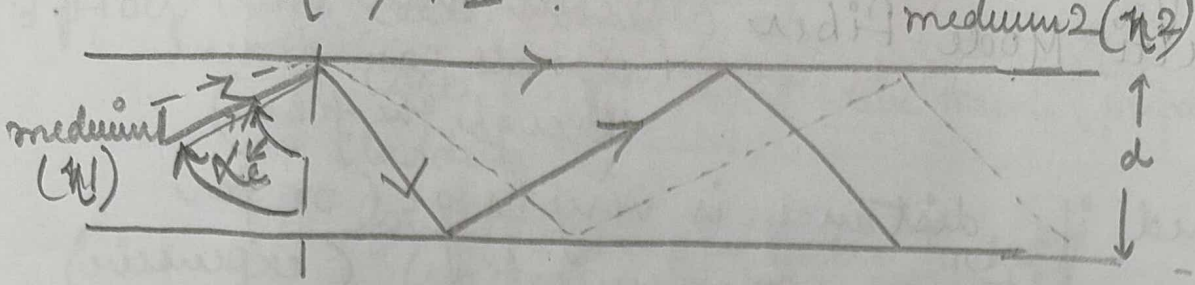
⊙ Power lines :-

In general, we don't use power lines for data communication

## * Optical Fiber Cable :-

### Total Internal Reflection Principle :-

Condⁿ - $n_1 > n_2$




$\alpha_c$ = Critical Angle Of Incidence
$n_1$ = Refractive Index of medium1
$n_2$ = Refractive Index of medium2
($n_1 > n_2$)

1) Optical fiber cable works on total internal reflection principle.
2) Optical fiber cable supports higher data rates at a rate of Tbps. But due to practical limitation the data rate varies between 100s Gbps to 1000s Gbps.
3) supports long-distance communication.
4) Optical fiber transmission system majorly consists of 3 components namely —
   (i) Optical source ← LED (Light Emitting Diode) / LASER } Differentiate
   (ii) Optical transmission medium - Fiber optic cable
   (iii) Photo detectors → at recievers end

↓ electrical signal converted to light signal at transmission end by Transducers

↓ light signal is converted back to electrical signals by Transducers

→ There are 2 varieties of fiber optic cable :-

Difference

(i) Single Mode Fiber (if d becomes very very small, only a single signal can pass)

(ii) Multi Mode Fiber (greater than one no. of signals can travel through the fiber)

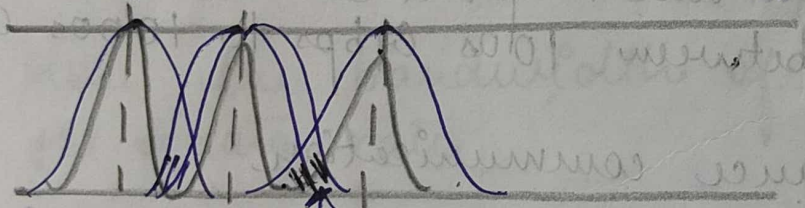
↳ preferred if distance is very large (or for long distance communication) (expensive)

(signal/noise) ratio very good

↳ preferred for short distance & high BW. (less expensive)

⊙ Demerits –

1. Fiber optic communication suffers from pulse spreading




fc - carrier signals

fig - Chromatic dispersion

2. Light signals can be absorbed by some ambient molecules like oxygen, hydrogen & nitrogen.

Date - 29/09/23

* Optical Fiber Cable :-

⊡ Fiber Optic Cable consists of $(\eta_1 > \eta_2)$
→ Core ($\eta_1$) - light wave travels (prepared from Glass or Silica)
→ Cladding ($\eta_2$)
→ Cover/Package (Outer jacket)

→ Carrier wavelengths are :-
1. $\lambda_1 = 0.8\,\mu m$
2. $\lambda_2 = 1.3\,\mu m$
3. $\lambda_3^* = 1.5\,\mu m$ (absorption of light wave is min$^m$ by ambient molecules)
↓ most widely used

$$c = \lambda f$$

$$f = \frac{c}{\lambda} = \frac{3\times10^8\ m/s}{1.5\times10^{-6}\ m}$$

$$= 2\times10^{14}\,s^{-1} = 200\,THz$$

## 2.2 Electromagnetic Spectrum :- (Fig 2.8)

$\uparrow$ few Hz ——————————→ $10^{12}$ Hz (f)

* → Radiowaves → 10KHz - 100MHz.
→ Microwaves → 100MHz - 100GHz.
→ Infraredwaves, Visible waves, UV waves ← $10^{12}$ Hz - $10^{16}$ Hz
→ X Rays, Gamma Rays ← $10^{18}$ Hz - $10^{24}$ Hz.

$$\uparrow E = \frac{1.24}{\lambda\downarrow}$$

$$c = f\lambda$$

⊙ Transmission :-

(*) Transmit an EM wave signal (data signal)

(*) For wireless transmission :-

techniques use either radio or micro waves (better frequency (greater bandwidth))

(1) FHSS (Frequency Hopping Spread Spectrum)

(2) DSSS (Direct Sequence Spread Spectrum)

- ⊙ Wireless LAN (IEEE 802.11b)
- ⊙ CDMA based cellphone n/w system (3G)

* Advantages (wireless transmission) -

1. Suppresses/Minimizes Data loss
2. High signal to noise ratio
3. Less cross-talk, lastly
4. ~~Elect~~ Minimize electromagnetic interference.

Date - 30.09.23

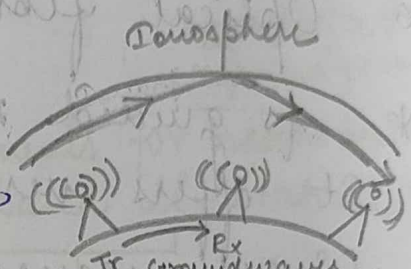
1 THz - $10^{12}$ Hz.

## * Spectrum Of Transmission :- (2.3)

1. Radiowave Transmission (upto 100 MHz)
2. Microwave Transmission (100 MHz - 1 THz)
3. Infrared Transmission (few THz)
4. Lightwave Transmission ($10^{14}$ Hz - $10^{18}$ Hz)

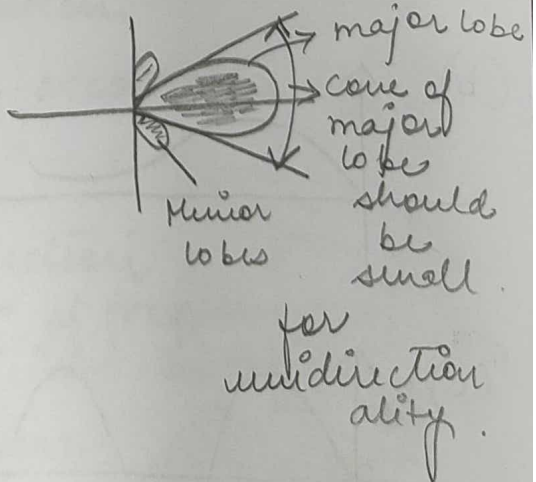
### 1. Radiowave Transmission :-

* Frequency → 10 kHz - 100 MHz
* AM radio, FM radio
* All kinds of broadcast network
* Two ways of transmission
  - → Ground waves transmission (penetrate on objects)
  - → Tropospheric transmission
* Frequency dependent
* Omnidirectional Antenna (can transmit in all directions)




### 2. Microwave Transmission :-

* Frequency → 100 MHz - 1 THz.
* Mostly use directional antenna for transmission & reception.
  - → line of sight communication (LOS)
* DTH link



3. Infrared Transmission :-

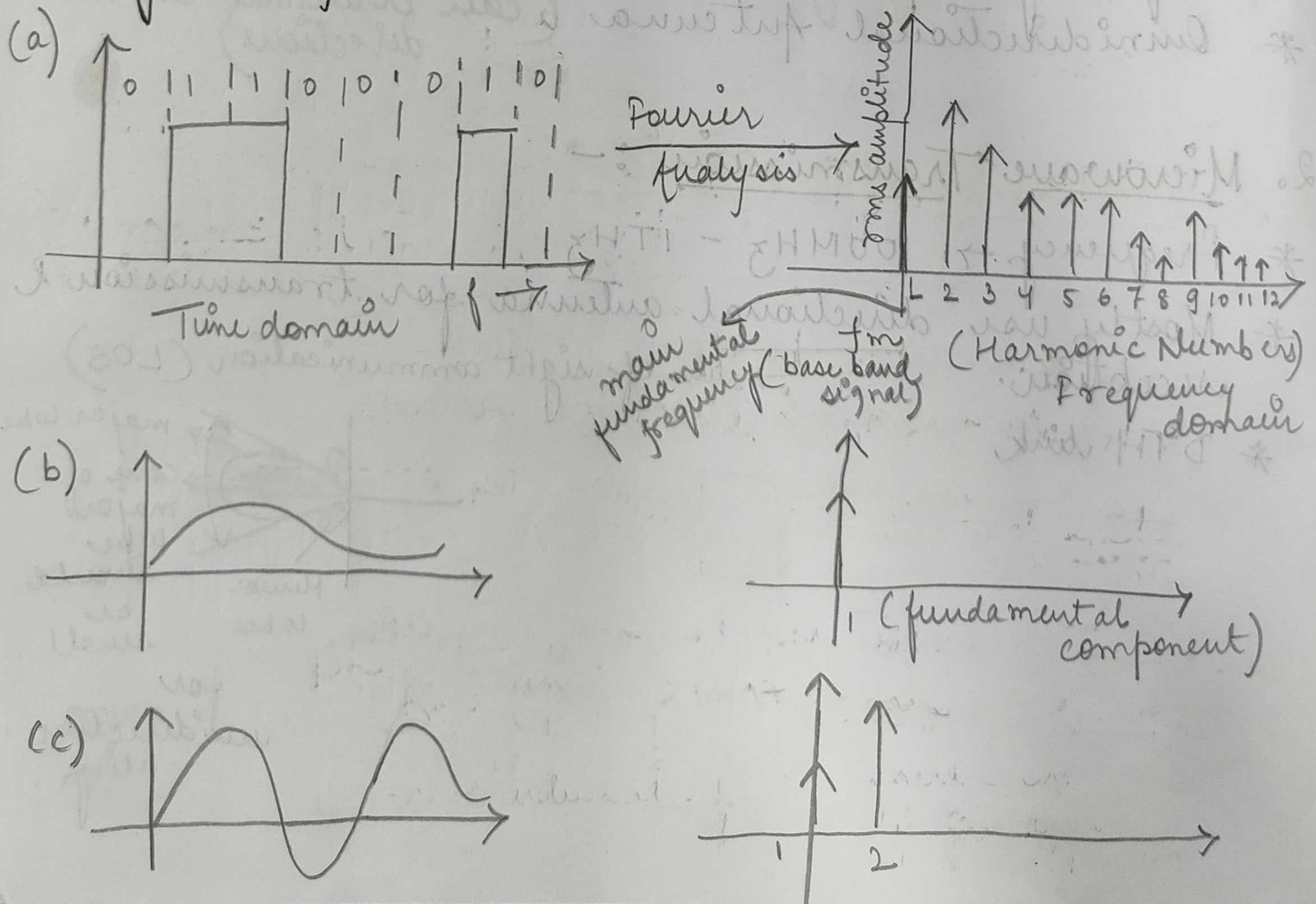
* These are meant for short-range communication (like TV remote)
* Highly directional & can't penetrate the objects

4. Lightwave Transmission :-

* It is a wired medium / guided medium
* Optical fibres are used for light transmission
* As guided media, it is inherently directional.
* It offers very high bandwidth, low cost & highly secured ways of data communication.

2.4. Waveforms to Bits :-

Digital Signal (data)



* Data signal is band limited
* The medium/channel is band limited

} – Objective :– maximize the data rate

Figure – (a)

8 bits of data signal ⟶ (analysis) ⟶ frequency component at different frequencies.

At receiver end, not all the frequency components are needed for reconstruction of data signal

But more no. of frequency components ⟶ fidelity ↑ of data signal.

But, using all frequency components for reconstruction makes a trade off with medium band limitation

The data rate = b bit/sec (Assume)

↓ bandwidth limitation.

b – bits are transmitted = 1s

1 bit " " = $\frac{1}{b}$ s

8 bits " " = $\frac{8}{b}$ s

$f_m$ or $f_b = \frac{1}{(8/b)} = \frac{b}{8}$ Hz

↓ First harmonic component for the example assumed.

BW copper cable – 1MHz
BW human voice – 3kHz

} Wired telecommunication

$\frac{1MHz}{3kHz} \approx 330$ subscribers can be accomated

Data rate effects signal reconstruction

At 19200 bits/s

↓ comes from trade off b/w BW of signal & medium

1 component of frequency is sufficient for reconstruction of the digital signal

↓ fundamental one

Date - 05.10.23

* Waveforms to Bits :-

| Data rate (bps) | No. of harmonic sent in the channel |
|---|---|
| 300 | 80 |
| 600 | 40 |
| 1200 | 20 |
| 2400 | 10 |
| 9600 | 2 |
| 19200 | 1 |
| 38400* | 0 |

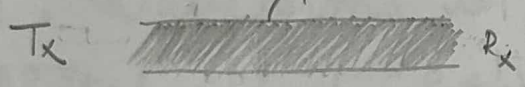
$\left(\frac{24000}{b}\right)^{th}$

b = data speed (bps)

limited bandwidth

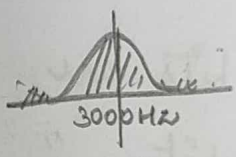
$3000 \times \frac{8}{b}$

6000 ↑ If increased




Human voice - 3.4kHz

~3kHz




limits the BW of channel otherwise channel capacity gets waste

* limiting the bandwidth of channel limits the data rate.

## # 2.4.3 Maximum Data Rate of a Channel :-

2 theories

- Nyquist
- Shanon

① Nyquist Max$^m$ data rate of a "Noiseless Channel"

$$DR|_{max} = 2 \cdot B \cdot \log_2 V \quad \frac{bits}{sec}$$

B → Bandwidth of noiseless channel

V → no. of levels in digital signal/data

for telephone line channel –

$B = 3000\ Hz$
$V = 2$ } will be given

$DR = 2 \times 3000 \log_2 2$
$= 2 \times 3 \times 10^3$
$= 6000$ bits/sec.

The max$^m$ data rate acc. to Nyquist theorem for telephone line channel is 6000 bits/sec

② Shanon's Theorem for max$^m$ data rate on a "Noisy channel":–

$$DR|_{max} = B \cdot \log_2 (1 + S/N) \text{ bits/sec}.$$

$B \rightarrow$ Bandwidth of channel.

$S/N \rightarrow$ Signal to noise ratio (in dB)

$$\frac{S}{N} = 10\ dB = 10 \cdot \log_{10} \left(\frac{P_S}{P_N}\right)^{10}$$

$$20\ dB = 10 \cdot \log_{10} \left(\frac{P_S}{P_N}\right)^{100}$$

can't put dB value in formula so, convert it as

for telephone line channel –

$B = 3000\ Hz$

$S/N = 30\ dB$ ; $20\ dB$

$$DR|_{max} = 3 \times 10^3 \log_2 (1 + 10^3)$$

$$= 3 \times 10^3 \times 9.96$$
$$\approx 29.88 \times 10^3$$
$$\approx 29880.00$$
$$\approx 29880$$
$$\approx 30 kbps$$

$$= 3 \times 10^3 \log_2 (1 + 10^2)$$
$$= 3 \times 10^3 \log_2 (101)$$
$$= 3 \times 10^3 \log \times 6.8$$
$$= 20.4 \times 10^3$$
$$\approx 20 kbps.$$

ADSL link –

BW = 1 MHz = $10^6$ Hz

S/N = 40 dB

$$DR|_{max} = 10^6 \log_2(1+10^4)$$

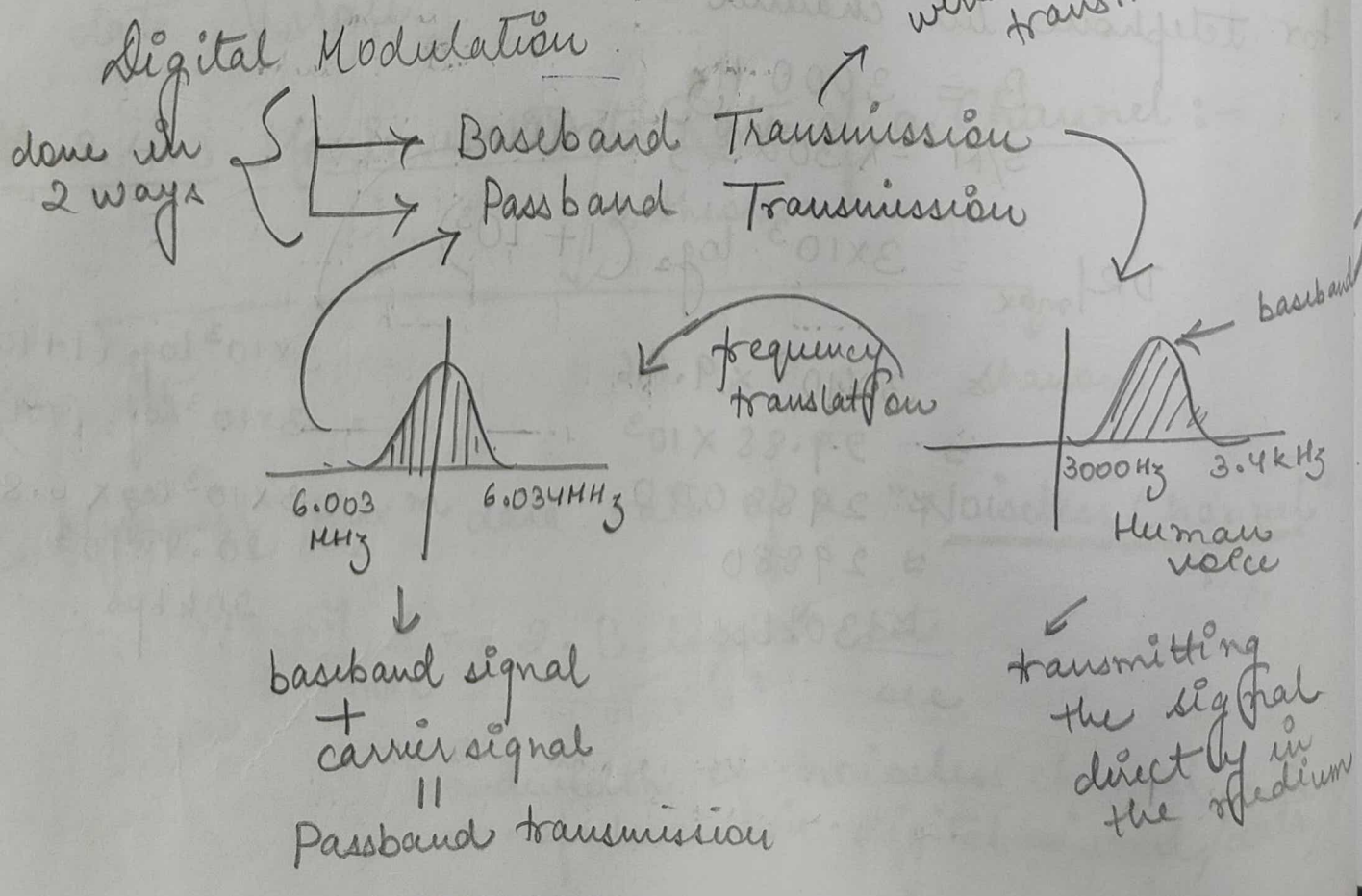
$$= 10^6 \times (\approx 13)$$

$$= 13 \text{ Mbps}$$

## # 2.4.4 (Digital Modulation)

→ Digital data (stream of 1s and 0s) can be sent through either wired or wireless link in analog form.

→ So, digital modulation is a process of conversion between bits and signals



## * i) Baseband Transmission :-

→ As the name suggests, digital information (stream of 1s & 0s) are transmitted in the form of signal through wired medium (Coaxial cable, UTP) as well as optical cable).

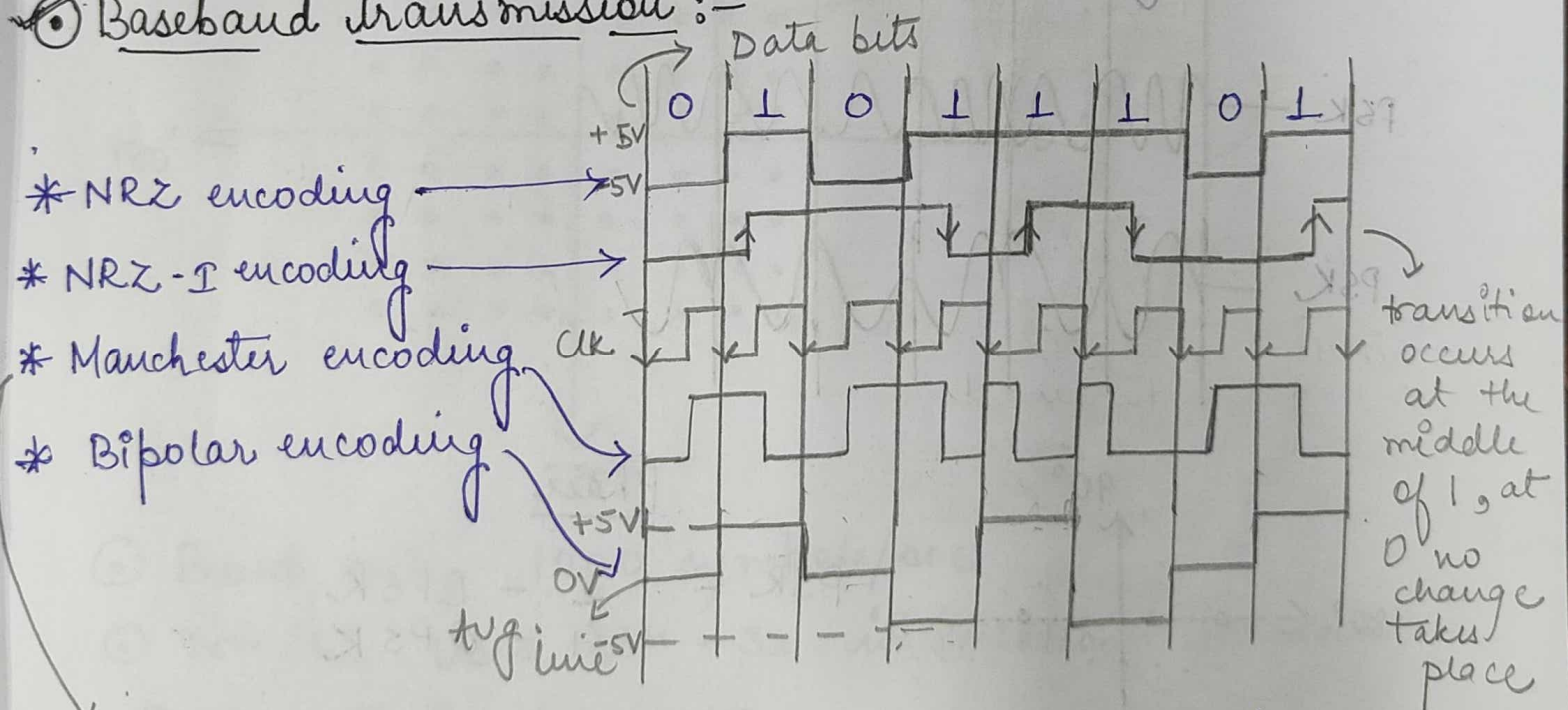
→ Baseband transmission is widely used in LAN's

→ The most preferably baseband transmission involves :-

(i) NRZ encoding (Non Return to Zero)
(ii) Manchester encoding
(iii) Bipolar encoding

Date - 06/10/23

### ⊙ Baseband Transmission :-



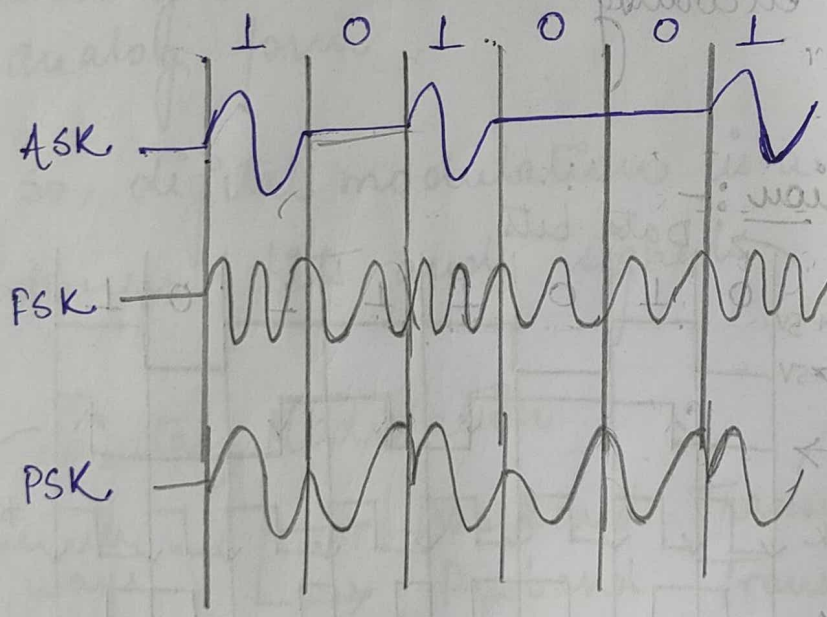

* • Manchester encoding involves clock (CLK) pulses.
  • Manchester encoding involves XOR operation b/w clock pulse & data bits (bit stream)

If data bit → 0 → same as clock pulse
" " " → 1 → inversion of clock pulse } Analog signal

* Bipolar encoding –
The average frequency for the signal should be maintained at 0.

*2) Passband Transmission :–
→ low frequency domain → high frequency domain
→ Amplitude (ASK – Amplitude shift keying) carrier
Phase (PSK) – Phase shift keying
Frequency (FSK) – Frequency shift keying
→ Wireless transmission –

↓
amplitude of the signal is changed according to data bit pattern



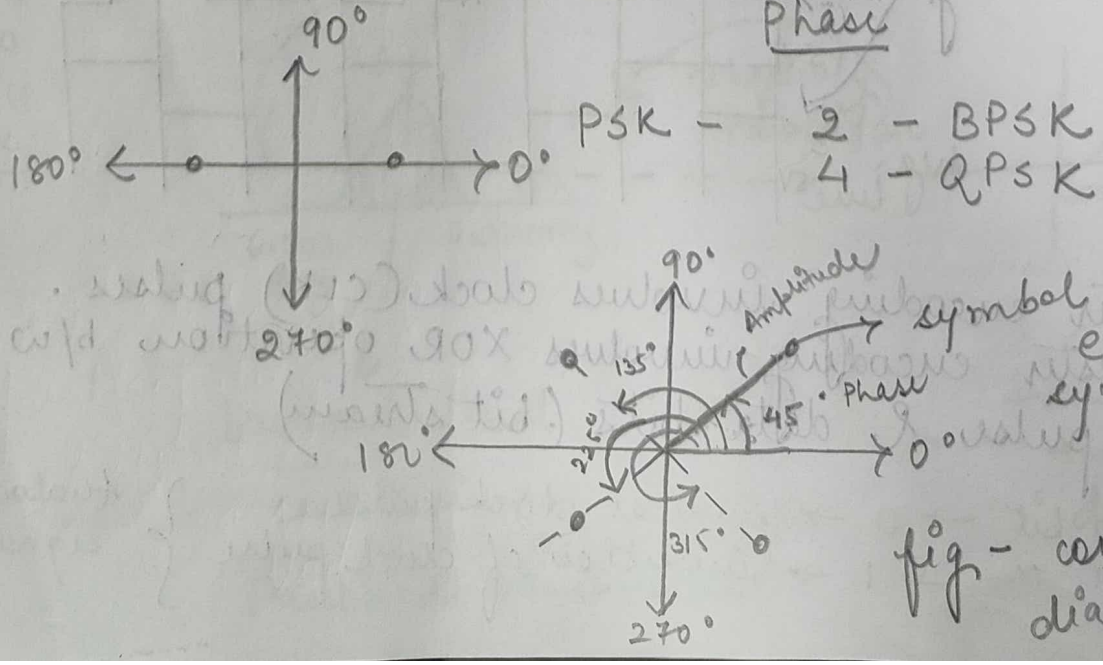




fig – constellation diagram.

* Baud rate – No. of symbols/sec

Bit rate = $\frac{\text{No. of bits}}{\text{symbol}} \times \frac{\text{No. of symbols}}{\text{sec}}$

= No. of bits/sec

⊙ QAM – Both amplitude & phase are involved for modulation.

QAM – n

n = no. of symbols.

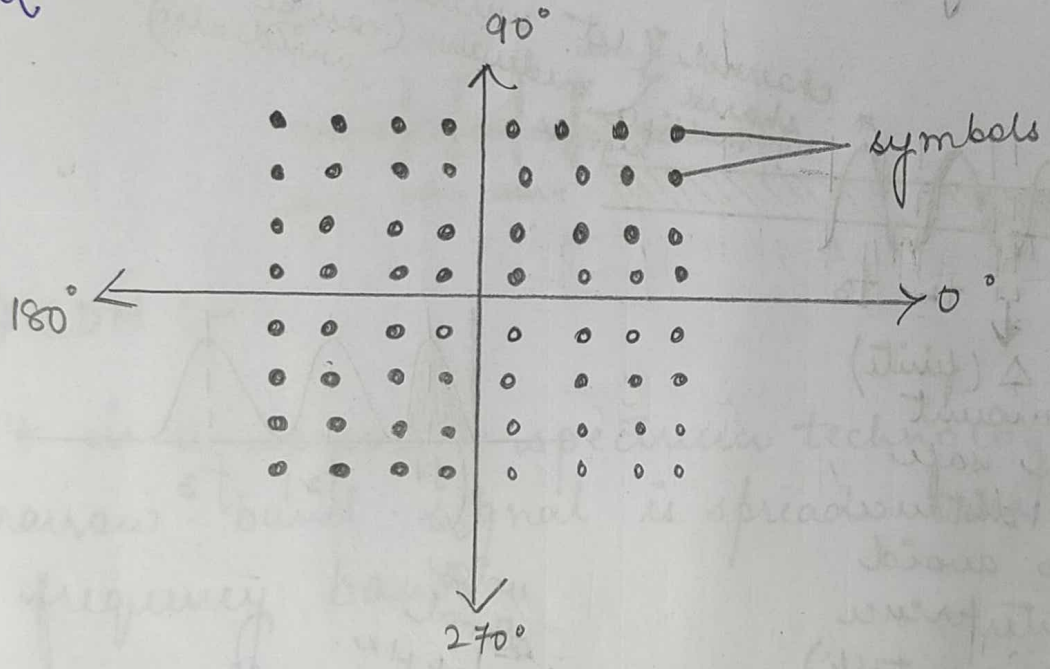
QAM-16 $2^m$

QAM-64

m → no. of bits in one symbol

Date – 7/10/23

⊙ QAM – 64




⊙ Baud rate = 1200 symbols/sec

⊙ Tx$^{n}$/Rx uses QAM – 32 modulation scheme

Data rate?

$(32 = 2^5)$ ↓ 5 bits to represent 32 symbols

Data rate / Bit rate = 1200 × 5

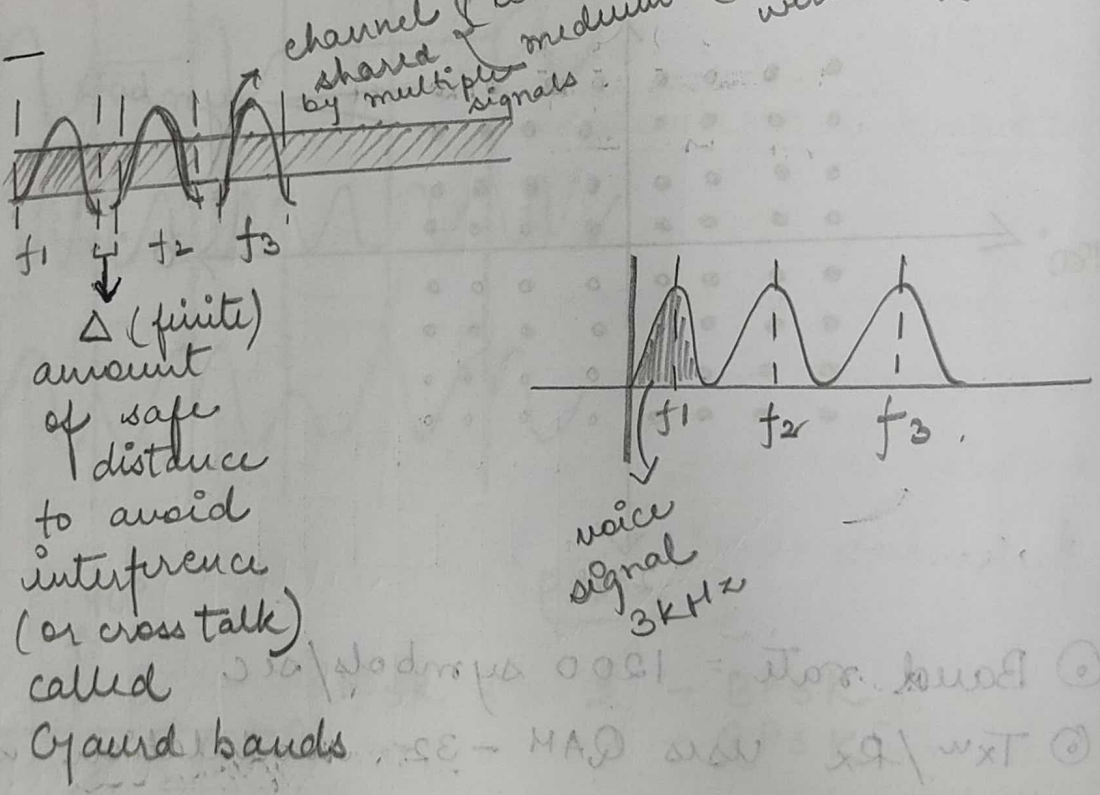
= 6000 bits/s

# * Multiplexing :-

It is a scheme where we can allow sharing of common channel by multiple no. of signals.

- One channel, shared by multiple signals.
- Different types of multiplexing :-
  (i) Frequency Division Multiplexing (FDM)
  (ii) Time Division Multiplexing (TDM)
  (iii) Code Division Multiplexing (CDM)
  (iv) Wavelength Division Multiplexing (WDM)

(i) FDM :-




→ In FDM, frequencies are divided among all participating signals to share a common channel.

ex - ○ AM/FM broadcasting
○ Voice-grade telephone system

* OFDM — Orthogonal FDM

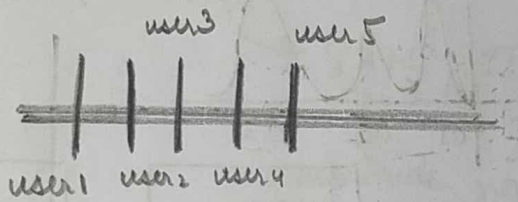
↓

we can minimize guard band distance as channel at that point remains unuse

In FDM,
frequency → discrete domain
time → continuous domain

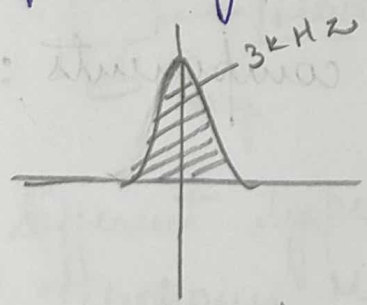
(2) TDM:-

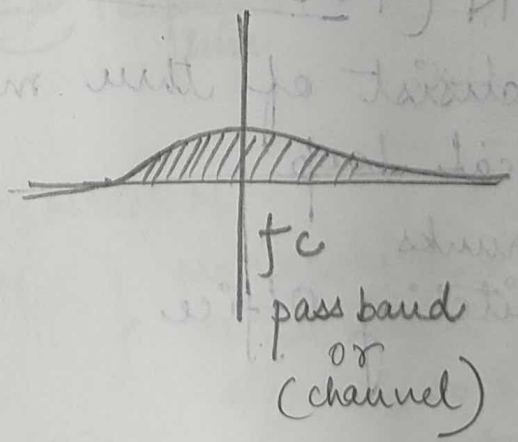
- All signals utilize the full bandwidth of the channel.
- In TDM, time is in discrete domain & frequency is continuous.



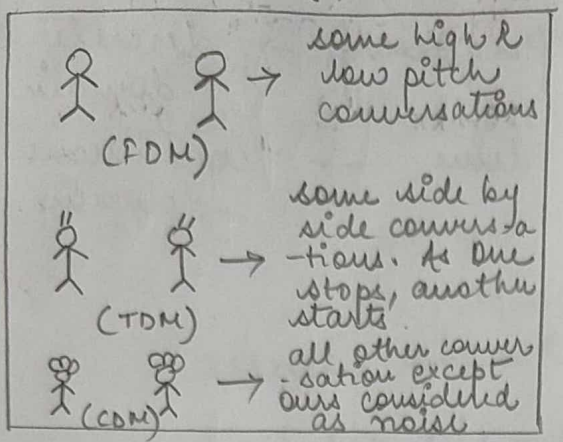

(3) CDM :-

- It is a spread-spectrum technology where a narrow-band signal is spread over a wider frequency band.



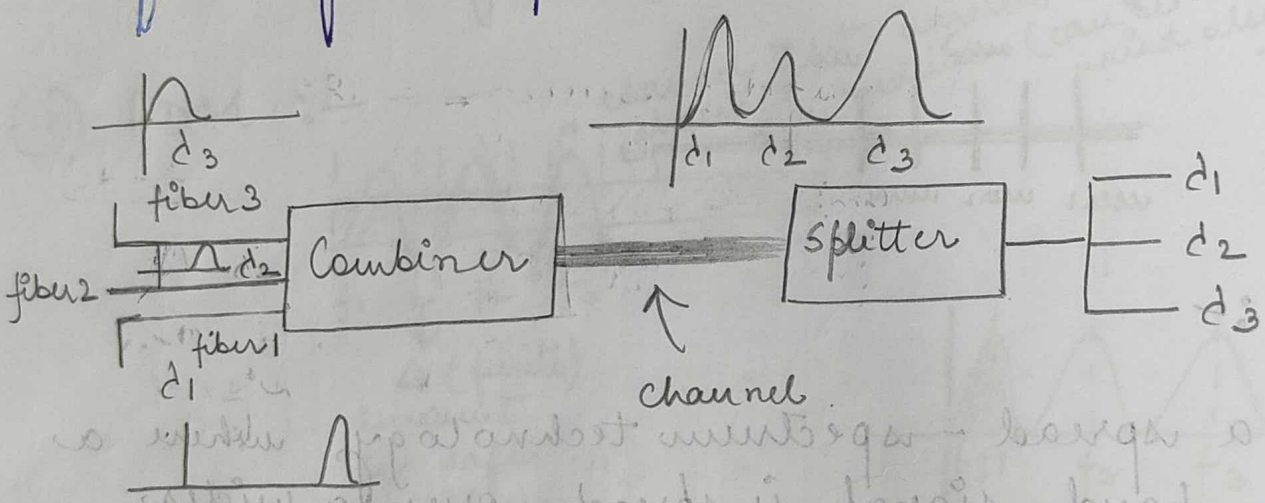



* Airport Lounge




(4) WDM

- It is a form of frequency division multiplexing where multiple light signals share a common fiber optic cable.

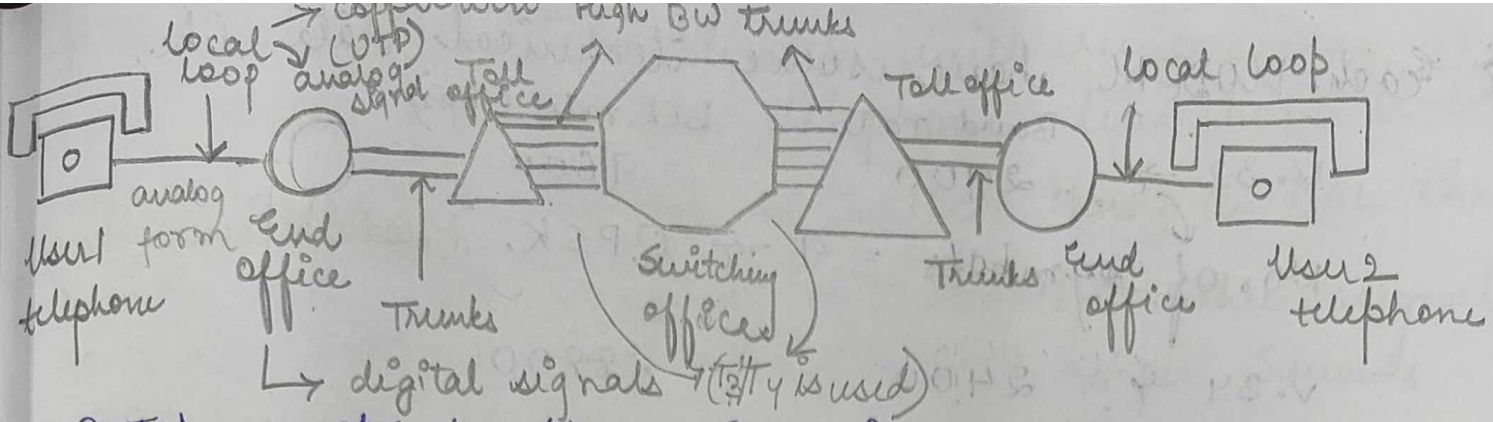



Date - 12.10.23

# 2.5 PSTN (Public Switched Telephone Network)

*1. PSTN consist of three major components :-

i. Local loop
ii. Trunks
iii. Switching Office

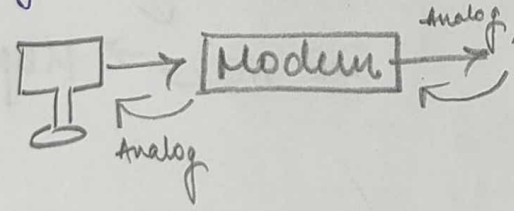



* PSTN was to handle voice signals.

→ ① The local loop :-
- Telephone MODEM
- DSL / ADSL
- fiber

- Telephone MODEM (sending/Transmitter, reception/recieving)
→ MODEM → Modulator & Demodulator
→ QAM (technology used for modulation as amplitude + phase)
no. of data bits in QAM is $2^m$
m → no. of bits in one signal.

→ Modulation/Demodulation with digital/analog signal but output is always analog.




→ Different types of MODEM -
① Telephone MODEM
② Cable MODEM
③ DSL MODEM
④ Wireless MODEM

} No MODEM for fiber optic as it is in the form of light signals, so no need to modulate it.

→ Each MODEM have some technical data like,

| | Baud rate | Bit rate (bps) |
|---|---|---|
| V.32 → | 2400 | 9600 |

No. of symbols = 4 → QPSK (Modulation scheme)

| | | |
|---|---|---|
| V.34 → | 2400 | 28800 |

No. of symbols = 12 → QAM (Modulation scheme)

| | | |
|---|---|---|
| V.90 → | 8000 | 56000 |

No. of symbols = 7+1 → QAM.

(7 for synchronization (reserved))

DR max = 56 kbps.

↳ Limitation → using telephone line signal

↓

BW = 3 kHz (Artificial) → due to voice signal

Concept of DSL Modem system → if we remove this artificial filter for voice signals on BW, the actual BW will be 1 mHz.

↓

DR max → Mbps.

- DSL MODEM

→ DSL → Digital Subscriber link

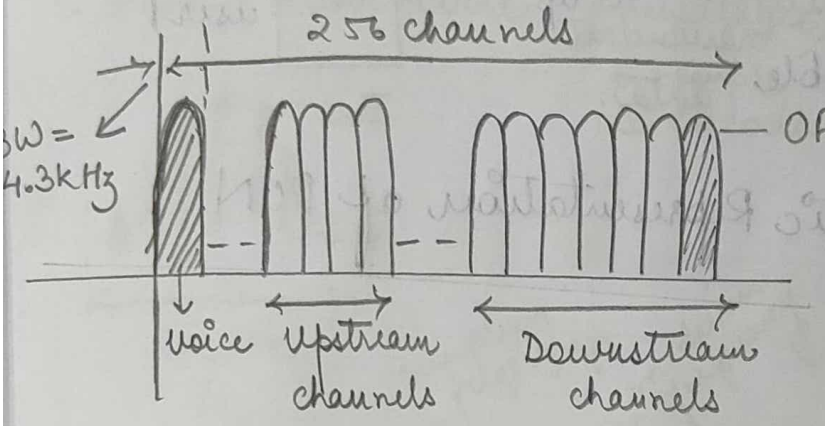
↕ → BW is same for all users. But demand is different, so BW gets wasted as it does not differentiate b/w users.

ADSL → Asymmetric DSL → The capacity of local loop falls very sharply with distance from the end office.

→ DSL uses a switch which will remove the artificial filter & makes the telephone line band limited to 1 mega Hz instead of 3 kHz. This, in DSL the max^m data rate limited to 13.2 Mbps when signal to noise ratio is assumed to 104 as per Shannon's theorem.

From end office → distance ↑ → data rate ↓.

→ ADSL stands for asymmetric DSL.




Total BW of Telephone lines — 1.1 MHz

No. of channels = 256

BW of each channel — $\frac{1.1\ MHz}{256} \approx 4.3\ kHz$

* Date - 13.10.23

⊙ local loop :-

→ fiber as channel :-

PON (Passive Optic Network)

no need of any active components like MODEMS

Splitter/Combiner → they are not active component, so they don't manipulate data.

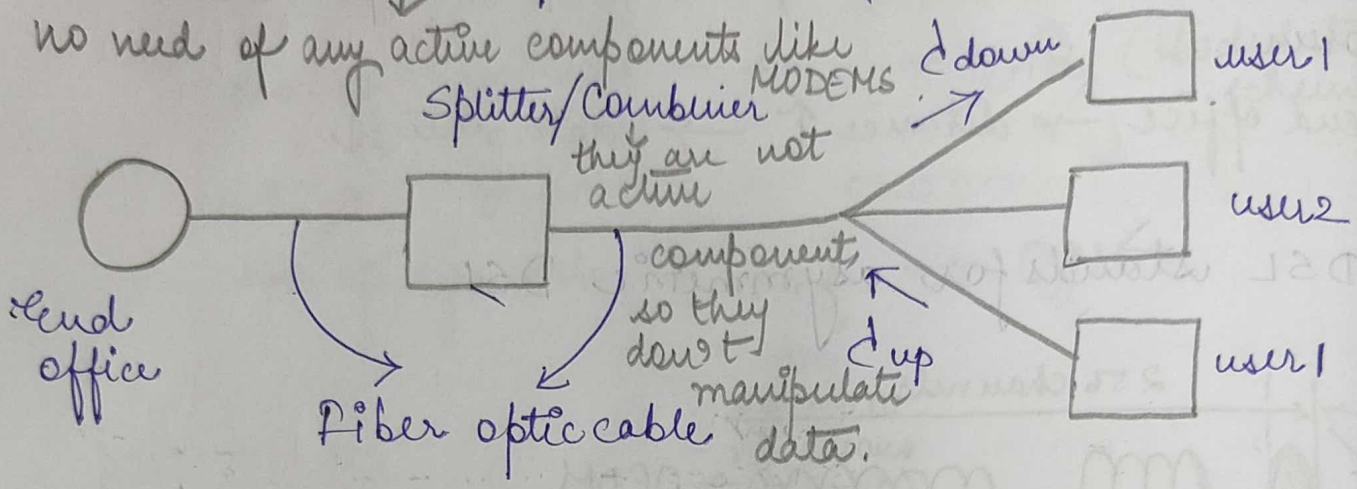


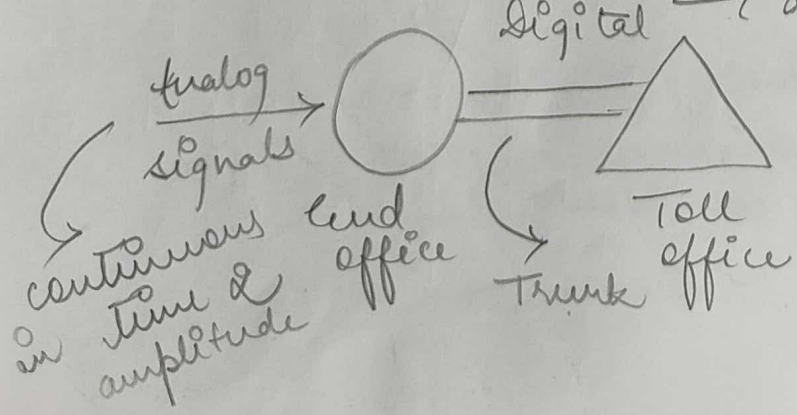

fig- Schematic Representation of PON

ADSL :-

- Asymmetic DSL (Digital Subscriber Link)
- 256 channels ; each is 4.3 kHz
- 1 - voice channel, rest is for data
- Upstream channel → user to End office (20%)
- Downstream channel → End office to user. (80%)

* Trunks and Multiplexing :-

Digital → discrete in time & amplitude



→ Trunks in telephone network are faster than local loop and different in two respect than local loops :-

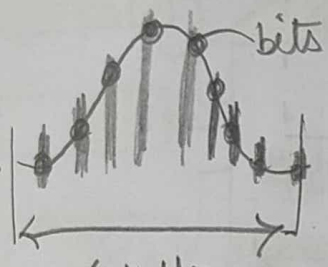
1. Trunks carry digital information.
2. Trunks implements multiplexing.

⊙ Trunks carry thousands of calls simultaneously using FDM/TDM technology.

# Digitalization of voice signal :-

1. PCM (Pulse Code Modulation)

① Sample
② encode → with finite bits } PCM




sampling frequency
medium frequency

→ Sampling ( $f_s \approx 2 f_m$ )

speed = 8000 sample/s
Encoding - 8 bits / sample

DR = 8000 × 8 = 64000 bits/sec
DR = 64 Kbps.

2. CODEC - (Coder - Encoder)
↓
device which performs PCM
→ performs → Analog ⇄ Digital

3. Each sample is of 125 μs.

64000 bits → 1 sec
1 bit → $\frac{1}{64000}$
8 bits → $\frac{8}{64000} = \frac{1}{8000}$ = 125 μs

# #. Multiplexing Of Digital Signals in Telephone Network :-

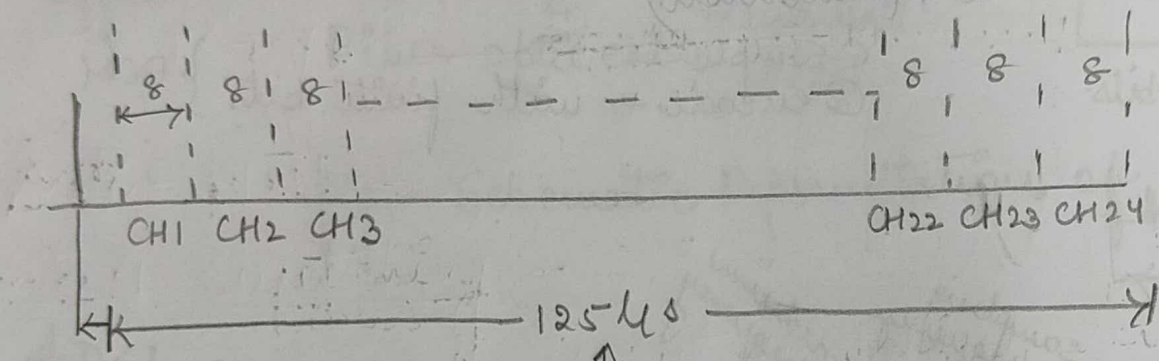
⊙ $T_1$ Carrier Multiplexing :-

→ 24 channels (i.e users)

↓

voice signals

(digital PCM signals)




Data rate = $\frac{193}{125\,\mu s}$ = 1.544 Mbps

Date - 14.10.23

⊙ $T_1$ Carrier System :- (Mostly followed)

≐ 24 channels

≐ Sampling speed = 8000 samples/sec

≐ 8-bit/sample encoding (PCM)

≐ Total bits/frame = 192 + 1 = 193 bits → signalling purpose

≐ 1 frame = 125 μs duration

≐ Data rate = $\frac{193 \text{ bits}}{125\,\mu s}$ = 1.544 Mbps

⊙ E1 Carrier System :-

≐ 32 channels

≐ Sampling speed = 8000 samples/sec

≐ 8 bits/sample (PCM)

≐ Total bits in one frame = 256 bits

≐ Duration of frame = 125 μs

≐ Data rate = $\frac{256}{125\,\mu s}$ = 2.048 Mbps

#. Multiplexing Of $T_1$ carrier system :-

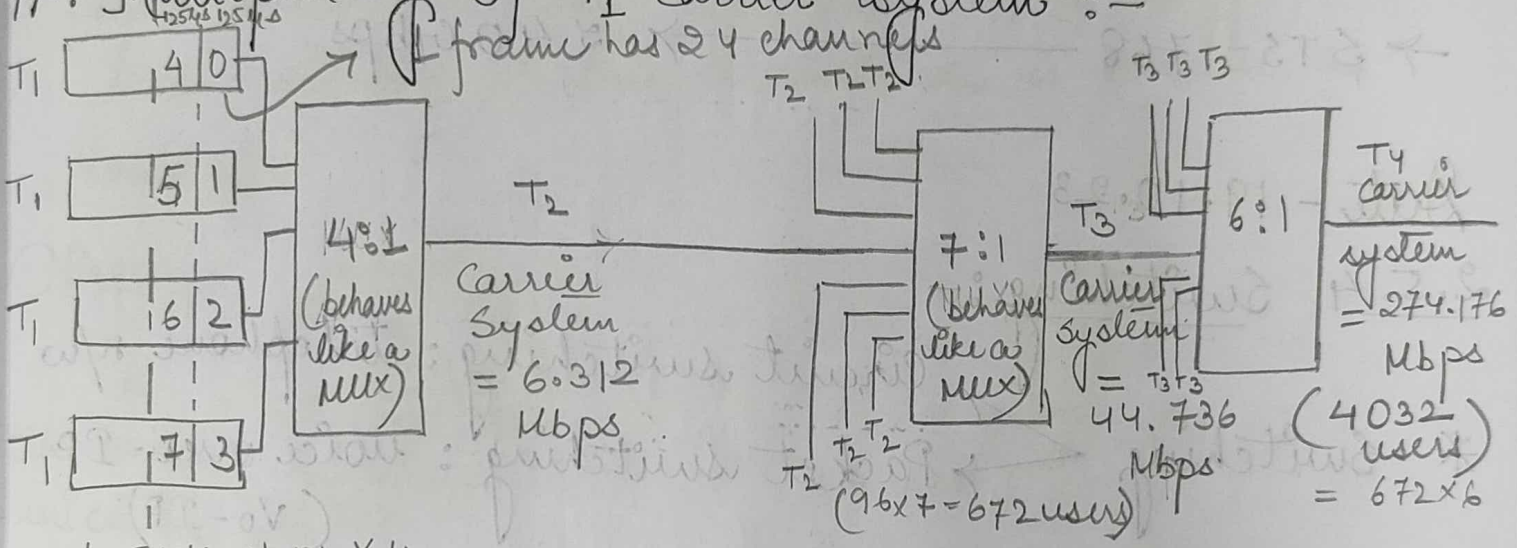



fig - Multiplexing of Trunks.

⊙ Multiplexing using optical fibre

* SONET - stands for synchronous optical network

→ SONET transfers & recievers at a rate of 8000 frames per second. Each frame is of 810 bytes (6480 bits) in 125 μs.

→ Data rate = $\frac{6480 \text{ bits}}{125\,\mu s}$ = 51.84 Mbps.

(1 SONET link is comparable to one $T_3$)

→ This SONET link is referred as STS-1
(optical domain) (synchronous transport signal)

→ STS-3 SONET link supports a data rate = 51.84 × 3 = 155.52 Mbps

→ STS-6 " " " " " = 51.84 × 6 = 311.04 Mbps

→ STS-768 ⟶ ≈ 40 Gbps

Date - 19.10.23

2.5.4 Switching :-

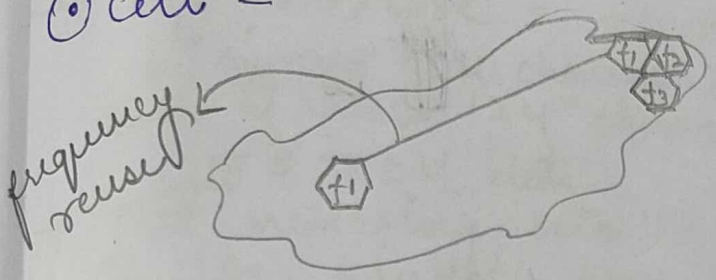
* Switching → Circuit switching : telephone n/w
→ Packet switching : voice over-IP (Vo-IP)

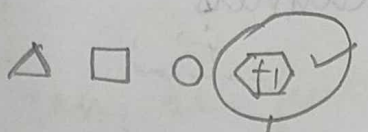
#. Cellular Networks :-

1. Cellular Networks :-
→ First Generation Mobile N/w (1G) - AMPS
→ Second " " " (2G) - GSM/CDMA
→ Third " " " (3G) - EDGE/WCDMA
→ Fourth " " " (4G) - LTE
→ Fift Generation Mobile N/w (5G) -

* Few terms / terminology in Cellular N/ws :-

⊙ cell -



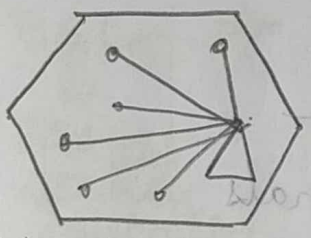




best shaped cell to cover any irregular geographical area.

→ No two adjacent cell have the same frequency

⊙ Handoff - As we move from one cell to another cell, our cell gets associated to a different base-station, this transition is known as handoff.

⊙ Paging -



the communication b/w cell & a base-station & multiple mobile users within a cell as (It also notifies when cell changes)
↓
(geographical area)

* First Generation (1G) :-

→ AMPS - Advanced Mobile Phone System.

→ 1G deals with only voice signals in analog form.

→ AMPS works in FDM (Frequency division Multiplexing)

→ AMPS has 832 no. of full duplex channels

→ Each consists of a pair of simplex channels.

→ Channel BW = 30 kHz

→ AMPS supports 880 MHz band.

824 MHz – 849 MHz → MS (Mobile Station) ----→ BS (Base Station) [Upstream link]

869 MHz – 894 MHz → BS ——→ MS (Down link)

$$\frac{(894-869)\,MHz}{30\,KHz} = \frac{25\times10^6}{30\times10^3} = \frac{5\times10^3}{6} \approx 833$$

(No. of channels)

## * Second Generation (2G) :–

→ Voice signals in Digital signals

→ 2 dominant mobile technology

(a) GSM * (Global System Mobile Communication)

* most widely used

(b) CDMA (Code Division Multiple Access)

→ GSM is based on both FDM and TDM.

→ GSM – 900 MHz / 1800 MHz / 1900 MHz

→ 900 MHz

- 890 MHz – 914.8 MHz, MS → BS: $\frac{24.8}{200}$ ⇒ Upstream link, 124 channels in FDM
- 935 MHz – 959.8 MHz, BS → MS: Downstream link, 124 channels in FDM

45 MHz separation b/w uplink & downlink, so no interference takes place

→ Each channel in GSM is of 200kHz

→ 124 × 200kHz = 24.8 MHz
↓ (simplex FDM channels)
each of these 124 channels can be further divided into 8 TDM slots.

→ Text messaging started in 2G.

→ In 1G, handoff transition is hard as the signal drops drastically

→ MAHO (In 2G) – Mobile Assisted Hand off
↓
discrete time vacant blocks are used for a easy
slots
or soft base-station transition → results in soft handoff

MAHO + BSC → soft handoff
↓
Base station controller

GSM
Handset — SIM Card
↓
Subscriber Identity Module

Date - 26.10.23

* Cellular Network :-

◉ More frequency → more transmitting power.

* Third Generation (3G) :-

2G → 3G :- transition of due to data is not smooth.

→ 2G → 2.5G → 3G

◉ 2.5G
→ Digital voice + data ] Apple iphone started
→ EDGE – Enhanced Data Rate for GSM Evolution

◉ 3G :- Wideband CDMA CDMA (No simcard needed)
→ { WCDMA/UMTS, CDMA 2000 } → Broadband CDMA technologies used.

UMTS → Universal Mobile Telecommunication System

⊙ WCDMA :-
BW of channel = 5 MHz

⊙ CDMA 2000 :-
BW of channel = 1.25 MHz

→ CDMA supports soft handoff.
as no frequency division is involved.

* Fourth Generation (4G) :-

→ Digital data / Packet switching * N/W (key development)

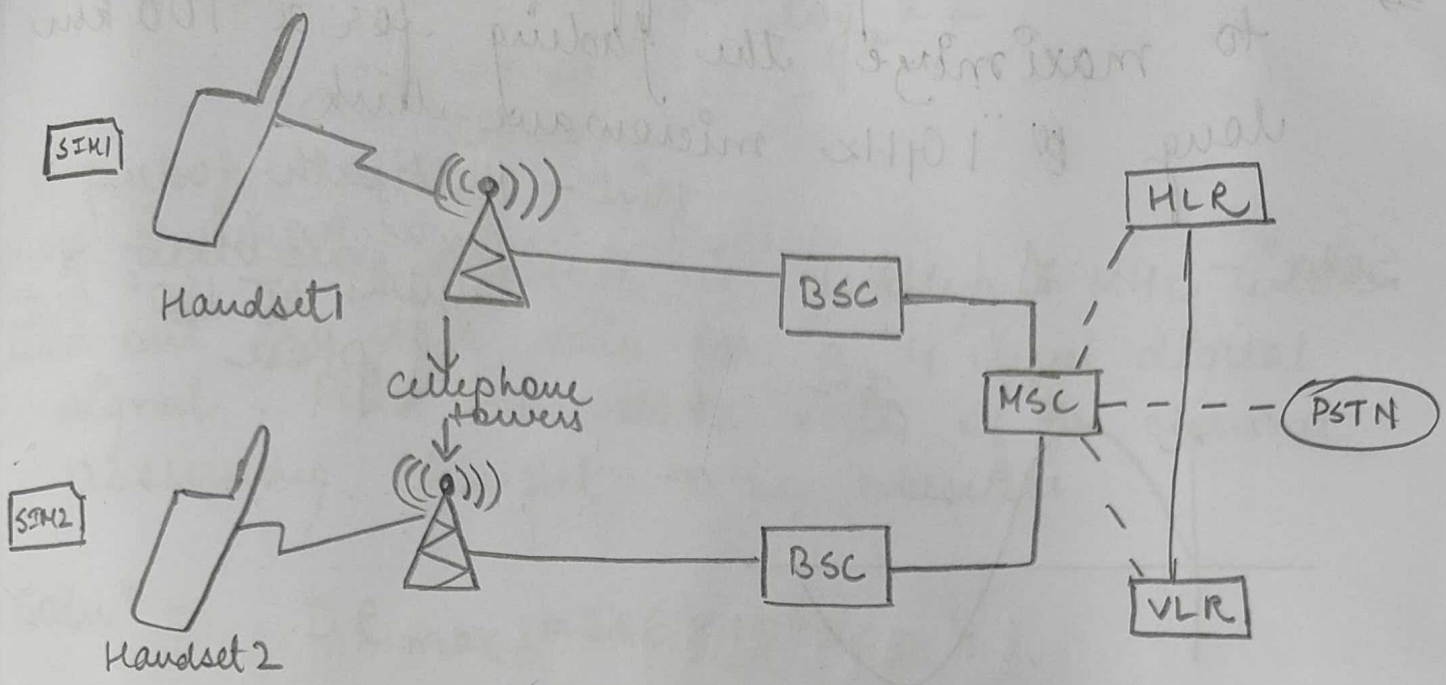
→ Technology used - LTE (Long Term Evolution)

→ The packet switching in 4G is referred as EPC (Evolved packet core) which is IP based (Internet protocol) networking that seperates voice traffic from data.

→ However, in 4G n/ws. voice traffic can be carried out ~~on~~ over EPC using VoLTE (Voice over LTE)

- EPC - IP based packet switching n/w
- VoLTE - Voice traffic on EPC (Voice over LTE)

# GSM Architecture :-




BSC – Base Station Controller
MSC – Mobile Switching Network
HLR – Home Location Register
VLR – Visitor Location Register.

Date - 27.10.23

Q1. Computer screen image = 3840 × 2160 pixels. Each pixel = 24 bits. Transmission speed = 50 image/s. Find data rate?

Soln – Data rate = 3840 × 2160 × 24 × 50 bits/s
= 9953280000
≃ 10 Gbps.

Q2. How much BW is there in 0.1 μm at a wavelength of 1 micrometer

Soln – BW = ? $c = f\lambda$ $c = f\lambda$

$\Delta f = \frac{c}{\Delta\lambda} = \frac{3 \times 10^8 \text{ m/s}}{0.1 \times 10^{-6} \text{ m}}$

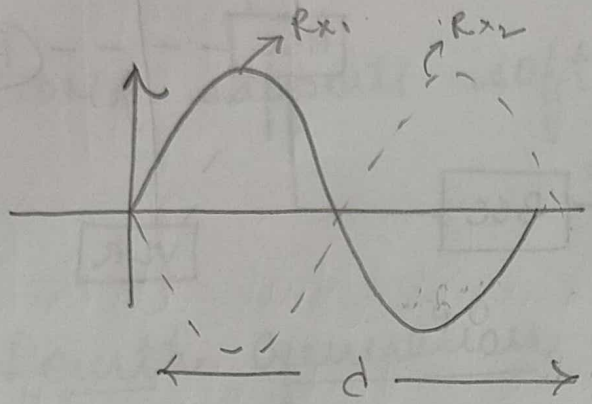
$= 3 \times 10^{13}$ Hz

* $\Delta f = \left| -\frac{c}{\lambda^2} \cdot \Delta\lambda \right|$

Q3. How much path difference is required to maximize the fading for a 100 km long @ 1 GHz microwave link

Hint – Multipath fading is max^m when 2 waves arrives at 180° out of phase

Soln^n – $\Delta d = ?$




Phase difference = 180°

Path difference = $d/2$

$c = fd$

$3 \times 10^8 \text{ m/s} = 10^9 \times d$

$d = \frac{3 \times 10^8}{109}$

$d = 3 \times 10^{-1} \text{ m}$

180 = d/2
... = d/4

Path difference = $\frac{3}{2} \times 10^{-1}$

$= 1.5 \times 10^{-1}$

$= 0.15 \text{ m}$

Q4- A noiseless channel of BW of 10 kHz is sampled at a rate of 1 in 1 ms. What is the max^m data rate? Assume V22

$DR_{max} = 2 \times 10 \times 10^3 \log_2 2$

$= 2 \times 10^4$

$= 20$ kbps

5. A television channel is usually 6 MHz wide. Find out the data rate for a 4 level digital signal. Find the data rate of the channel assuming channel to be noiseless

Solⁿ - $DR_{max} = 2 \times 6 \times 10^6 \log_2 4$

$= 24 \times 10^6$

$= 24$ Mbps

Q6. A binary signal is sent over a 3 kHz channel where S/N is 20 dB. Find the max$^m$ data rate?

Solⁿ - $DR = B \log_2 (1 + S/N)$

$= 3 \times 10^3 \log_2 (1 + 10^2)$

$\approx 20$ kbps.

Q7. What is the min$^m$ BW is required to achieve a data rate of B bits/sec, if the signal is transmitted using NRZ encoding.

V = 2 (NRZ) V = 3 (Bipolar encoding) ↓ beneficial but complexity increases.

Solⁿ - $DR = 2B \log_2 V$

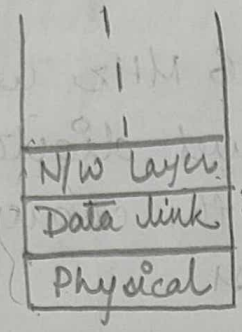
$B = 2 \times BW \log_2 2$

$BW = B/2$

Date - 28.10.23

# Chapter - 3 (Data link Layer)

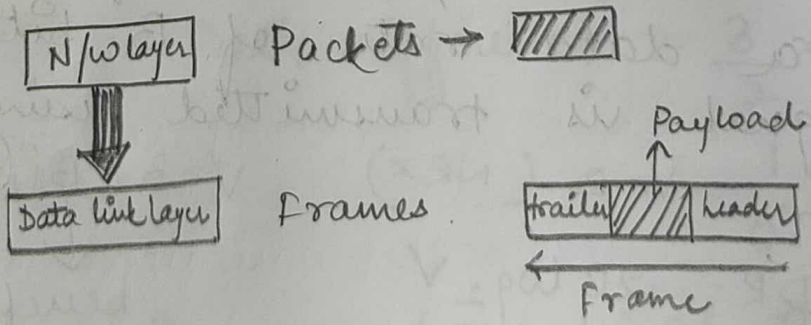
3.1




Protocol, Services & Interfaces
↓
the lower layers provides n/w services to the upper layer

## 3.1 Data link layer Design Issues :-

1) The data link layer provides a well defined interface for giving services to upper layer i.e network layer.
2) Data link layer deals with detection & correction transmission errors.
3) Regulates the flow control of data
4) To achieve this functionality, the data link layer recieves the data from N/w layer & encapsulate them into data frames before transmission




⊙ Trailer + Header → Overheads

Thus, the frame management is the basic goal of Data link layer.

3.1.1 Services provided to N/w layer:-

Services :-

1. Unacknowledged Connectionless Service
2. Acknowledged Connection-less Service
3. Acknowledged Connection-oriented Service

1) Unacknowledged Connection-less Service:-

(i) No acknowledgement from destination to source.

e.g - Ethernet (LAN).
Real-time voice/video traffic

(ii) If a frame is lost/erroneous then no attempt is made to detect/recover the frame.

2) Acknowledged Connection-less Service

(i) In this service, each frame is acknowledged. Thus the sender knows whether a particular frame has arrived correctly at the destination or not. However, if the frame is lost or not recieved by the reciever within a stipulated amount of time, then the frame is resent.

e.g- WiFi (channel is air medium)

3) Connection Oriented Service

(i) As it is a connection oriented service, both sender & reciever establishes a connection before transmission

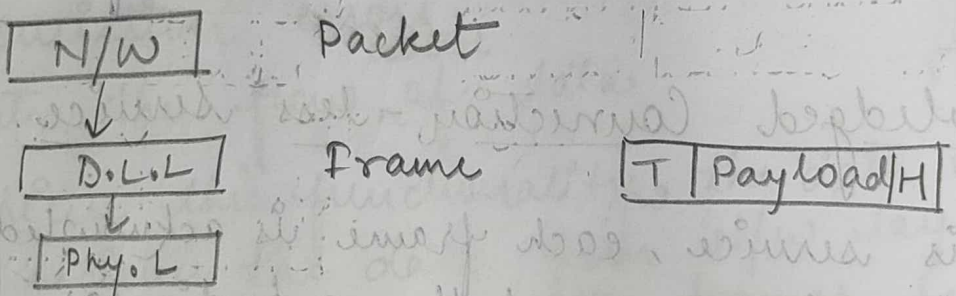
(ii) Each frame that is transmitted is given a number. The data link layer guarantees each frame transmitted is received indeed.

(iii) The data link layer also ensures that each frame is received only once and all the frames are received in the same order as it was sent.

e.g- fiber optic cable
here, overheads becomes un-necessary as the route is already fixed for transmission

Date - 2.11.23

* FRAMING :-




* Techniques or methods followed by D.L.L. to create frames -

- Before transmission data link layer append some bits referred as checksum-bits

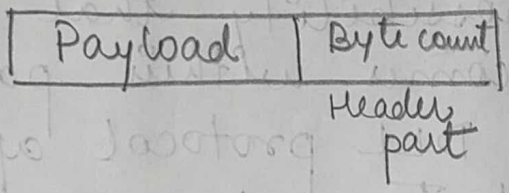
- At the destination, the data link layer of receiver will recalculate the checksum bits and compare.

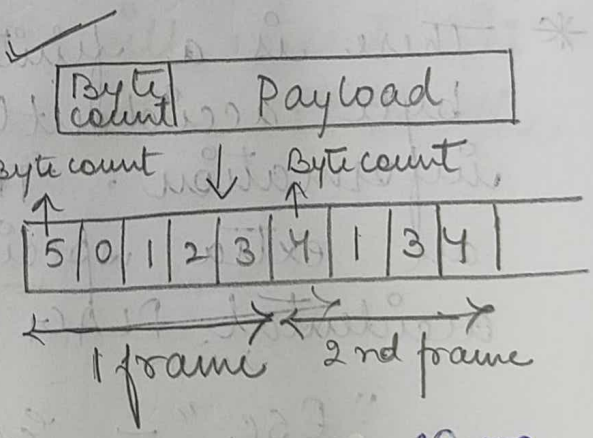
⊙ If there is a match b/w checksum bits, there is no transmission error else the data link layer at the receiver end may or not acknowledge this error by sending a transmission error report.

#. Four different techniques are available for framing :-

1. Byte/Character Count
2. Flag byte with byte stuffing
3. Flag bits with bit stuffing
4. Physical layer coding violation.

1) Byte/Character Count :-

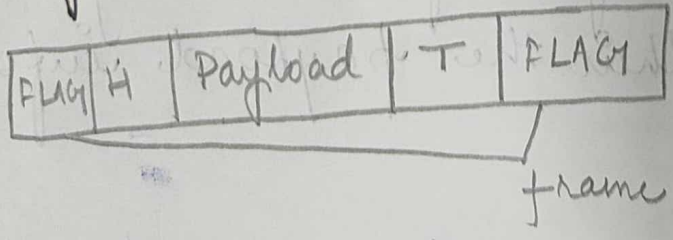


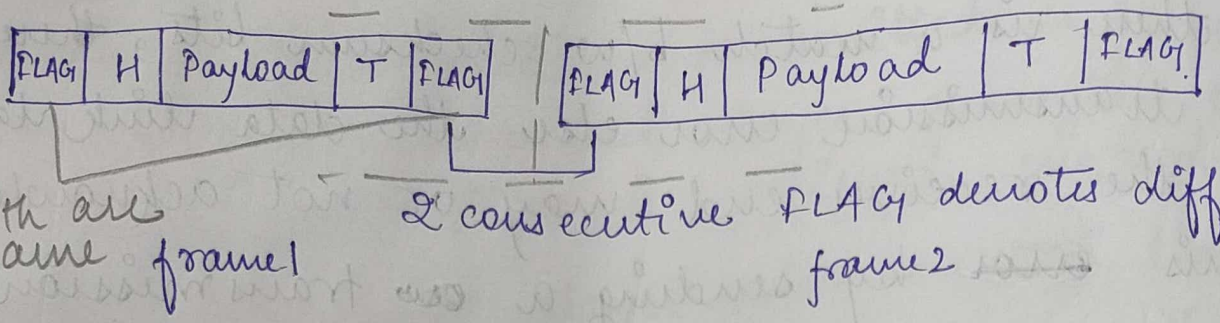




There is finite possibility of synchronization error and always ambiguity persists

Date - 3.11.23

2) Framing by "FLAG Bytes" with "Byte Stuffing".

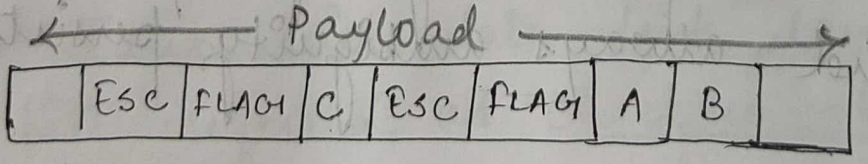





* Presence of two consecutive FLAG bytes repres end of frame 1 and start of frame 2. This helps in restoring synchronization issue due to transmission errors.

* Assume FLAG = 11001010
  If payload = 11001010
  ↳ This is also considered as delimiter

* There is a finite possibility that FLAG byte accidentally comes within payload information. Then DLL protocol appends an extra special byte before every accidental FLAG bytes.
  "ESC" — Escape byte




* At the receiver end, the DLL will dro every "ESC" byte followed by the FLAG bytes within the payload information

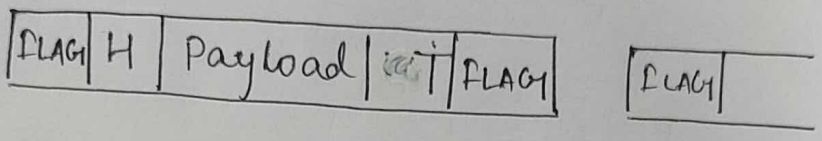
* Insertion of ESC byte before FLAG byte is known "Byte Stuffing" Process.

3) framing by "FLAG bits" with "bit stuffing".

10 bytes

10 ESC / 10 FLAG  overhead - 10 ↓ — 100% ↓

*




FLAG → 0 1 1 1 1 1 1 0

7 bits, $E_H$

* The data link layer protocol will insert bit '0' after every 5 consecutive 1s in the payload.

* payload — all are bits

*eg- bit pattern :-

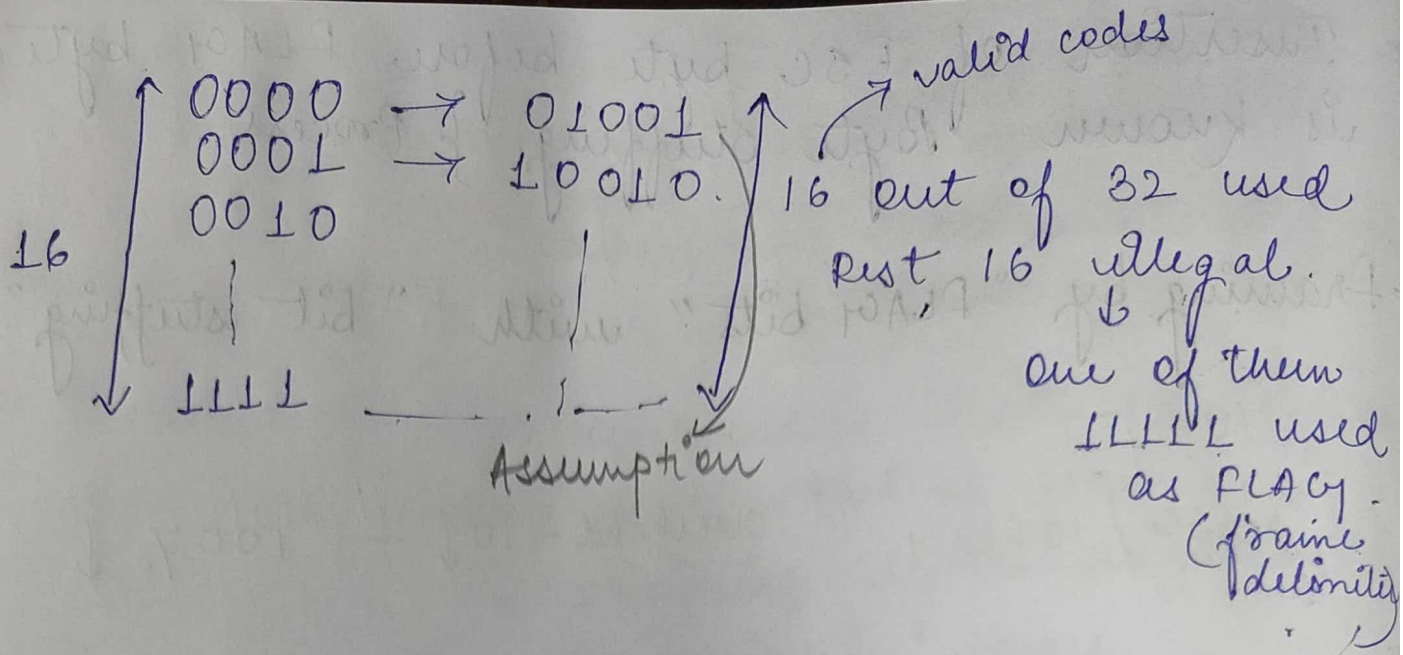
0 1 0 1 1 1 1 1 1 0 1 0

0 1 | 0 1 1 1 1 1 | 0 1 | 0 1 0

Max^m overhead = 12.5 % = $\frac{1}{8} \times 100$

4) Physical layer coding violation framing technique

→ Physical layer coding → NRZ
NRZ-I
Manchester
Bipolar
4B/5B (4 data bits, 5 signal bits)


0000 → 01001
0001 → 10010
0010
1111
16
Assumption
valid codes
16 out of 32 used
Rest 16 illegal.
one of them
IIIII used
as FLAG.
(frame
delimiter)