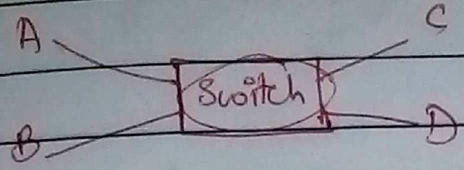
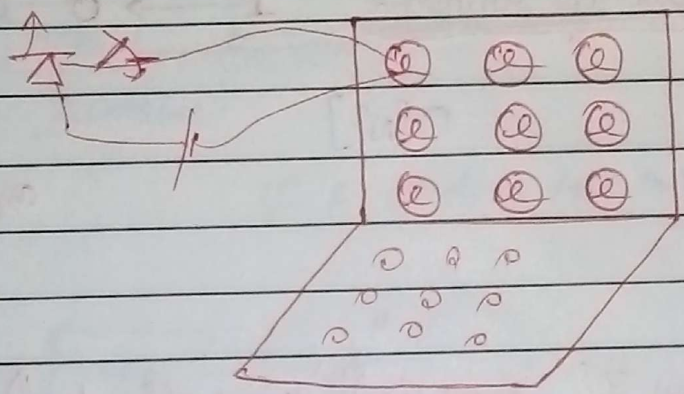
Switching Systems



Circuit Switched Networks:-
(telephone N/w)

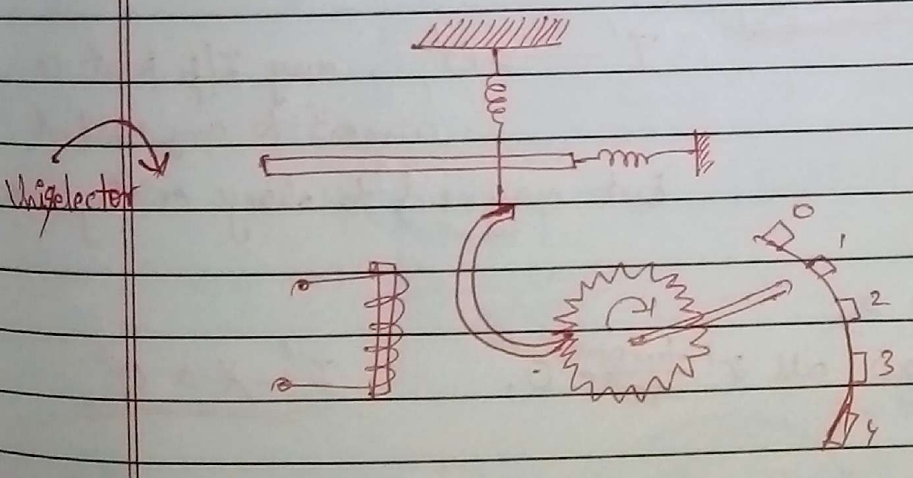


Call Data Register (CDR)

Register

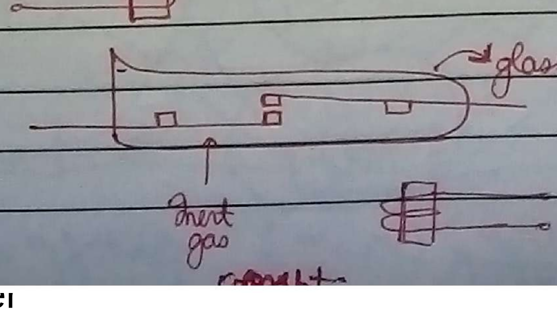
caller Rxr Time

then come (Automated Exchanges)
by A.B. Strowger



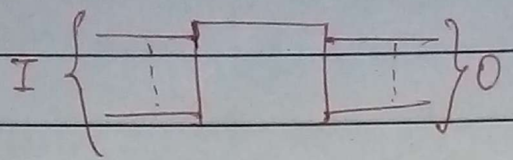
Cross bar

why 2 electromagnets?



Date :

Type of Switches :-



I' free I/p   O' free o/p.

Strictly non-blocking switch :   I' → O'   any I/p port is able to connect to any O/p port w/o any change in existing connections.

$O[N^2]$

Clos theorem:

If from any I' there is "free multi casting tree", then strictly non-blocking switch.

Rearrangeably non-blocking :

I' → O'   any I/p port can connect to any o/p port but may need to change existing connecti

Blocking switch :-

Doesn't allow all I' to connect O'.   I' ↛ O'

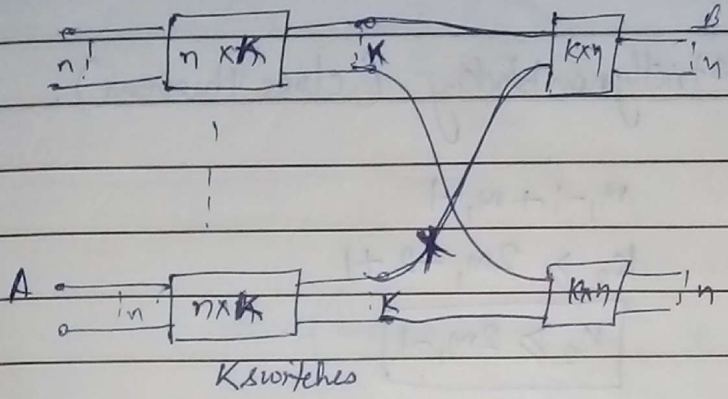
Wide sense non-blocking :-   I' → O'

given ~~that~~ an algorithm is followed.

Scanned by CamScanner

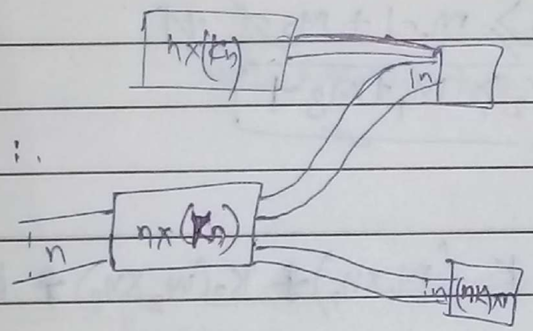
Strictly non-blocking $\longrightarrow O[N^2]$
↳ fewer crosspoints??

network → distributed switch



if A wants to talk to B ∴ X busy ∵ other 'n' user can't connect to that switch

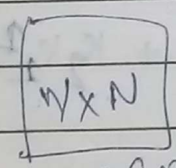
∴ not strictly non blocking



∴ total no. of cross pts ⇒ $K \times (n \times nK) \times 2$

$\Rightarrow 2(nK)^2$

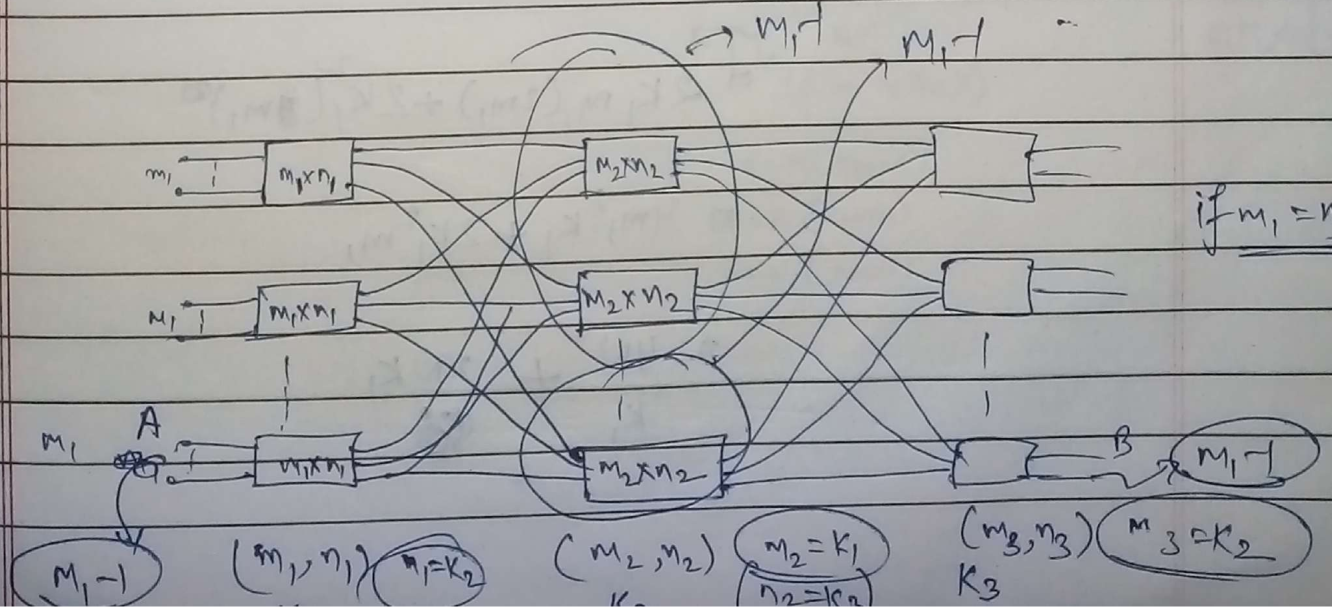
$= \underline{2(N)^2}$



$\underline{O(N^2)}$

∴ no. of cross pts not reduced.

⇒



if $\underline{m_1 = n_3}$

for symmetric, $m_1 \times k_1 = n_3 \times k_3$

$n_3 = m_1$

$k_1 = k_3$

(m_1, k_2) (k_1, k_1) (k_2, m_1)

k_1 k_2 k_1

$k_2 \longrightarrow$ strictly non blocking (Clos theorem).

$$m_1 - 1 + m_1 - 1$$

$$k_2 \geq 2m_1 - 2 + 1$$

$$\boxed{k_2 \geq 2m_1 - 1}$$

(m_1, n_1) (m_3, n_3)

$$k_2 \geq m_1 - 1 + m_3 \cancel{-1} + 1$$

$$\boxed{k_2 \geq m_1 + m_3 - 1}$$

No. of cross points $\Rightarrow$ $k_1(m_1 \times n_1) + k_2(m_2 \times n_2) + k_3(m_3 \times n_3)$

$\Rightarrow k_1(m_1 \times k_2) + k_2(k_1 \times k_1) + k_1(k_2 \times m_1)$

$\Rightarrow 2k_1 k_2 m_1 + k_2 k_1^2$

$k_2 \geq 2m_1 - 1 \simeq 2m_1$

$\Rightarrow 2k_1 m_1 (2m_1) + 2k_1^2 (m_1)$

$\Rightarrow 4m_1^2 k_1 + 2k_1^2 m_1$

$$\Rightarrow \frac{4N^2}{k_1} + 2Nk_1$$

$$NC = \frac{4N^2}{k_1} + 2Nk_1$$

$$\frac{d(NC)}{dk_1} \Rightarrow -\frac{4N^2}{k_1^2} + 2N = 0$$

$$\frac{\overset{2}{\cancel{4}}N^{\cancel{2}}}{k_1^2} = \cancel{2N}$$

$$2N = k_1^2$$

$$\boxed{k_1 = \sqrt{2N}}$$

$$m_1 = \frac{N}{2\sqrt{N}}$$

$$\boxed{m_1 \Rightarrow \frac{\sqrt{N}}{2}}$$

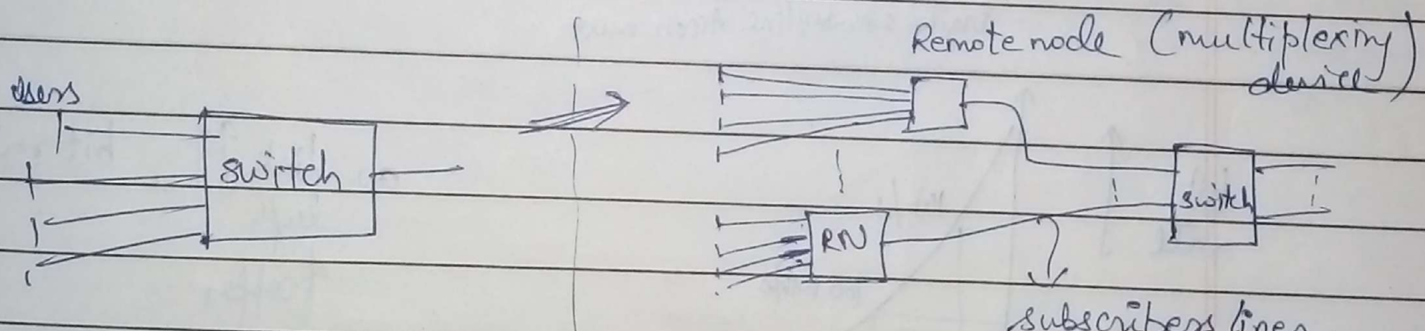
$$(NC)_{min} = \frac{4N^2}{\sqrt{2N}} + 2N\sqrt{2N}$$

$$\Rightarrow 2\sqrt{2}(N)^{3/2} + 2\sqrt{2}N^{3/2}$$

$$\Rightarrow 4\sqrt{2}N^{3/2}$$

. this switch is known as a cross switch.

⇒



(wired or wireless)

(Digital subscriber line) DSL ← → Copper (twisted pair)

Cable TV ← → coaxial

→ optical → FTT_x (fiber to the x)

→ Radio (wifi, wimax, LTE, 3G, 4G, ...)

→ optical (free space optics, LIFi, etc)

FTTH $x = H$ (Home)

FTTC $x = c$ (curb)

$x = N$ (node)

Page :
Date :

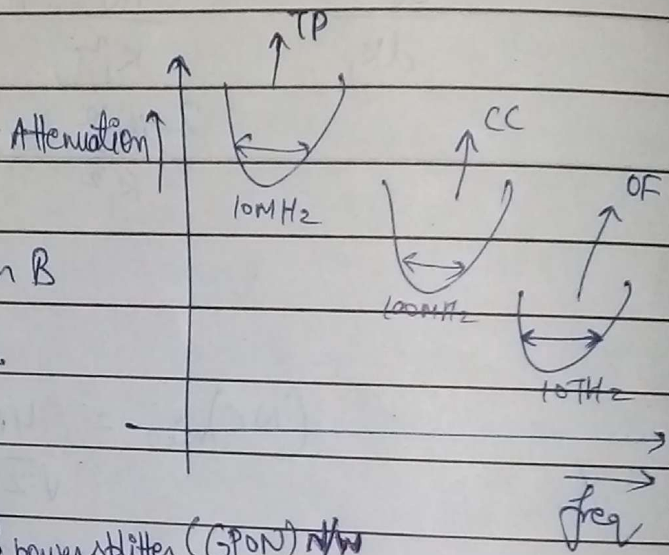
Bandwidth

$$C = B \log_2 \left(1 + S/N\right)$$

signal power (at rxr)

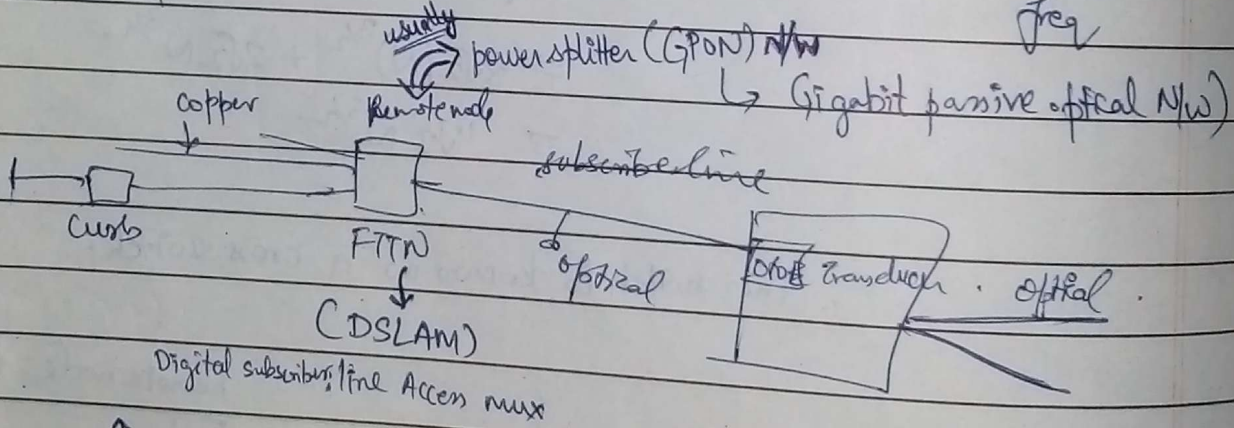
noise power ~~(at rxr)~~.

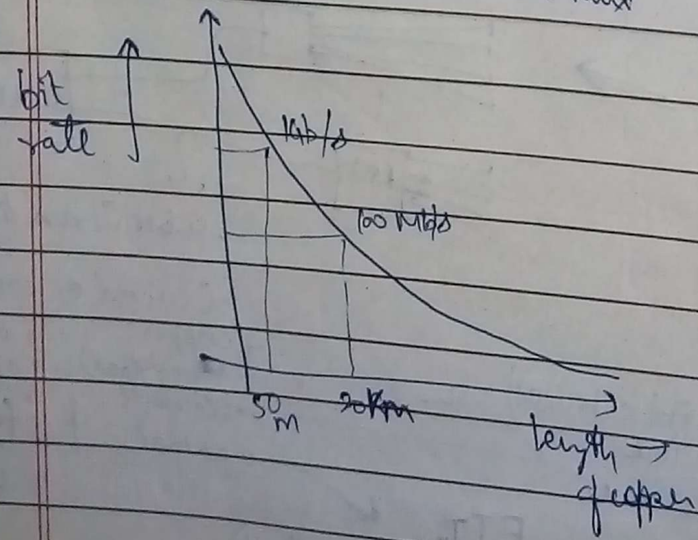
Channel Capacity
(bits per sec)
(data rate)



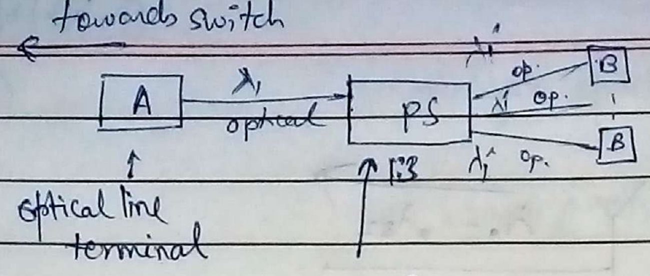
as optical fibre has higher B
∴ can support higher C.

→ cheapest.



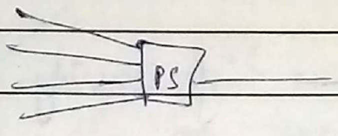


as link length of copper ↑↑, bit rate supported ↓

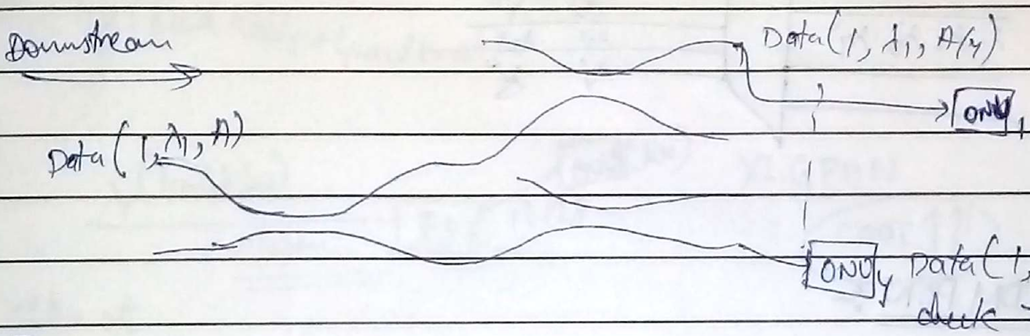


optical N/w unit / optical N/w terminal
(ONU) (ONT)

(∴ GPON is called Passive optical N/w)



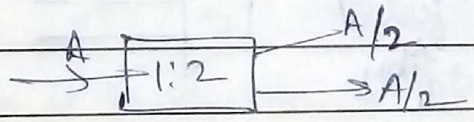
pblm occurs if two users use same wavelgth & ~~txn~~ occurs at same time.
∴ TDM is reqd.



check the destination address & discard it.

(PS) → create copies of incoming signal.

upstream



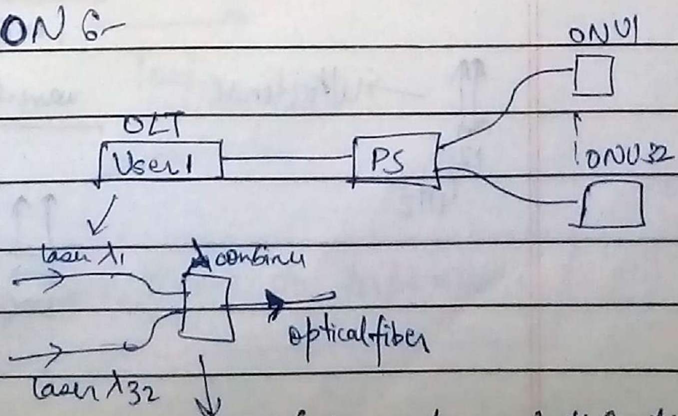
loss = 3dB 1:4

$1:2^N \Rightarrow \underline{N \times 3dB}$

$= 1:2^2 \Rightarrow 2 \times 3$ dB
$= 6$dB

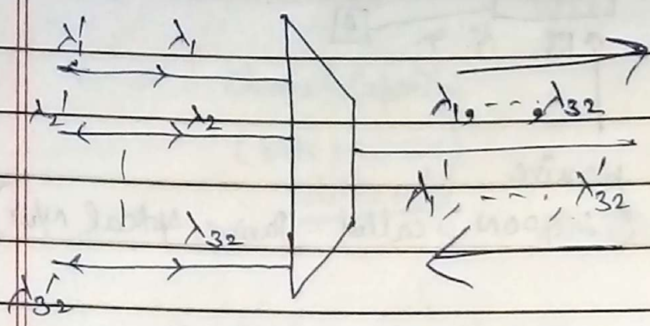
Wavelength Division multiplexed PON :-

Every user → a dedicated upstream & downstream wavelgth

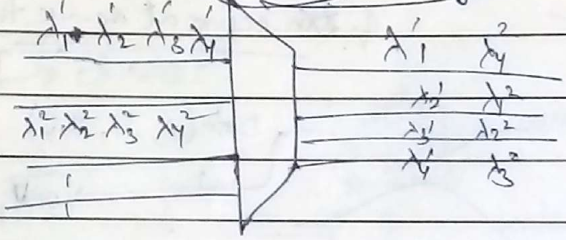


AWG (Arrayed wavelgth Grating)

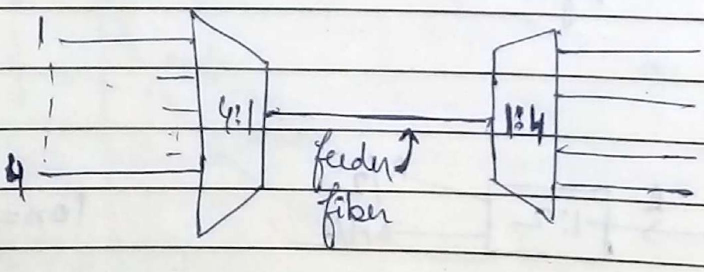
Grating → some kind of periodicity in the structure.



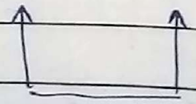
Latent Routing → high security (never ever two same λ's come out of same port)



WDM PON :-



ITU-T



→ coarse WDM

100 GHz

wavelength spacing

→ ultradense

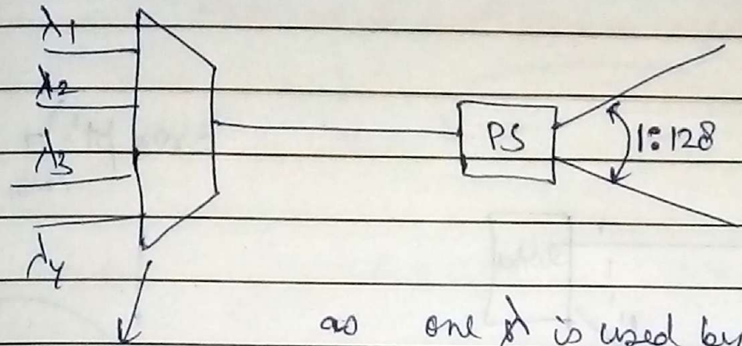
12.5 GHz

→ Dense WDM

50 GHz

flexi-grid systems (wavelength spacing is adaptive).

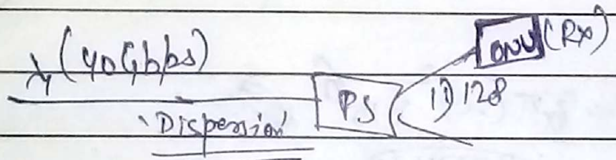
(10Gb/s) Both WDM & TDM



TWDM (time & wavelength division multiplexed)

as one λ is used by 32 users ∴ TDM

$BW = 4 \times$ (Band 10Gb/s + Guard band)



XLGPON

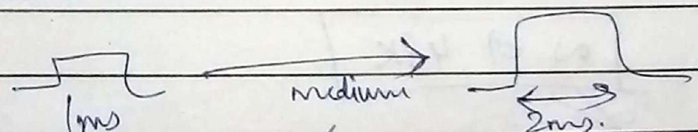
cost ↑↑

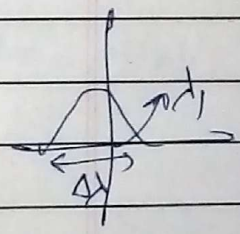
clks at Txr & Rxr needs to work very fast (at 40Gbps) ∴ ∴ costly

it limits data rate

$\boxed{\text{Dispersion is limiting pblm to data rate.}}$

Causes ISI





40 Gbps → $\frac{1}{40}$ ns pulse

1ps/Km/$\Delta\lambda$ dispersion

$\boxed{\text{higher data rate systems are more prone to dispersion.}}$

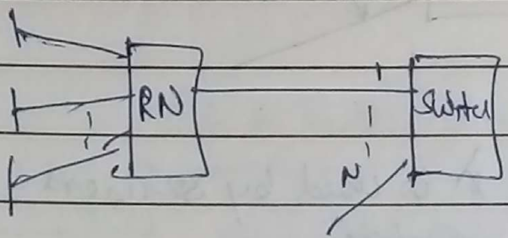
dispersion $\neq f$ (data rate)

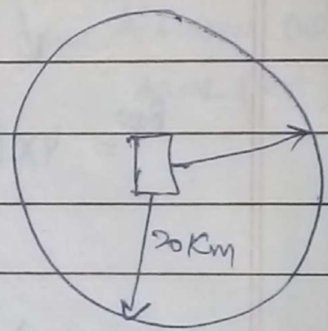
Page :

Date :

why dispersion occurs:-

cross pt's$)_{min}$ ⇒ $4\sqrt{2}\, N^{3/2}$





$\therefore$ no. of users $= \dfrac{4\times\pi(20)^2\times 10^6}{250\times 4}$

Area $= \pi(20)^2\ Km^2$

Home ⇒ $100\ m^2$

Residential / user $= \dfrac{100\ m^2}{4} = 25\ m^2$

others

$\therefore$ on avg 1 user $= 250\ m^2$.

$\pi \simeq 3$ ⇒ $4\pi(1600)\times 10^3$

⇒ 48×10^5

$\simeq 4.8\times 10^6$

per port = 100 users

$N \Rightarrow \dfrac{4.8\times 10^6}{100}$

$\boxed{\approx\ \Rightarrow 48K}$

Little's theorem :-

Mean waiting time = mean no. of customers × h (call time)

mean no. of customers = mean arrival rate × mean waiting time.

$$N = \lambda W$$

$$A = \frac{c \times h}{T} \qquad c/T = \lambda.$$

$$A = \lambda h$$

$$= \frac{\lambda}{\mu} \qquad \mu = 1/h$$

$\mu = 1/h \rightarrow$ service time

service rate.

$$P\{A(t+\tau) - A(t) = n\} = \frac{(\lambda\tau)^n e^{-\lambda\tau}}{n!}$$

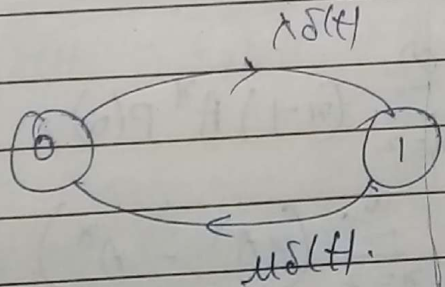
$$p(1) = \lambda\tau e^{-\lambda\tau}$$

$$= \lambda\tau\left(1 - \lambda\tau + \frac{(\lambda\tau)^2}{2!} + \cdots\right).$$

$$\tau = \delta(t) \qquad = \lambda\delta(t) - \frac{(\lambda\delta(t))^2}{1!}$$

$$\boxed{p(1) = \lambda\delta(t)}$$

$M/M/1/\infty = M/M/1$



$$P(0)\,\lambda\cancel{\delta(t)} = P(1)\,\mu\cancel{\delta(t)}$$

$$P(1) = p(0)\frac{\lambda}{\mu} = p(0)\,A.$$

Page :

Date :

$$M|M|1/\infty = M|M|1$$

mean no. of users $\bar{L} = \dfrac{A}{1-A}$

~~mean delay~~ ~~waiting time~~

$$\boxed{\bar{T} = \frac{\bar{L}}{\lambda} = \frac{A}{(1-A)}\frac{h}{A} \Rightarrow \frac{h}{1-A}}$$

$$T = \underbrace{WT}_{\text{waiting time}} + \underbrace{h}_{\text{delay}}$$

mean waiting time

$$\boxed{\begin{aligned}\bar{W} &= \frac{h}{1-A} - h \\ &= \frac{Ah}{1-A}\end{aligned}}$$

$$\bar{N}_Q \Rightarrow \lambda \bar{W} \Rightarrow \frac{Ah}{1-A} \times \frac{A}{h} \Rightarrow \frac{A^2}{1-A}$$

mean no. of users in Queue.

$$N_Q = \sum_{x=2}^{\infty} (x-1) A^x p(0)$$

$$\Rightarrow \sum_{x=2}^{\infty} \left(xA^x - A^x\right) P(0)$$

~~$(-) \Rightarrow 2A^2 + 3A^3 + 4A^4$~~

~~$2A^3 + 3A^4$~~

chapter 5 and 6 → self study

$M/M/N/\infty$

↳ one of these things

$$\bar{L} = \sum_{x=1}^{\infty} \left(\frac{A}{N}\right)^{x} P(N)\, x$$

$$P(N+1) = \frac{A}{N} P(N)$$

$$N_Q = \frac{A^2}{1-A}$$

mean waiting time ⇒ $\sum_{x=0}^{\infty} (x+1)\, h\, A^{x} p(0)$

$$\Rightarrow h\, p(0) \sum_{x=0}^{\infty} (x+1) A^{x}$$

$$\left[1 + 2A + 3A^2 + 4A^3 + \cdots\right]$$

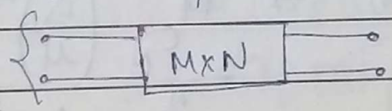
⇒ $P_B = P(N)$ $\quad$ $P(N)$ → switch is in blocked state

$E_{1,N}(A)$

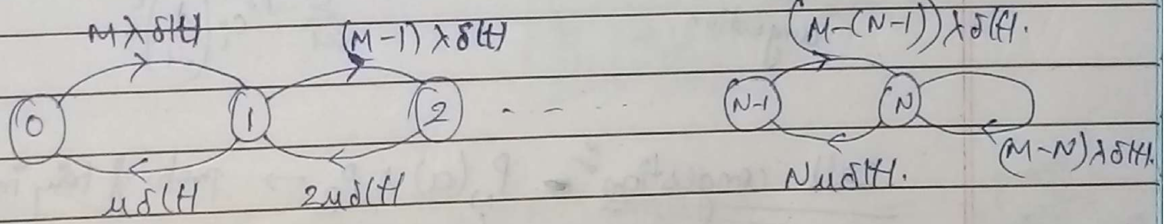
$$\overset{\tau}{\longleftrightarrow} \qquad T$$

call congestion = fraction of calls lost $\quad$ ⇒ $\frac{\tau}{T}$ (time congestion)

traffic arrival is poisson with arrival rate (λ).



when arrival rate is dependent on the state of the system



$N < M$

then $(M-N)$ sources will be free. $(M-N)\lambda\delta(t)$

$$p(1) = \frac{M\lambda\, \delta(t)\, p(0)}{\mu\, \delta(t)}$$

$$\boxed{p(1) = \frac{M\lambda\, p(0)}{\mu}}$$

$$p(2) \Rightarrow \frac{(M-1)\lambda}{2\mu}\, p(1)$$

$$p(2) \Rightarrow \frac{(M-1)M}{2}\, p(0) \left(\frac{\lambda}{\mu}\right)^2 \Rightarrow {}^{M}C_{2} \left(\frac{\lambda}{\mu}\right)^2 p(0)$$

$$p(N) = {}^{M}C_{N} \left(\frac{\lambda}{\mu}\right)^{N} p(0).$$

$$p(0) = \frac{1}{\sum_{i=1}^{N} {}^{M}C_{i} \left(\frac{\lambda}{\mu}\right)^{i}}$$

$$\boxed{p(i) = {}^{M}C_{i} \left(\frac{\lambda}{\mu}\right)^{i} p(0)}$$

$$p(i) \Rightarrow \frac{{}^{M}C_{i} \left(\frac{\lambda}{\mu}\right)^{i}}{\sum_{i=1}^{N} {}^{M}C_{i} \left(\frac{\lambda}{\mu}\right)^{i}} \quad \text{(I)}$$

Engset Distribution
(for MxN switch)
having poisson traffic

$$P_B = p(N) \Rightarrow \frac{{}^{M}C_{N} \left(\frac{\lambda}{\mu}\right)^{N}}{\sum_{i=1}^{N} {}^{M}C_{i} \left(\frac{\lambda}{\mu}\right)^{i}} \quad \text{(II)}$$

time congestion

call congestion: $P_N(a) \times P_B \rightarrow$ prob. of being in state N i.e. all trunks used.

prob. of call arrival when sys. in state N.

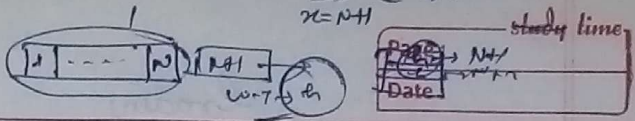
$P_N(a) \times P_B = P(a) \cdot P_L \rightarrow$ prob. of call lost. (call congestion)

prob. of call arrival

M/M/N/∞

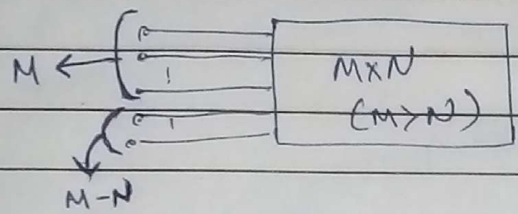
$$\overline{N_Q} = \sum_{x=N+1}^{\infty} (x-N)\,P(x)$$

$$\overline{W.T} = \sum_{x=N+1}^{\infty} (x-N)\,P(x)\,h$$



$$P_L = \frac{P_N(a)\cdot P(N)}{P(a)}$$

if $P_N(a) = P(a)$
in erlang system when arrival prob is same for all states.



$$P_N(a) = (M-N)\lambda\delta(t).$$

$$P(a) = \sum_{i=0}^{N} (M-i)\lambda\delta(t)\,P_i$$

$$P_L = \frac{(M-N)\lambda\delta(t)}{\sum_{i=0}^{N}(M-i)\lambda\delta(t)P_i} \times P_B.$$

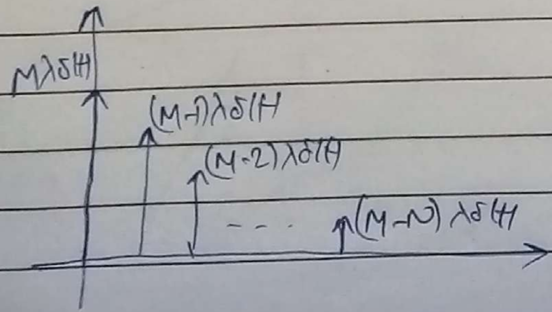
from (i) & (ii)

$$P_L = \frac{(M-N)\cancel{\lambda\delta(t)}}{\sum_{i=0}^{N}(M-i)\cancel{\lambda\delta(t)}\left[\frac{\binom{M}{i}\left(\frac{\lambda}{\mu}\right)^i}{\cancel{\sum_{i=0}^{N}\binom{M}{i}\left(\frac{\lambda}{\mu}\right)^i}}\right]} \times \frac{\binom{M}{N}\left(\frac{\lambda}{\mu}\right)^N}{\cancel{\sum_{k=0}^{N}\binom{M}{N}\left(\frac{\lambda}{\mu}\right)^k}}$$

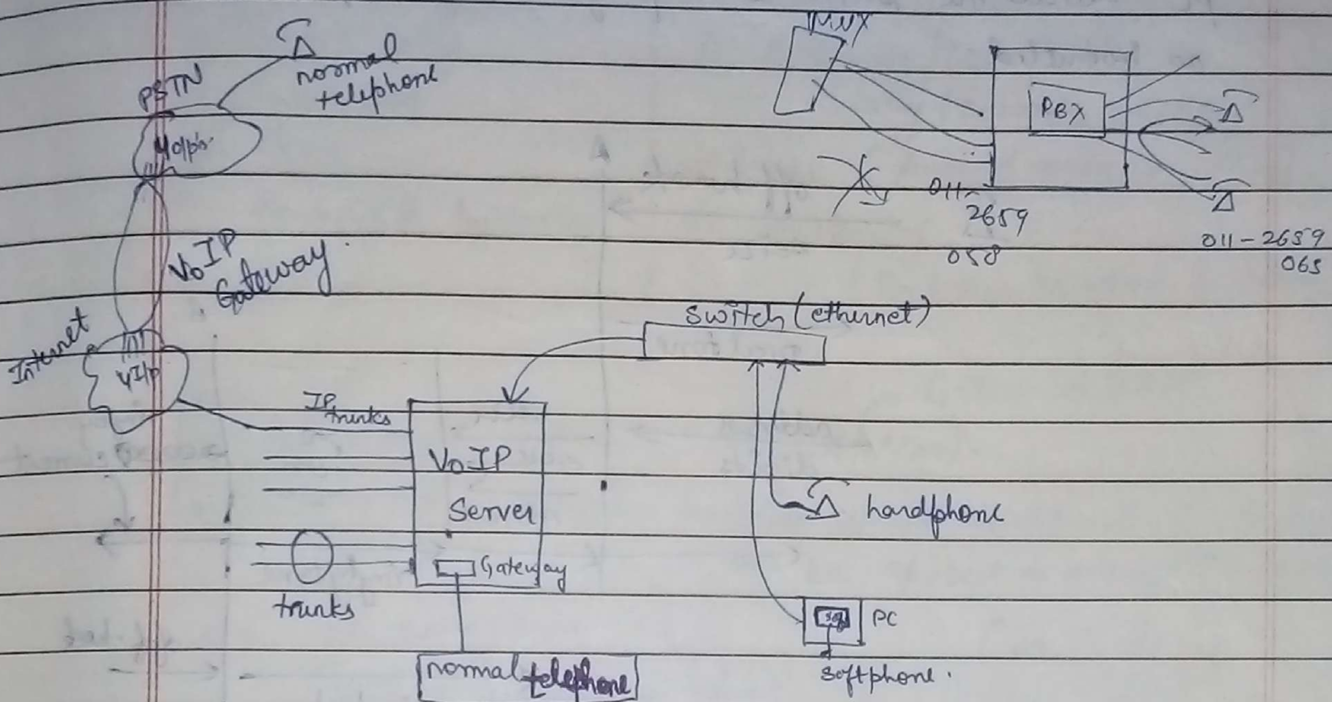
$$P_L = \frac{(M-N) \times \binom{M}{N}\left(\lambda/\mu\right)^N}{\sum_{i=0}^{N}(M-i)\binom{M}{i}\left(\frac{\lambda}{\mu}\right)^i}$$

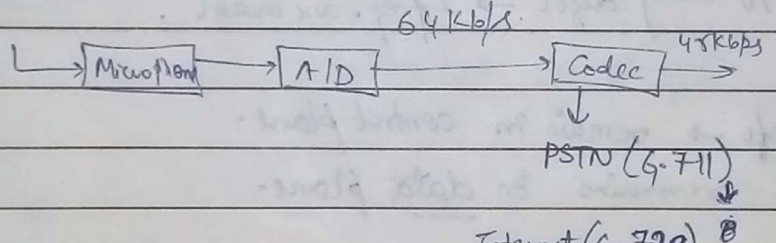
prove?
H.W

$$P_L = P_B(N-1)$$



Voice Over IP (VoIP)



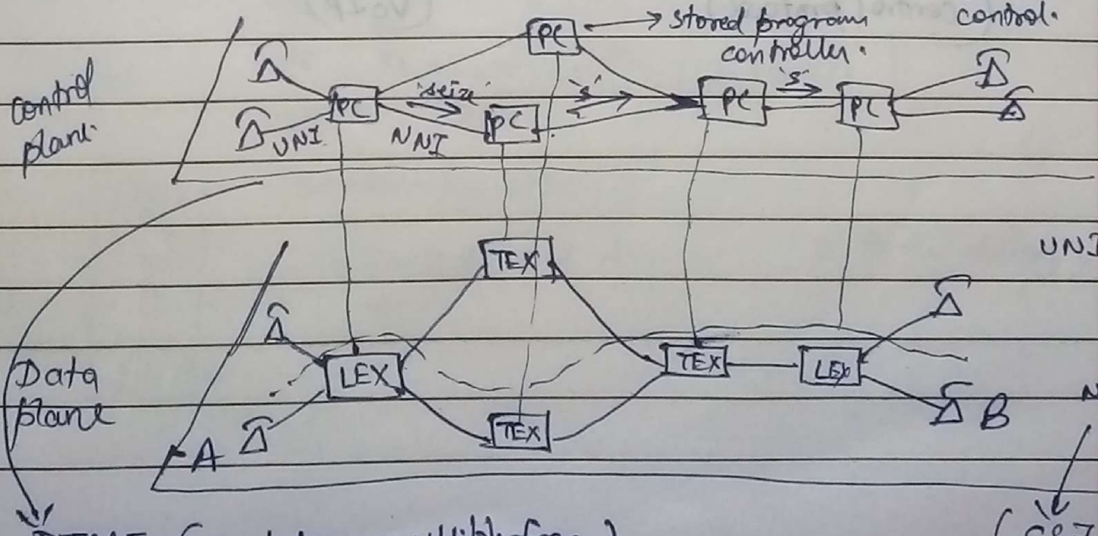


(for PSTN, B.W saving is not imp as circuit switched. While internet is packet based ∴ B.W is needed to be saved.

∴ diff. Codecs are used.

open source platform
SIP servers
SIP Gateways

SIP (Session Initiation Protocol) → e.g. of Signalling protocol or control.



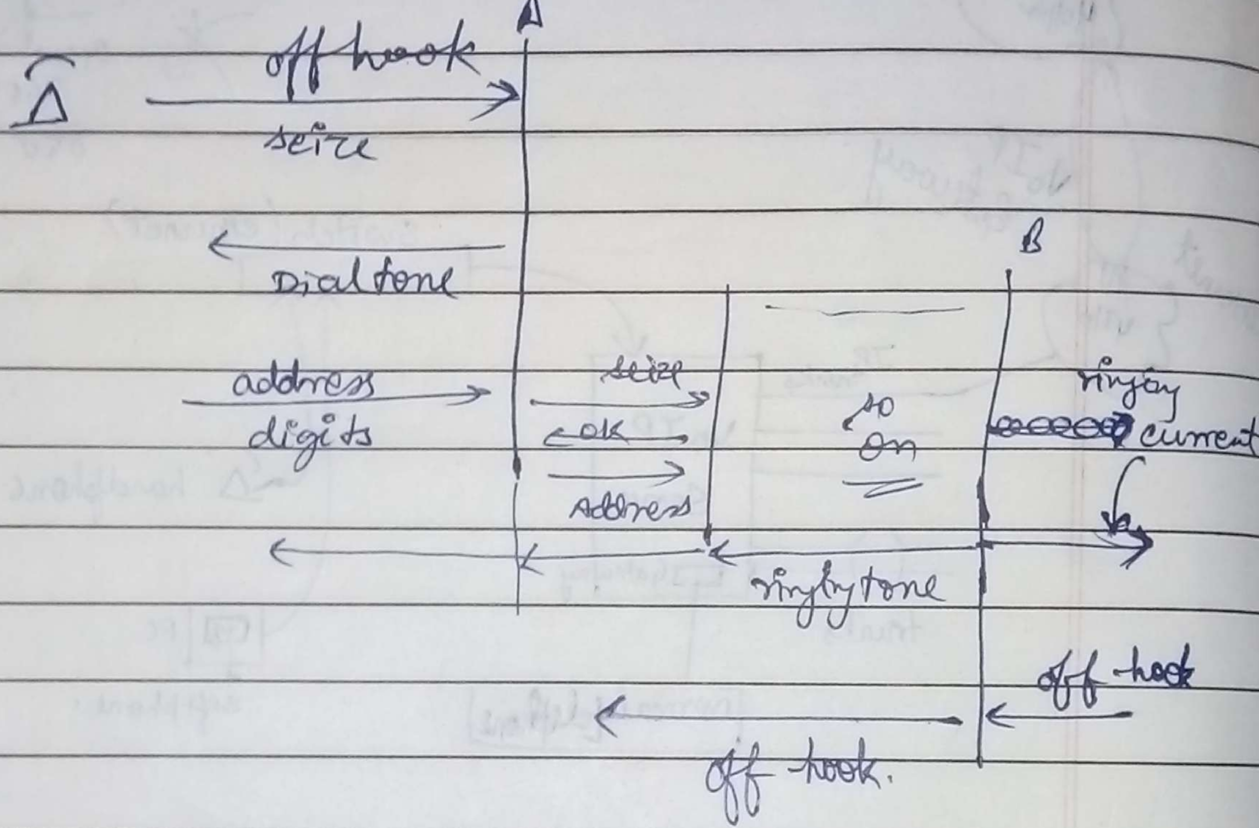
UNI - user network Interface

NNI - Network network Interface.

protocol used in UNI - DTMF (Dual tone multiple freq.)

(SS7) protocol

PC decides the path and programming of switches is done as instructed.



Corresponding to every digit → 2 freq. are used.

Signalling Info → remain in control plane.
Data bits remains in data plane.

SIP → analogous to SS7 → signalling protocol (decides the routing path)
↳ protocol used in (voice) telephone system. (VoIP)
(control protocol)

Page :
Date :

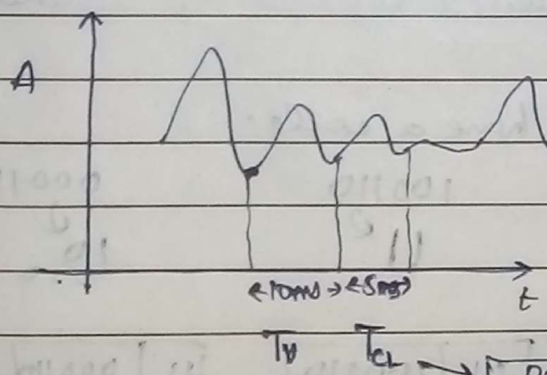
VoIP (Challenges)
1. Packet Delay
2. Packet lose
3. Jitter
4. Bandwidth limitation

Sender
1) Compression / Decompression (Coding / Decoding : Codec)
2) FEC (forward error correction)
3) Interleaving
4) RTP (Real time transport protocol) / RTCP (Real time control protocol)

Codec
→ waveform Coders (Δ mod., DPCM, ADPCM). → G.722 → G.725
→ Vocoders (speech coders) : considers special characteristics of speech signal
can't be applied to every other waveform.
(saves B.W).

e.g. 64 kb/s → PCM
16 kbps → waveform coders
G.729 → 8 kb/s
vocoder
10ms / 10 Byte.

Vocoders → english 44 Phonemes → 10 ms each phoneme
∴ sample at 10msec.
∴ saves B.W.



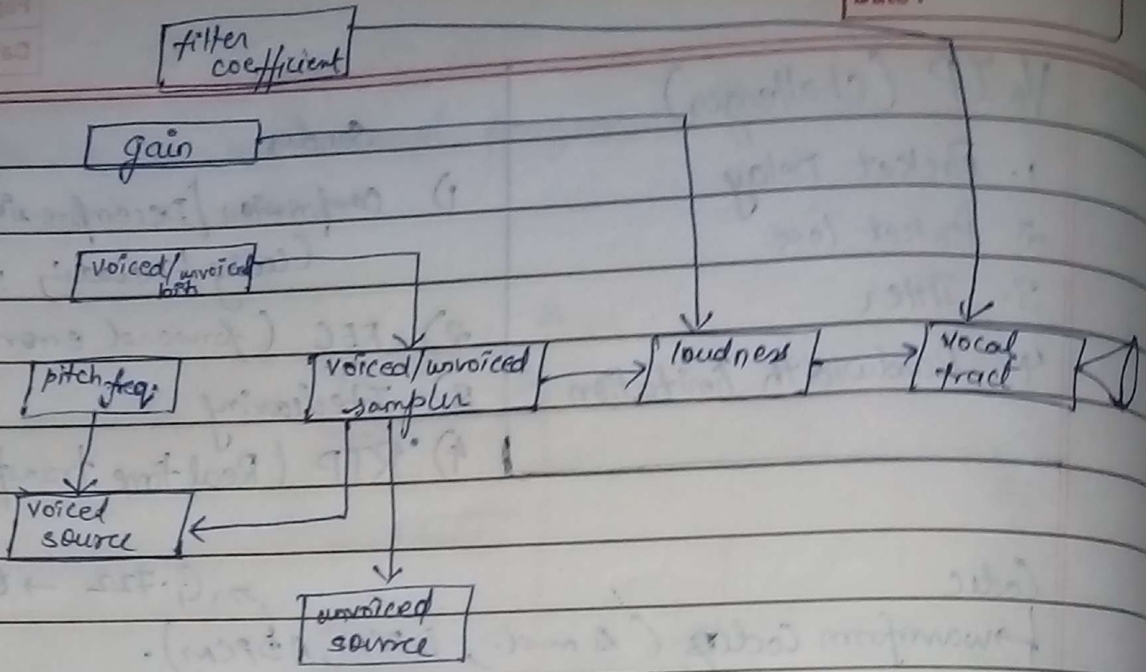
Voice signals are delay sensitive
∴ UDP is used.
UDP use 20 bytes header

10msec
10B
Packet | header | 20 Byte

20B → header by UDP.
1
6 packets are send. ∴ total delay ⇒ 65 msec
6

Vocoders :-

eg of G.729.



FEC :- here it is used for detecting packet loss.

helps in recovering the lost packages.

| 101101 | ~~100110~~ | 000110 | 001101 |

101101
100110
000110
001101

if it is lost, then using this that can be detected.

lost packet can be generated by XOR'ing detected 3 packets

FEC another way

for each packet, we can have a code.

101101 01^2 100110 11^2 000110 10^2

| | 101101 | | 01 | 100110 | | 11 | 000110 |

| 10 B | → packet

Interleaving :- packets are send in interleaved manner through defind standards.

1 2 3 ~~4 5 6~~ 7 8 9 10

1 ~~2~~ 3 4 ~~5~~ 6 7 8 ~~9~~ 10 ✓ better

∴ 1 10 7 ~~4 8 2~~ 9 6 5 3

∴ QOS is better.

GSM

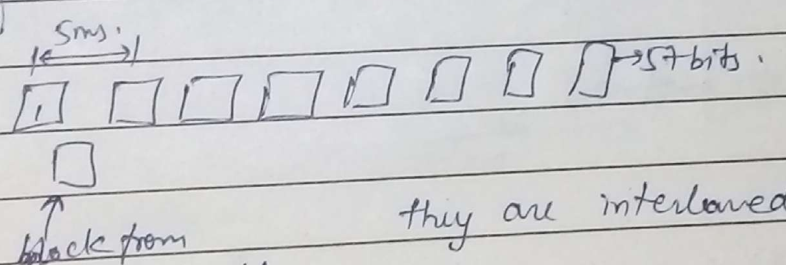
Coder: 13 Kbps

260 bits + 196 bits of overhead

|← 20 ms →| ⇒ 456 bits / 20 ms

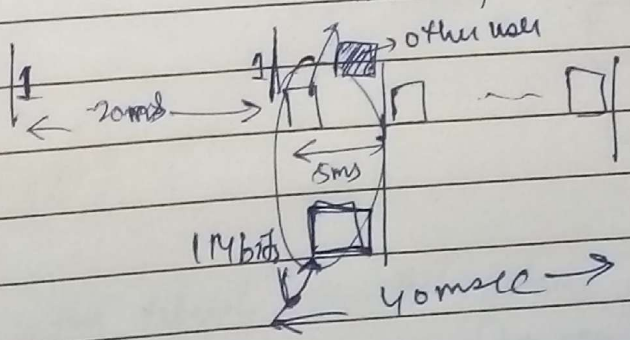
⇒ 22.8 Kbps.

this information is divided into 8 blocks.



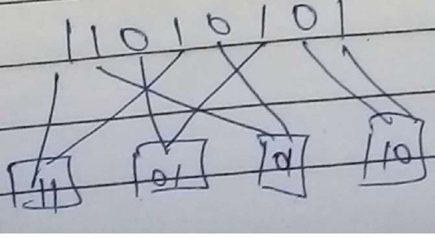
they are interleaved & txd.

not the first 57 bits (they are also interleaved)

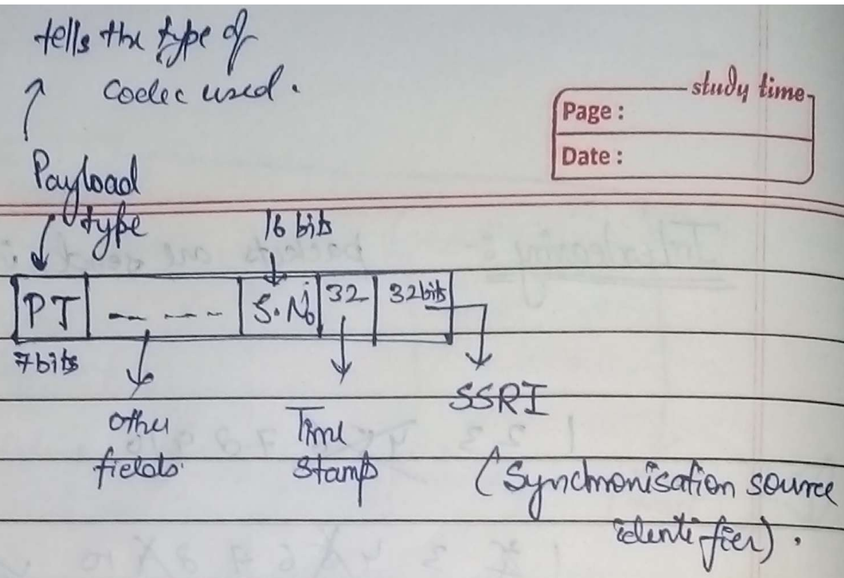


total delay → 60 msec.

for eg



RTP



S.No → seq. no. of packet

T.S → time stamp of when packets are txd

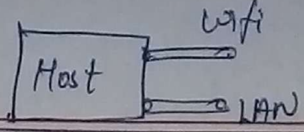
SSRI → tells the identification of the source

these fields are not in UDP.

[A/D] → [Codec] → [RTP] → [UDP]

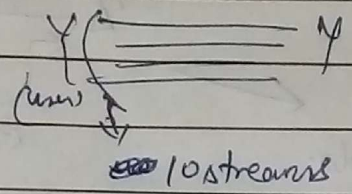
Page :
Date :

IP Address :-



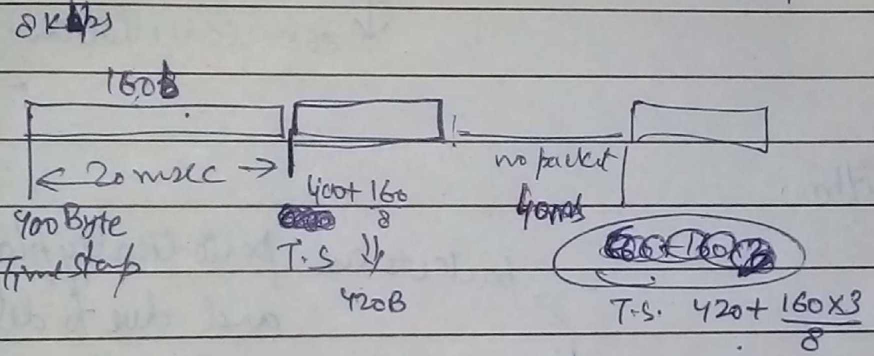
↳ address of it's interface (Ports). All ports have their separate IP's.

RINA (Recursive internet Architecture) every host will have 1 IP address.



SSRI denotes the address of each stream.

e.g. video stream will have diff. SSRI.
voice stream " " " SSRI.



Data layer Protocol :-

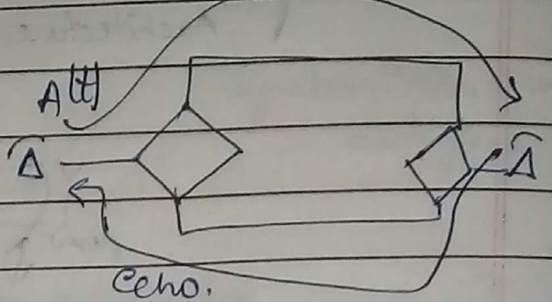
RTCP
- Receiver Reception packet (contains info. like packet loss, SSRI, Jitter, SN of last packet received). — for which stream these parameters are.
- Sender ~~Report~~ Packet
  - SSRI
  - no. of Packets that are txd
  - no. of bytes txd
  - time stamp of last txd packet.
- It is in control layer (to improve the quality of service)

In VoIP, packets retxn depends upon the distance of the sndr & rxr. (i.e. round trip delay).

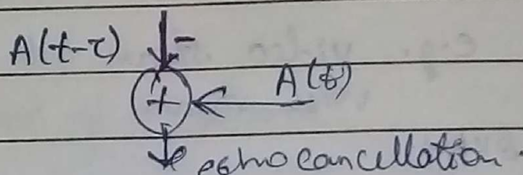
Page :
Date :

Receiver :-

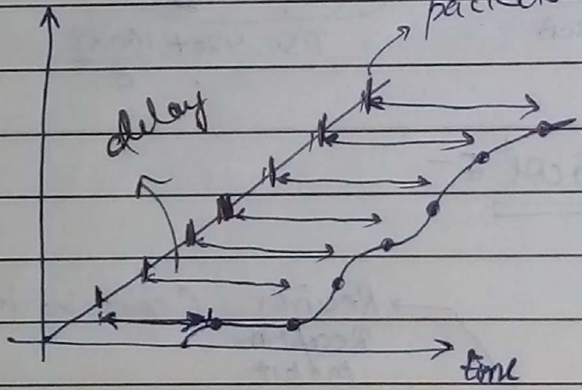
1. Dejitter algorithm
2. packet Concealment
3. Echo cancellation circuit.



will happen at both ends.



Dejitter algorithm.



MOS (Mean opinion Score) tells about the quality of experience.

MOS for PSTN is 4.

PAMS (Perceptual Analysis Measurement system)

ITU-P.862 (Perceptual Evaluation of speech quality) (PESQ)
ITU-P.861 (Perceptual Quality Speech Measurement) (PQSM)