Introduction:

telecommunication - communication at distance.

data - form of info agreed by 2 parties.

data communication - exchange of data b/w 2 parties via some medium.

Effectiveness of data communication.

i) Delivery ii) Accuracy iii) Timeliness iv) Jitter.

Components

1) Protocol in sender / reciever
2) Message
3) Sender
4) Medium
5) Reciver.

Data representation:

Text, number, images etc. all are stored in sequence of bits.

Data flow

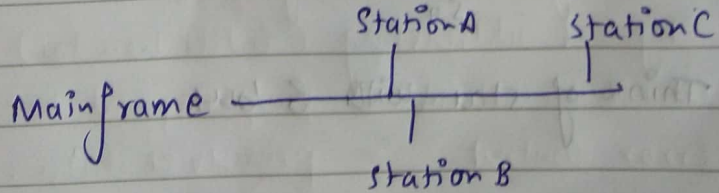
1) Simplex : Flow of data in one dir.
2) Half-Duplex: Flow of data in one dir at one time, other dir at other time.
3) Full duplex : Flow of data in both dir. anytime.

Network: Set of devices (nodes) connected by communication links.

Types of connection:

1) point to point A ——— B

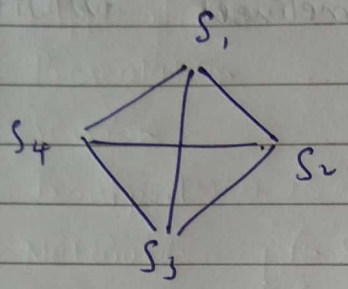
2) multipoint



Topology : way in which network is laid out physically

2 or more device connect to link. 2 or more links connect to topology. Its geometric representation of all links and their relationships.

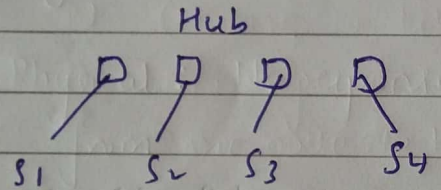
Mesh



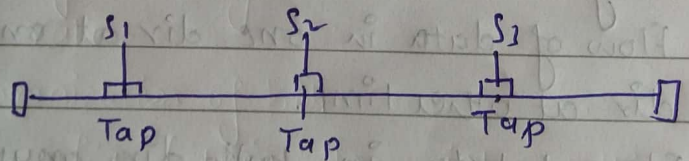
n station $n(n-1)/2$ duplex mode links.

n-1 ports.

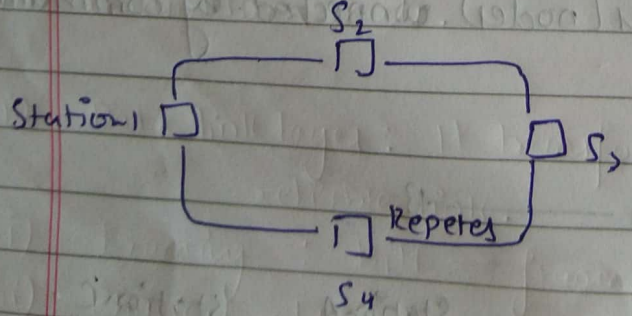
Star.



Bus



Ring.



Think of star with 3 bus.

Categories of network-

LAN: Privately owned, links to devices in a single office

WAN: Internet

MAN: covers area inside a town or city. Cable TV model can be used for internet

Internet

When 2 or more networks are connected, they become internetwork, or internet.

OSI model (Open system interconnection)

It is a layered framework for the design of N/W systems that allows comm^n between all types of computer systems.

7 layers.

Each layer calls upon the service of the layer just below it.

Layer.

7. Application
6. Presentation
5. Session
4. Transport
3. Network (Soure to destination delivery)
2. Datalink (Hop to hop delivery)
1. Physical

i) Physical: Its responsible for moving individual bits from one node to the next.

Functions:

i) Transmission medium
ii) Types of encoding
iii) Data rate
iv) Synchronization of bits
v) Line config (point-to-point, multipoint)
vi) Topology
vii) Transmission mode.

ii) Data link layer: It transforms the physical layer into reliable link.

i) Framing : bit → frame
ii) Physical addressing (add header)
iii) Flow control - proper speed to be maintained.
iv) Error control - preserved data.
v) Access control - which device control which.

iii) Network layer : Responsibe for source to destination delivery of packet.

i) Logical addressing : adds header to packet coming from up. (logical add. like IP)

ii) Routing : (which route to choose from availeble routes.

iv) Transport Layer : Responsible for process to process delivery.

i) Service point addressing : (Port address) (address at which app is running) add port address into packets.

ii) Segmentation and Reassembly : message divided into tranferable segments and at recieving ~~sign~~ side its assembe.

iii) Connection control : connection less
connection oriented.

iv) Flow and error control

v) Session layer :

i) Dialog control : Half duplex — allows 2 ~~comm~~ party to
Full duplex. communicate.

ii) Synchronisation : Add checkpoints.

vi) Presentation : It deals with syntax and semantics of the infor exchanged b/w 2 systems.

i) Translation : Convertion of normal language (msg.) into bit. stream.

ii) Encryption : Encryt data Plain to cypher.

iii) Decyption : Cypher to Plain.

iv) Compression : Use minimum no. of bits
Reduce no. of bits in the info.

Application: It enables the user (Human/S/w) to access the network.

i) N/w Virtual terminal : S/w version of physical terminal. (Remote HOST logic is facilitated).
ii) File Transfer, access and management.
iii) Email service
iv) Directory service

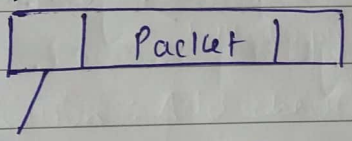
A (N/w access)
P (Encrypt, Compress)
S (Manage Sessions)
T (Process to process delivery)
N (Soure to dstn routing)
D Framing Flw /error
P Data rate media, mod.

TCP/IP reference model.
Developed before OSI model
contain 4 layers but now it contains 5 layers.

1.	Application	→ Application	App, Presentation, Session } OSI
2.	Transport	→ Transport	
3.	Internet	→ Network	
4	Network interface	→ Data link, Physical.	

i) Physical : Unit of comm^n is single bit.
- No specific protocol.
- Comm^n b/w two hops, nodes, computer.

ii) Data line layer.
No specific protocol
Comm^n b/w two hops/nodes
Unit of comm^n is frame



Source and distination address of frame.

iii) Network layer : IP is used for transmission mechanism
- Unit of comm^n is called datagram.
- Comm^n is end to end.

iv) Transport layer.
Responsible for delivering whole msg.
Unit of comm^n is called segment.
Two protocol
TCP (Trans. Ctrl P) UDP (User datagram P.)
connection oriented Connection less.

v) Application layer: It is combⁿ of session, presentation and app. layer of OSI model.
Unit of commⁿ is msg.

Physical layer

Data and Signals.

Data is an entity which is used to exchange info based on mutually agreed rules and convention b/w sender and reciever.

Analog and Digital.
Analog is continuous, digital is discrete.

Signals : means by which data is propagated. Its electric representation of data which can be sent over comm^n media.

Data can be analog and digital.
Analog data are continuous and take continuous values.
Digital data have discrete state and take discrete values.

Signals can be analog or digital.
Analog signals can have infinite no. of values in range.
Digital single can have only a limited no. of values.

Periodic / Non-p signals:
Completes a pattern in a given time and repeats the same pattern each time. One full patter is one cycle.

Non periodic : Changes without any pattern.

— Analog signal

Periodic A S

Simple
(a sine wave)

Composite.
(multiple sine wave)

Composite signal.

Single freq sine wave is not useful in commⁿ. Acc. to fourier, composite signal is composition of many single sine wave of diff. freq, amp, phases.

If composite signal periodic - on decomposition it gives a series of discrete freq.

If composite signal non-periodic - on decomposition it gives combination of sine waves of continuous freq.

A sine wave can be represented in 3 params.

i) Peak amplitude
ii) Period
iii) Phase

i) amplitude : absolute value of maximum intensity.

ii) Period : Time taken to complete 1 cycle.
frequency is no. of cycles per second.

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

iii) Phase : Position of waveform relative to time 0.
measured in deg. 360° → shift complete period.
180° → shift one-half period.

iv) Wavelength : for an analog signal distance of one cycle is wavelength.

wavelength = λ : T x propagation speed.

$$= \frac{\text{speed}}{f}.$$

Time domain - X axis : time Y axis : amp.
Freq domain - Y axis : freq Y axis : amp.

A complete sine wave in time domain can be represented by one single spike in freq domain.

Bandwidth: The band width of composite signal is diff- b/w highest and lowest freq. in that signal.

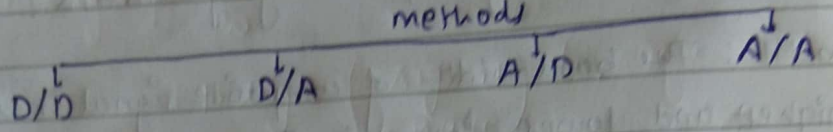
— Digital signals
discrete.

Bit rate : No. of bits /sec.
Bit length : the distance one bit occupies on the transmission medium.
BL = propagation speed x bit duration.

Based on fourier, a digital signal is composite analog signal.
If we add more and more component it becomes square wave
In digital signal
horizontal line - freq 0
verticle line - freq ∞
So bandwidth = ∞.

If signal is
periodic : decomposed signal has discrete freq component of ∞ BW
non-periodic : decomposed signal has ~~discrete~~ continuous freq- component of ∞ BW.

- Signal Transmission
  In CN, info needs to be transmitted. For that it should be converted into analog or digital.



Analog signal Transmission require band pass channel.
Digital " " " base band.

Baseband transmission requires that we have a low-pass channel, where Bw starts from 0.

Analog transmission: during transmission, they become weaker so they are amplified. This may boost noise component so more distortion. A bit of distortion can be tolerated.

Digital transmission: Transmitted limited distance. Repeater is used to achieve great distance

- Transmission Impairments.
  Due to imperfection in transmission medium impairment occour. This causes.

* Attenuation.
- loss of energy.
  When signal travels through a medium some energy is used to overcome resistance of medium so energy is lost
  So amplifier used to amplify signals.
  (Amplification) $dB = 10 \log_{10} \frac{P_2}{P_1}$

P_2 = power of signal at receiver
P_1 = power of signal at sender
-ve means attenuated, +ve means amplified.

* Distortion
Signal changes its form or shape.
Nao each component may have diff speed. So they may come to destination at different time so distortion due to delay

* Noise.
Thermal noise - random motion of electrons
Induced - machine.
Crosstalk - effect of one wire on other
Impulse - spike from power lines

- Channel capacity
Data rate depends on.
- BW available
- level of signals we use
- quality of channel (level of noise)

Nyquist BW:
If signal transmiss = 2B.
signal with bandwidth = B.

For binary signal. B Hz suppor 2B bps data rate
But if multilevel then max data rate.
$C = 2B \log_2 M$ (M levels)

Shannon Capacity formula:

If there is noise and data rate is more, same noise effects large no. of bits.

$$SNR = \frac{P_s}{P_N}$$

$$= 10 \log_{10} \left(\frac{\text{signal}}{\text{noise}} \right) dB.$$

Capacity $C = B \log_2 (1 + SNR)$ bps.
(not in dB)

- Performance.

Bandwidth: range of f.
but can also refer to no. of bits per sec that a channel, a link, or even a network can transmit.

Throughput: measure of how fast we can send data through network.

Bandwidth is potential measurement of link; throughput is actual measurement of how fast we can send.

MPI

Digital Transmission.

Various approach for conversion of data

Digital to digital encoding.

3 techniques:

- Line encoding
- Block encoding
- Scrambling.

Signal element vs dat element

data element is smallest entity which can represent info its a bit.

signal element carries data elements.

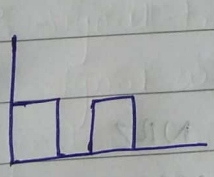
data element is what we need to send, signal element is what we can send,

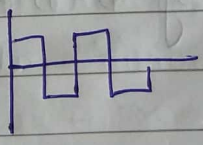
data element - carried signal element - carrier.

Data rate = No of bits / sec

Signal/Baud rate = No. of signal elements / sec.

Signal levels : No. of allowed value in a signal.





Line encoding : conversion of digital data to digital signals.

Encoding characteristic:

* DC component: when voltage line is constant for a while
  i) this makes freq go low.
  ii) The freq around 0 is called DC component.

There are desirable
- DC comp. can't pass through transformers.
  We need scheme with no DC comp.

* Self synchronization: The bit interval of reciever must match sender. So the message also contains timing info which tells the beg, mid, end of pulse.

* Signal spectrum: Different encoding leads to diff. spectrum. Use of proper encoding technique to match with medium so signal suffer min distortion and attenuation

* Cost of implementation: Choose a encoding technique so that its not costly.

* Error detection: Can be built into signal encoding

Types of D-D encoding.

Line encoding	Unipolar	NRZ
	Polar	NRZ, RZ, Manchester, diff.
	Bipolar	AMI, psudoternary
	Multilevel	2B/1Q, 8B/6T
	Multitransition	MLT3

→ Unipolar encoding.

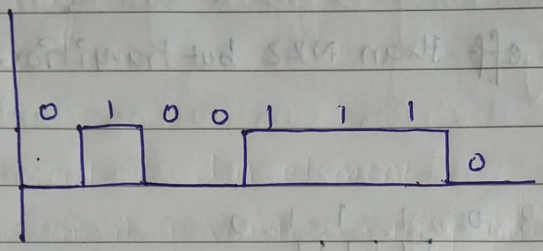
NRZ (non return to zero)

Unipolar uses 1 signal level

1 - high voltage

0 - no voltage.

easy but DC componet and not self synchronized.



→ Polar — NRZ — NRZ L
NRZ I
RZ
Biphase — Manchester
Differential manchester

NRZ

NRZ L - (Level) — poor synch.

0 with one polarity (say +5V)

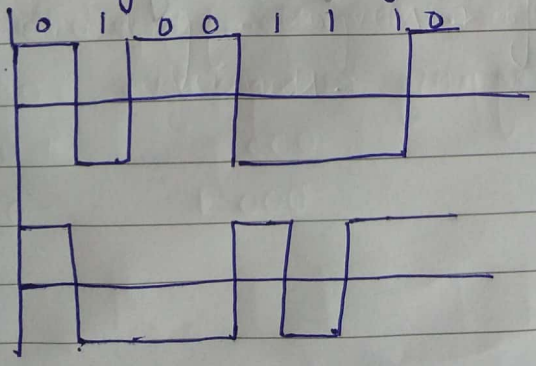
1 with one polarity (say -5V)

NRZ I - (Invert) - better synch with stream 1 but poor for 0.

0 - no change in polarity with prev bit

1 - change in polarity with prev bit

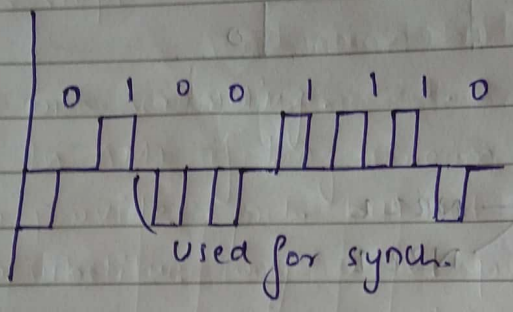
NRZ-I gives better synchronization than NRZL.



easy and good use of B/w.
but DC component and lack of synchronisation.

RZ encoding (return to zero)
3 voltage levels: +ve, 0, -ve
1 encoded as (+V ↓ 0V) (+V)
0 encode as (-V ↑ 0) (-V)

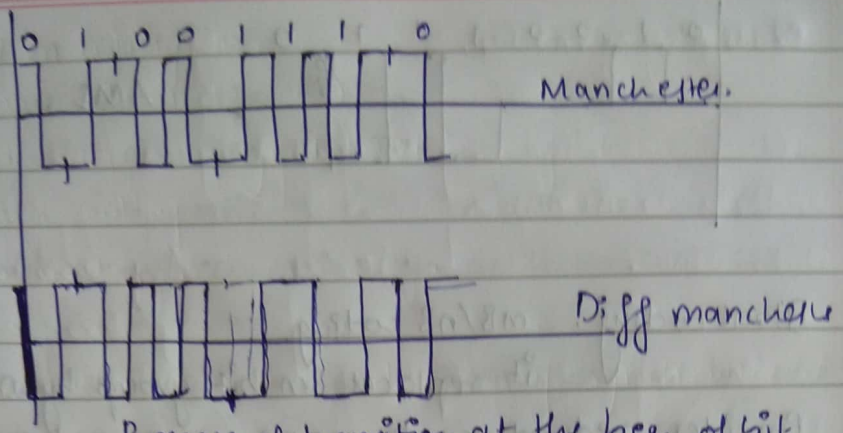
spectrally less eff than NRZ but transition.



Manchester.
1 - low to high - ⌐¬ Achieves same lvl of sych as RZ with 2 levels.
0 - high to low ¬⌐

Diff manchester.
Transition at start of a bit = 0
No transition at start of bit = 1.

Diff manchester require 2 signal - 0
1 signal change - 1.



Presence of transition at the beg. of bit

Biphase Pros, cons.

Con.

max modulation rate 2x of NRZ

more BW req.

Pros.

Synch on mid bit transition

No dc comp

Error detection.

- Bipolar. 3 voltage levels.

  0 - 0v.

  1 - alternate +V -V volts.

  Types — Alternate mark inversion (AMI)

  Pseudoternary.

AMI - alternate 1's at +V, -V

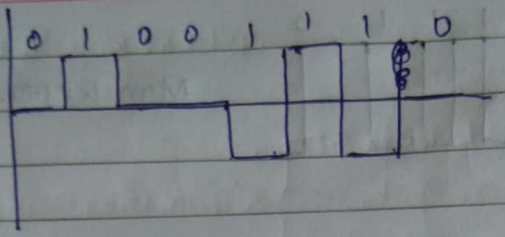
  0 at 0V.

  lacks in self synch for long stream of 0.

  No dc comp.

Pseudoternary - 1 is 0V

  0 is alternate +V, -V.



Block coding: mB/nB coding.
it replaces m bit group by n bit group.
Provides redundancy to ensure synch and provide inherent error detecting.
3 steps: division substitution combination.

AMI with scrambling.
In AMI if long stream of 0 then no synch.
So to provide synch but not ↑ no. of bits a so 1. is to substitue long 0-lvl pulses with other lvels for synch called scrambling.

- Scrambling — B8ZS
  — HDB3.

B8ZS :
If octect of 8 0's occour and last voltage pulse preceding this octet is +ve, then encode as
000+-0-+

If -ve 000-+0+-.

HBD3 sub.

Polarity of preciding pulse	No. of Bipolar Pulse. Even 0dd	odd even
-	000 -	+00+
+	000 +	-00-

See eg.

Analog to digital.

Pulse code modulation (PCM).

Analog is sampled.

Sampled is quantized.

Quantized values are encoded as streams of bits

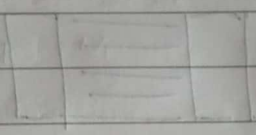
$$\Delta = \frac{V_{max} - V_{min}}{L}$$

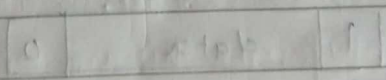
PCM is refined by non linear encoding.

Delta mod.

analog input is approximated by staircase fn.

see this.

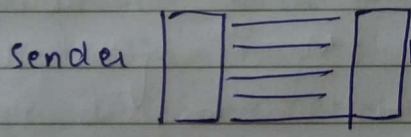




Transmission mode.

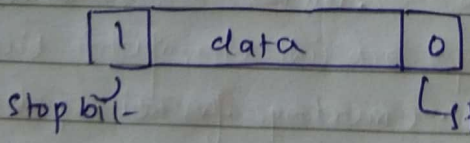
Data Transmission
- Parallel
- Serial
  - Asynchronous
  - Synchronous
  - Isochronous.

Parallel : Binary data organized in group of n bit.
Send all n bit at a time.
Adv : speed.
Dis : cost.



Serial : One bit follows other.
conversion device required b/w the sender and the line.

Asynchronous : We have start and stop bit to verify 8 bit data.



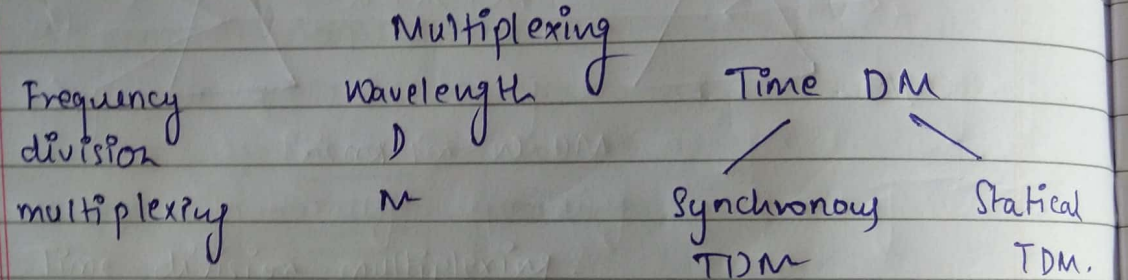
Synchronous : Send bit one after other. Faster than async. Although no gap b/w char. there may be gap b/w frames.

Isochronous : If realtime audio / video in which uneven delay in frame not acceptable. Isochronous guarantees data arrive at fixed rate.

Multiplexing.

Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a data link.

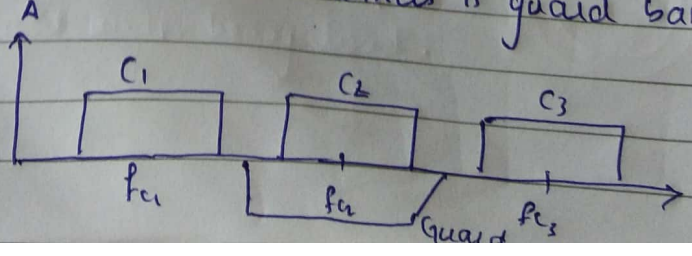
n input to multiplexer. It combines them and transmit over a higher capacity data link. The demultiplexer recieves it and separets them and send to appropriate output lines.

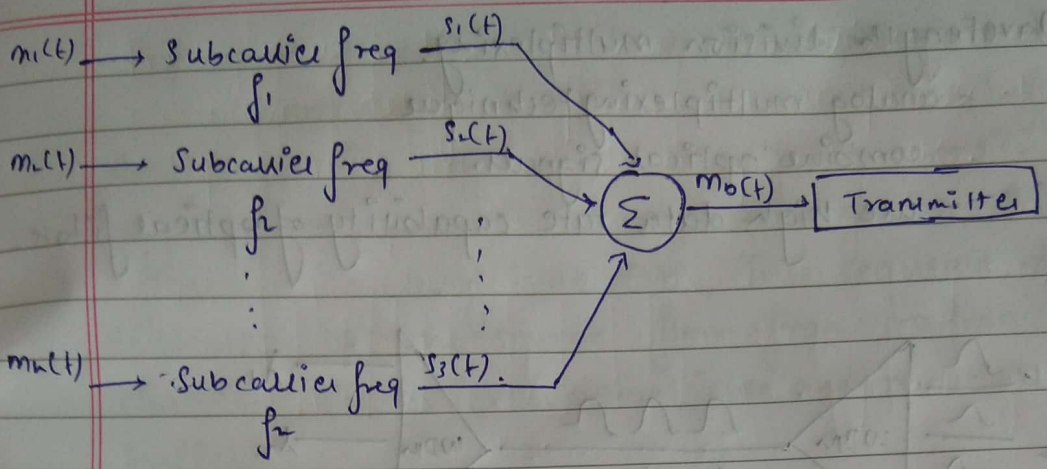


FDM : analog multiplexing.
combines analog signals.
bandwidth of link > combine bandwidth of signals to be transmitted.

- multiplexer modulates each signal onto a different freq.
- modulated signal require bandwidth centered on carrier freq. This b/w is called channel.
- To avoid interference this are seperated by guard bands, (unused portion of spectrum).
- Composite signal transmitted along medium is analog.

Guard bands: If channels are close, leads to inter channel cross talk. This must be seperated by strips of unused bandwidth. This unused channels is guard band





The composite signal may then be shifted to whole new carrier and transmitted.

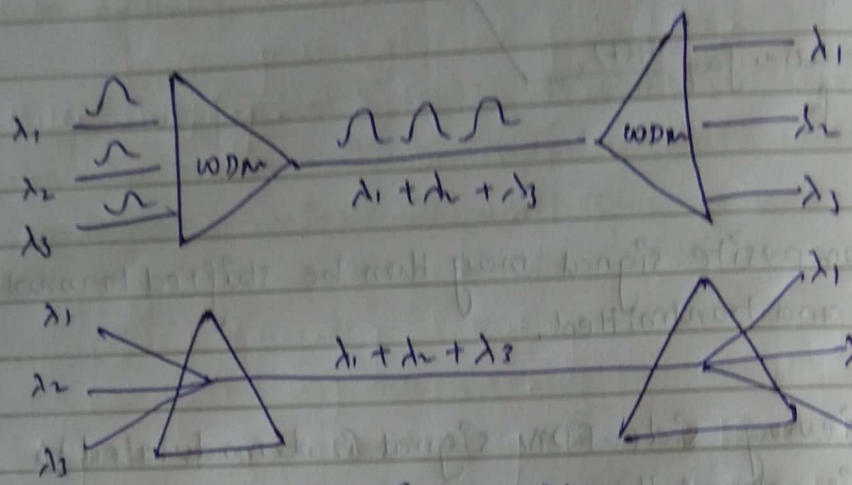
At recieving side FDM signal is demodulated to $m_o(t)$. which is passed through n bandpass filter each filter centered on fi. So we get all signal back.

Eg. Assume that a voice channel occupies a b/w of 4 kHz. we need to combine 3 voice channels into a line with b/w of 12 kHz from 20 - 32 kHz. Use FDM and assume no guard bands.

We take 20-24, 24-28, 28-32. and combine them and modulate them and send. At reciever side we use 3 filter to demodulate.

Application:
AM, FM radio broadcasting
TV broadcasting
Cable Television
First generation cellular phones.

Wavelength division multiplexing.
- analog multiplexing technique
- combine optical signals.
- use high data-rate capability of optical fiber.



Prisms in W-DM

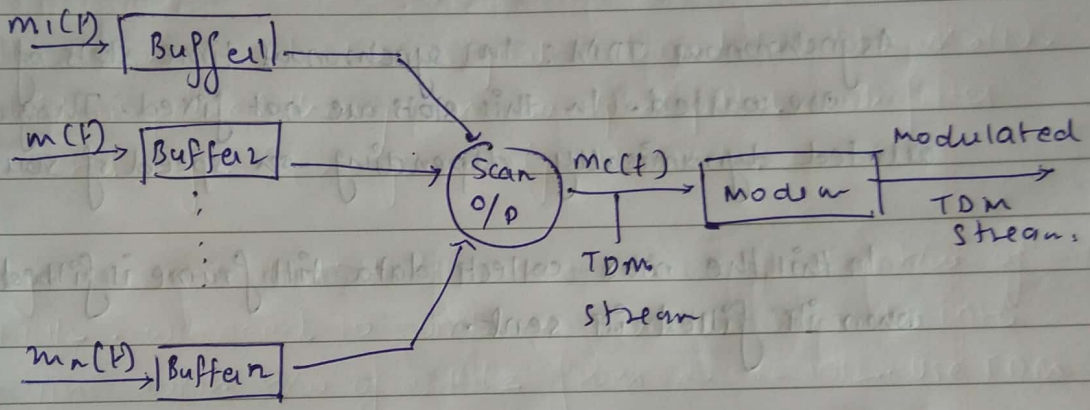
Time division multiplexing.
In this instead of sharing a portion of bandwidth as in FDM, time is shared.
- Each connection occupies a portion of time in link.

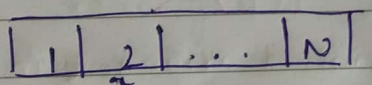
- digital multiplexing technique
- combine several low rate channels to one high rate.
- Time slots are so small that it appears like

Synchronous TDM.
Pre assigned and fixed time slot.
Each source is given its time slot. If the source is empty the slot is transmitted empty.

Process : A no. of signals are multiplexed on transmission medium. The data of each source is buffered. Each buffer is 1 bit long. The buffer is combined sequentially to form composite signal. It's organised into frame. 1 frame = 1 cycle of time slots. The sequence of slots dedicated to one source, from frame to frame is called channel. The reciever demultiplex and route to appropriate buffer.

data rate $m_c(t) = \sum_{i=1}^{n} m_i(t)$ data rate.





Time slot : may be occupied / free

Frame.

Link Control.

- Flow control.
  - data rate of line is fixed.
  - If one channel can get data others must cally on leaving empty slots.
- error contro.
  - error detected and handled on individual slots.

Framing :

Pulse stuffing :

Asynchronous TDM : In synchronous time slots of a frame are wasted. In this slots are not fixed. They are alloted dynamically depending on speed of source.

In this the mux collects data till frame is filled, and when it filled it sent.

On output the demux receives frame and send to appropriate buffer.

Data rate or multiplexed line is less than sum of data rates of devices.

Since this can lead to any ordering, each slot consist address as well as data.

2 ways :

1) One source data in 1 frame

Address	Data

inefficient under heavy load.

2) Multiple data sources.

Subframe consits of a sequence of data fields, each with address and length.

| Add | Len | Data | ..... | Add | Len | Data |

Advancements:

- Relative addresing
- 2-bit label for length.

We know that data rate of output of multiplexer is more than sum of inputs. But in some cases there may be chance that the input may exceed o/p so we use buffer to store extra.

I = no. of I/p sources
R = data rate of each source, bps.
M = effective capacity of multiplexed line, bps
α = mean fraction of time $0 < \alpha < 1$.

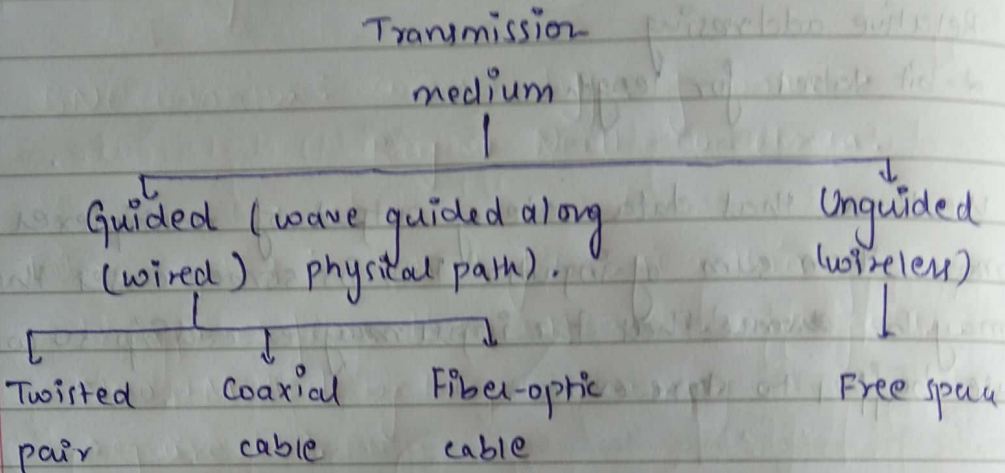
$k = \frac{M}{IR}$ = ratio of multiplex line capacity to total max input.

k = mease of compression.
if $k = 0.25$
the 4 time more devices handled as by STDM.

$0 < k < 1$.

Transmission medium.

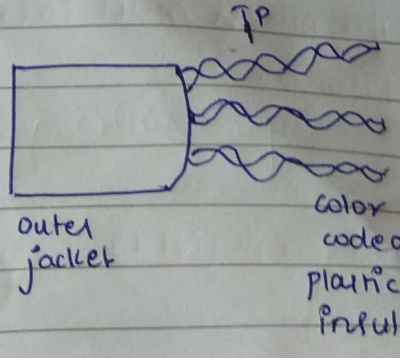
TM : anything which carry info from source to destination
In data comm^n
- medium is air, metallic cable
- info is signal obtained from data.

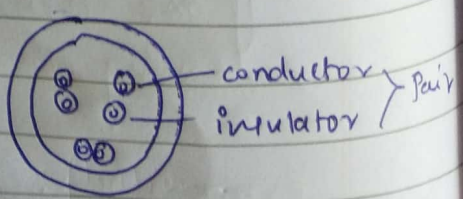


unguided provide a means for transmitting EM waves but not guide them.

Guided TM
Twisted pair cable. (TP)
2 insulated copper wires arranged in spiral form.
Low freq. transmission medium.

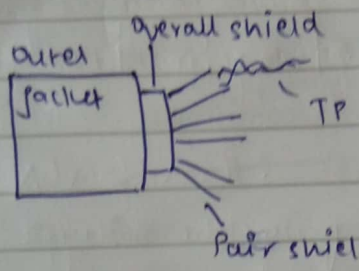
Types :
U.TP (unshielded TP)
each wire is insulated with plastic wrap, but the pair is encased in an outer covering.

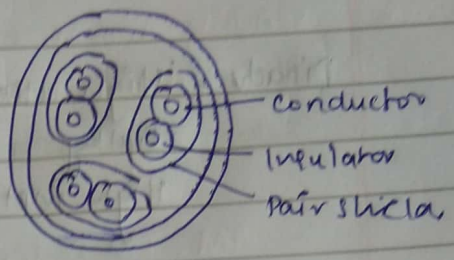




STP (shielded TP)

The pair is wrapped in metallic foil to insulate pair from em interference.





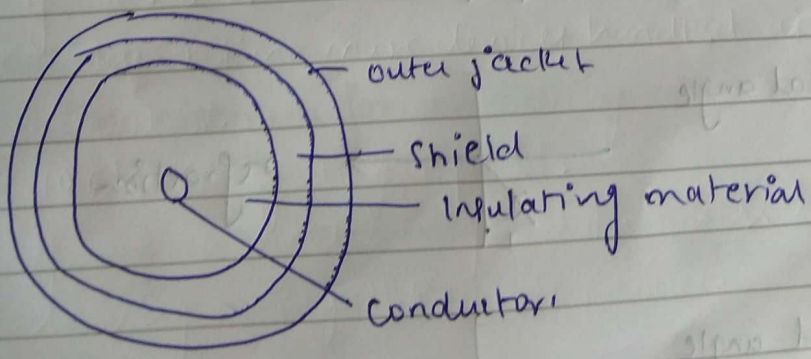
TP adv : inexpensive, easily available.
light weight.
easy to install

disadv : problem of interference and noise.
Attenuation problem.
low b/w.

Application : Telephony.
most common UTP connector is RJ45.
(RJ – registered jack)

Coaxial cable :

Used for telephone, cable television LAN.
Inner conductor surrounded by braided mesh.

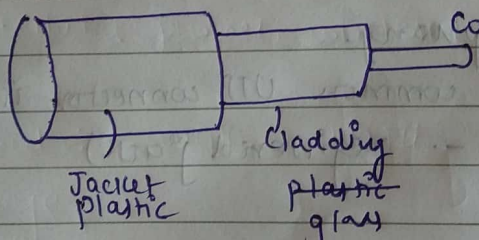


Adv : High bandwidth. (400 - 600 Mhz.
Can be tapped easily.
Less chance of interference.

Disadv : High attenuation
Bulky
High installation cost.

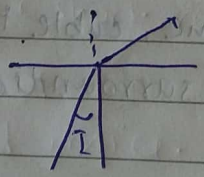
BNC connector : common type of connector.
Bayone-Neill-Concelman.

Fibre optics : Optical fibre is a thin, flexible, transparent fibre that acts as a wave guide.
New TM used by telephone comp.
require LED.



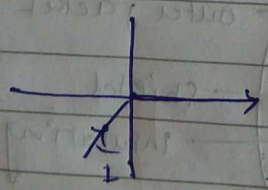
Bending of light

I < critical angle



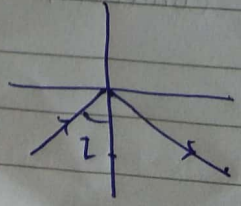
refraction

I = critical angle

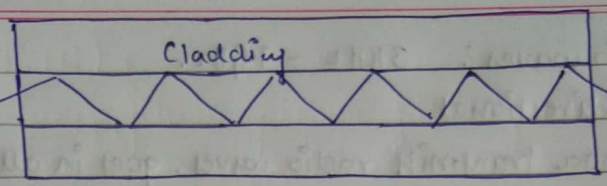


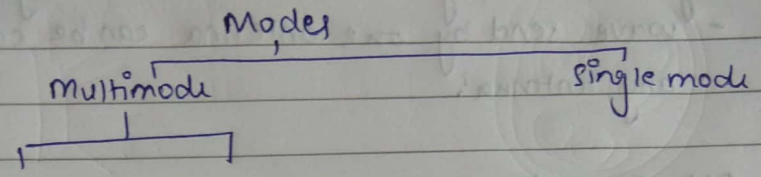
refraction

I > critical angle



reflection.





In multimode : multiple beams move.
In step index ; density of core remain same from center to edge
In graded index , density of core decrease as move away from center.

Adv : highest bw (2 Gbps)
small and light
low attenuation.
secure.

Dis : expensive
high skill installation.
adding extra node is difficult.

Unguided
EM spectrum for wireless comm^n.

Radio waves | Infrared | Light wave
3 kHz | 300 GHz | 400 THz | 900 THz

Types of propagation :
1) Ground 2) Sky 3) LOS

Radio waves: 3KHz - 1GHz.

- omnidirectional
- antenna transmit radio waves, goes in all direction.
- sending and recieving antennas do not be aligned.

Dis - wave send by one antenna can be caught by any antenna.

- AM, FM radio
- Television

Microwaves: 1GHz - 300GHz.

- unidirection.
- sending recieving antennas need to be aligned.

Adv: pair of antenna can be aligned without interfacing with another pair.

- Cellular phones, wireless LAN's

Infrared: 300GHz - 400THz.

- long range
- High frequency, cant penetrate walls.

Application: Used for short range comm in close area using LOS

wireless keyboard, mice.