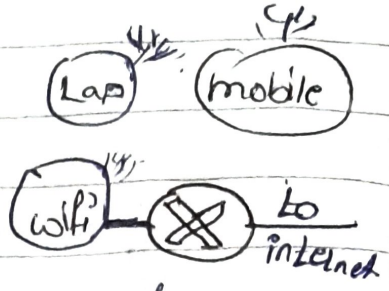
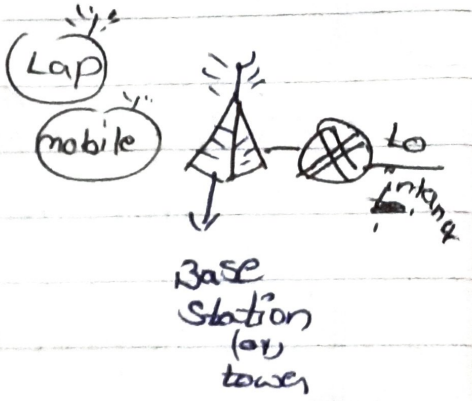
1. wireless local area networks (WLANs) :-

- distance :- 100 ft
- 11, 54, 450 Mb/sec
  - different speed for different types of wifi



2. Wide-area Cellular access network :-

- distance : ten's of km
- ten's Mb/ps



Lecture - 4

Access Networks: Data Center Networks.

~~Data Center Network~~:-

→ Company's like google,... which store data in thousands of server. is called as
- ~~Each server is a~~ known as Data Center.

→ with in the datacenter, "Data Center Networks" will be there. (inside data center, data center Networks

Data Center Network:-

high bandwidth links (several Gbps)

Connects hundreds to thousands of servers together, and to internet.

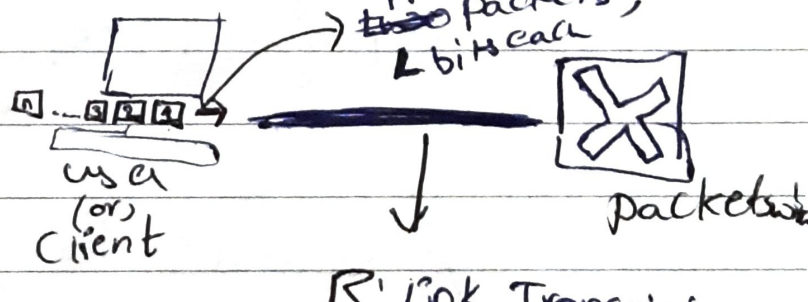
HOST: send packets of Data

Host:- client, server. {client is also known as user

Host sending function:-

1. First takes application message
   (↳ application msg have some data)
2. Now break the data into smaller chunks known as packets
   ↳ Each packet has "L" bits.

3) transmits packet into access network at transmission Rate 'R'



Packet Transmission delay = Time needed to transmit L-bit packet into Link = $\frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$

Links: physical Media
↳ The link b/w Edgerouter & End system

(i) → HFC: Co-axial cable

(ii) → DSL & Ethernet:- Copper wire

(iii) FTTH :- optical fiber

(iv) Mobile access Network:- Radio spectrum.

Bit:- It propagates b/w transmitter & receiver.

↳ The bit when travelling from source to destination, passes through a series of different transmitter - receiver pairs.

(Here source is transmitting
destination is receiver)

→ Each transmitter receiver pair, the bit is sent by propagating EM waves (or) optical pulses across a physical Medium.

(•) physical link / physical medium:-
what lies b/w transmitter & Receiver.

↳ Guided Media:-
Signals propagate in solid media.
Ex:- Copper, fiber, Coaxial Cable

↳ unguided Media:-
signals propagate freely
Ex:- Radio

1. Twisted pair (TP) Copperwires.
   ↳ Commonly used for Residential Internet Access

→ Twisted pair consists of two insulated Copperwires, each 1mm thick, arranged in spiral pattern

* → The wires are twisted together to reduce Electrical Interference from similar pairs close by.
* → Typically, a no. of pairs are bundled together in a cable by wrapping the pairs in a protective sheild.

→ A wire pair constitutes a single Communication link.

(1) Unshielded twisted pair :- (UTP)
   ↳ It is used for LAN's
      ↳ 1 pair for 1 Link

→ For Twisted pair, → single Communication link.

(2) Co-axial cable:-
   ↳ guided shared medium (many communication links)
   ↳ Two Concentric Copper Conductors (inner & outer) → Inner & outer are seperated by dielectric.

Notes In twisted Copper wire & Co-axial cable. we transmit the signal in electrical form.

→ bi directional →
↳ It can transmits both directions.

→ Broad band :-
↳ Multiple frequency channels on cable

(3) Fiber optic cables :-
↳ Transmits signal in optical form.
↳ glass fiber carrying light pulses, each pulse a bit.
↳ high speed orientation.
↳ Low error rate (error :- If 1 transmits bit 1 then bit goes to zero then it is error)
↳ Immune to Electro Magnetic Noise
↳ High security
↳ longest distance (100 kms)
↳ so, it is used for "overseas links" for optic.

(4) Wireless Radio :-
↳ signal caused in various bands in EM spectrum
↳ No physical wire :
↳ broad cast : "half-duplex"
↳ propagation environment effects :-
↳ Reflection
↳ obstruction by objects
↳ Interference
{ signal travelled in air

(5) Radio link types:

(1.) Wireless LAN:- (Wifi)
10's of Meters

(2.) Wide Area:- (4-G Cellular):-
~10 Km

(3) Bluetooth:- (Cable replacement).
↳ Shortest distances, limited rates.

(4) Terrestrial Microwave:-
↳ point to point, 45 Mb/sec Channels.

(6) satellite radio Channels:
↳ Communication b/w satellite and ground stations is known as communication satellite link.

Ground stations:- Earth-based micro-wave transmitter (or receiver.

→ The satellite receives information from 1 frequency band, regenerates using a repeater and transmits the signal on another frequency.

→ Two types of satellites are used in Communication

(i) geo stationary satellite:-

↳ permanently remains the same spot on the Earth.

→ Huge distance blw satellite & Groundstation so, it has delay of 280 msec

→ provides loomblse

(ii) LEO satellites (Low Earth orbiting) :-

↳ These satellites are placed on orbit so it revolves along with the moon.

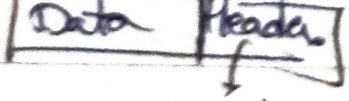
→ To provide Continuous Coverage to area, many objects need to be placed in orbit

↳ May be used for internet access in future

Network Core:

→ Mesh of interconnected routers.

→ packet switching: hosts break application layer messages into packet

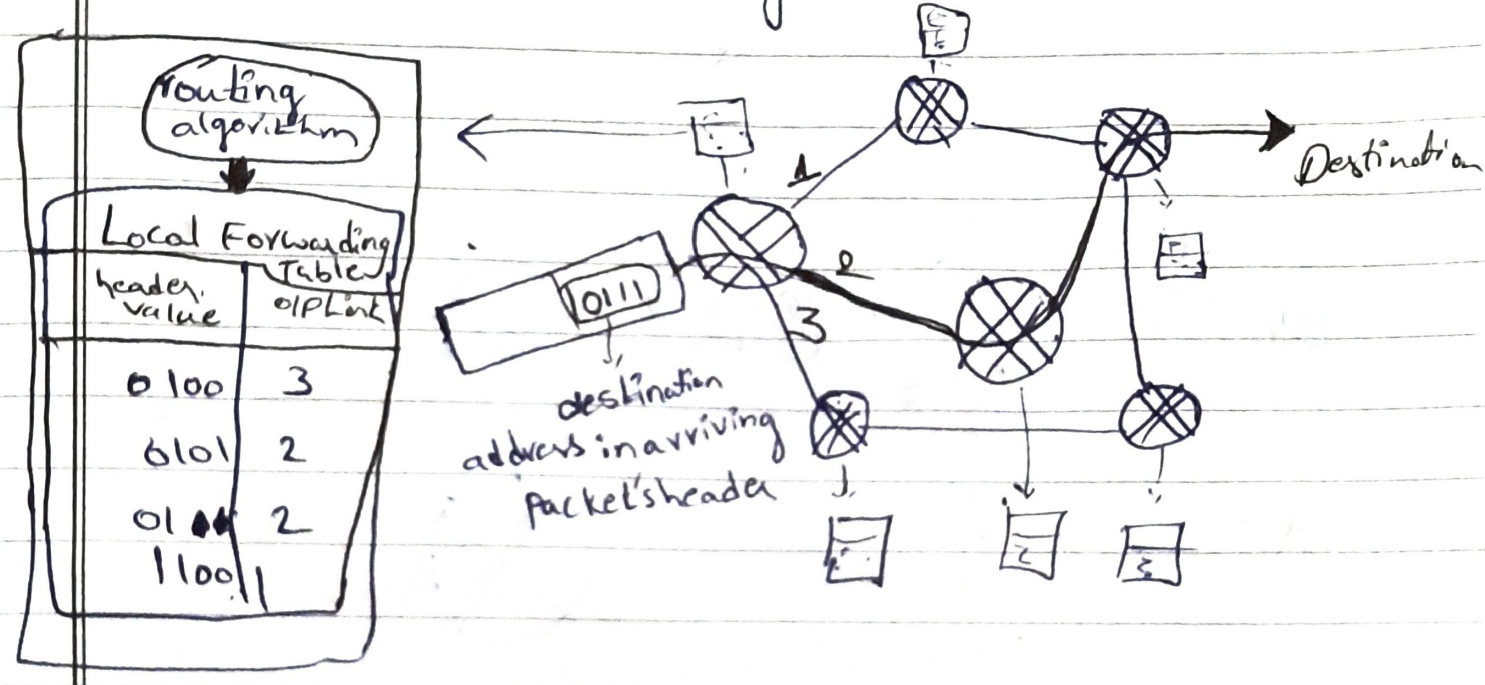


Its like destination address.

→ Network forwards packet from one router to next, accross links on path from source to destination.

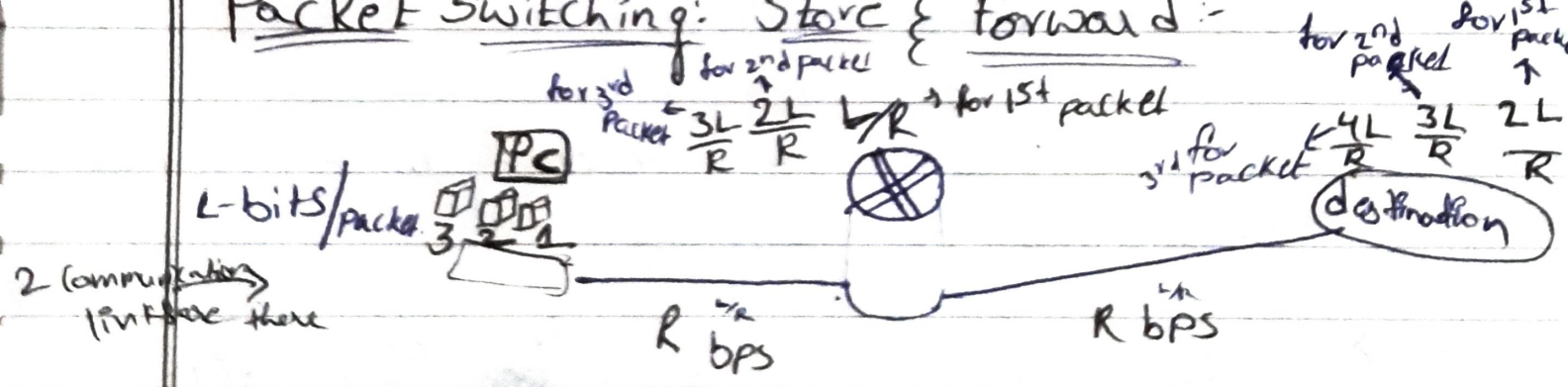
Two key network-core function:-

1. Routing → finding route (shortest path) for source to destination
2. Forwarding (or switching) → forwarding the packet the o/p of the router



→ Every router has routing algorithm

Packet switching: Store & Forward :-



for 1st packet :- If we have "n" communication links = $\frac{nL}{R}$ //

If we have "p" packets & "N" links

the $\boxed{pT\ Delay = \frac{(N+p-1)L}{R}}$

L → no. of bits in the packet

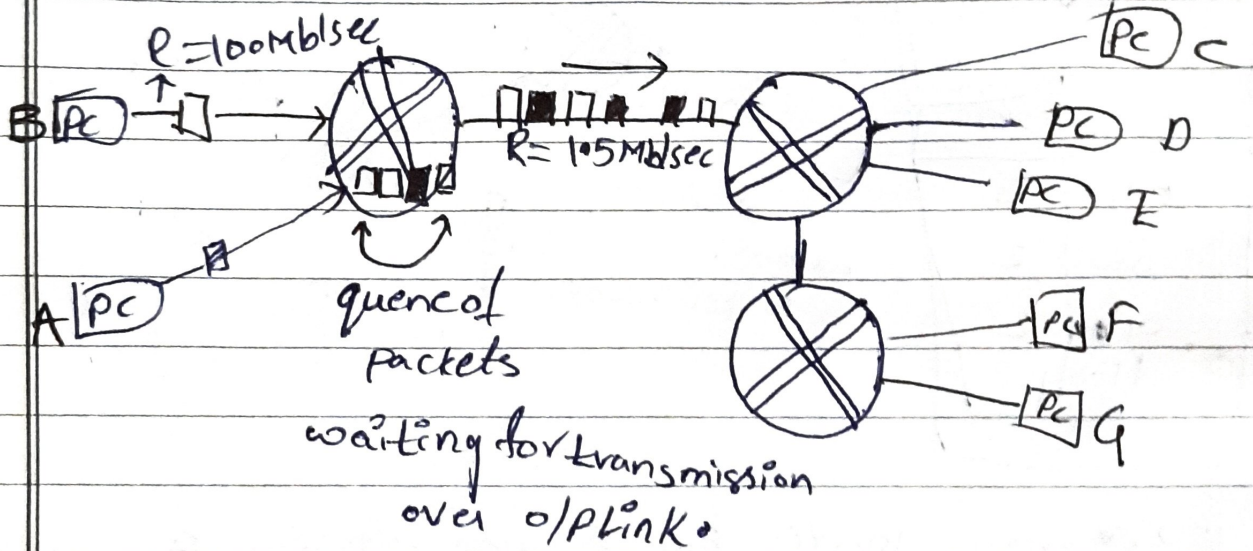
N → Communication links

p → packets

R → transmission rate

→ First, all the bits in the packet come to router then only we can forward it to destination.

Packet-switching: Queueing



** Queueing occurs when work arrives faster than its ~~served~~ serviced.

(or)

Queueing occurs when incoming is having higher speed than its out going speed

→ If Router memory is full (filled by packets) then incoming packets coming to router is lost (queue is full)

Alternative to packet switching: Circuit switching

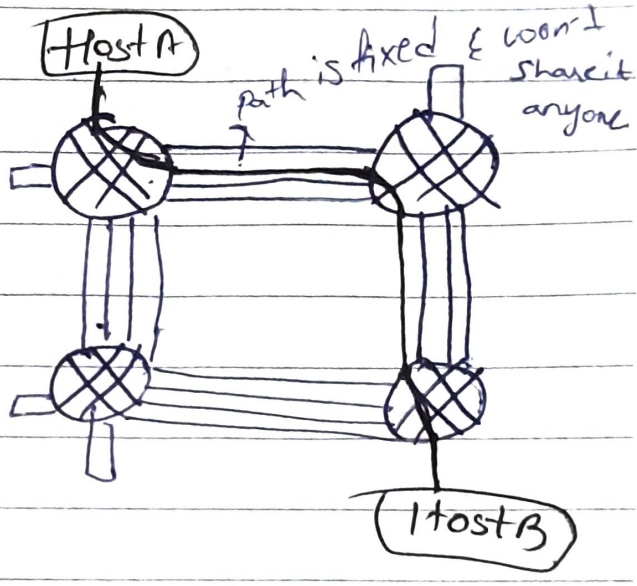
Circuit switching:-

↳ when Host A & Host B are communicate each other than a path is reserved between Host "A" and Host "B"

→ Initially, it takes "time" to setup the path once the path is setup; it will continuasly flows the packets (without storing data)

↳ once the path is setup, it won't share with other users (no sharing)

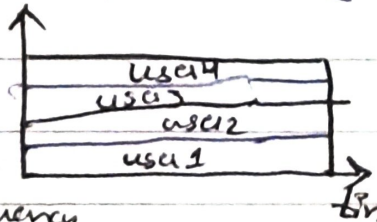
↳ Even though if you are not using then also it won't share



⇒ Commonly used in Telephone networks

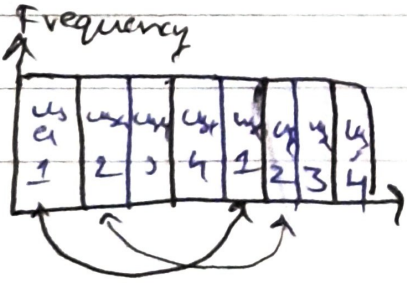
Circuit Switching: FDM & TDM: frequency ↑ users

FDM: → optical, electromagnetic frequencies divided into narrow frequency bands



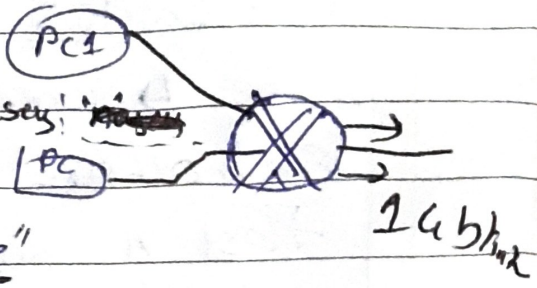
TDM (Time division Multiplexing) :- Time divided into slots.

↳ user will get periodically after certaine time



packet switching (Vs) Circuit switching

Ex:
→ 1 Gb/s link
→ Each user:
→ 100mb/se when "active"
→ active 10% of time



Q) How many users can use this network under Circuit & packet switching.

Ans: Circuit switching:-

1Gb/sec → link
& each user has 100mb/sec

So, Total no of users = $\frac{1\text{ Gb/sec}}{100\text{ mb/sec}} = 10$

∴ It has maximum of 10 users

packet switching:-

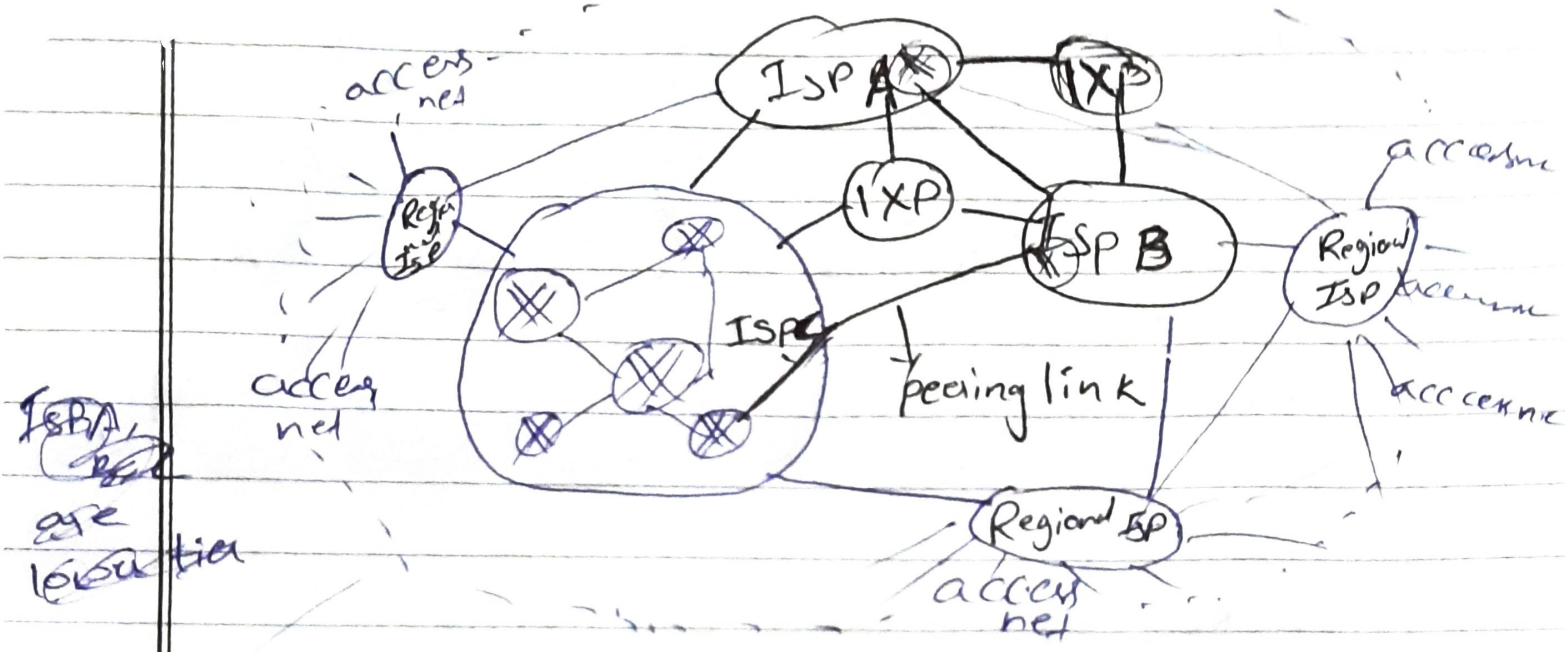
with 35 users,
Probability > 10 users active at same time is less than ≤ 0.004

→ so, it shows, it can service 35 users

Q) How to provide circuit-like behaviour with packet switching

Sol) There are various techniques that try to make packet switching as "circuit-like" as possible.

Network of Networks



→ Internet also include points of presence (POPS), multihoming, peering & internet exchange points. (IXP)

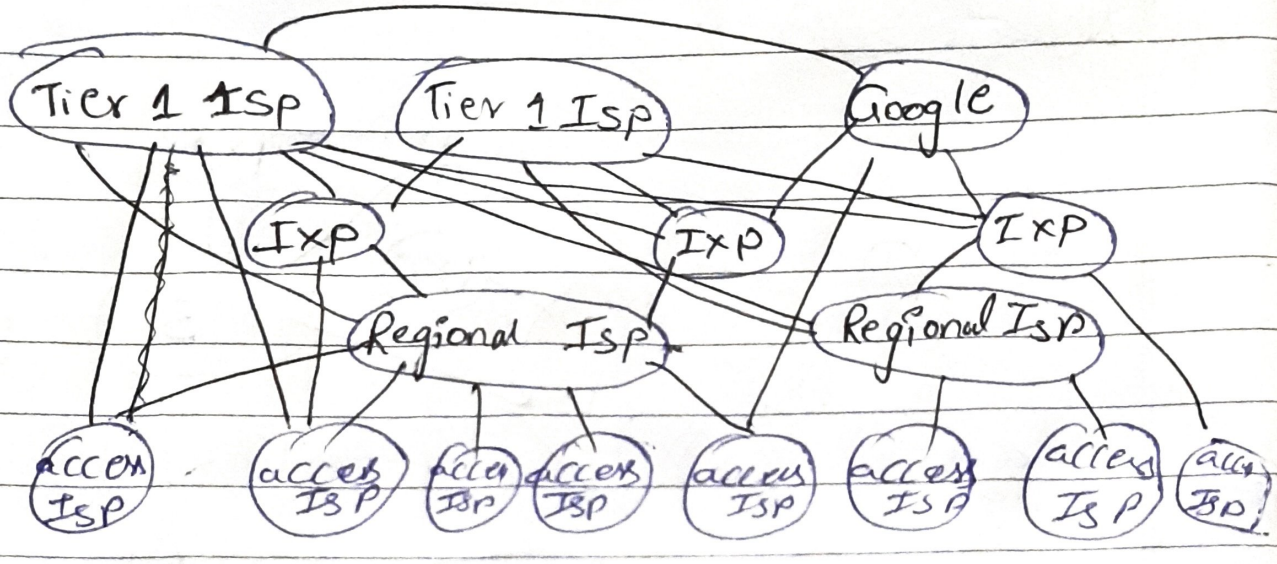
POP:- a group of one (or) more routers (at same location) in the provider's network where customer Isp's can connect into the provider Isp.

Multi-home:-

An access Isp connecting two (or) more provider Isp's

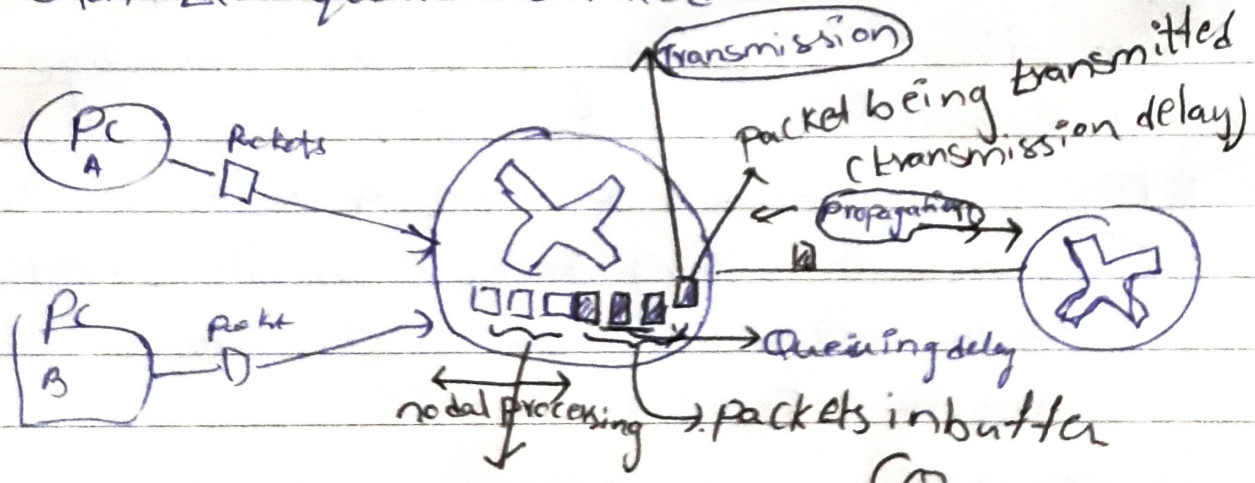
peering:- Isp's at same level can directly connect their networks together. So that all the traffic blw them pass directly

→ A third party company can create Internet Exchange point (IXP) which is a meeting point where multiple Isps can peer together.



Packet delay and loss occur:

→ When the quene is filled



Quene is full
arriving packets will be lost

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

before packet arrives into router, it will check some... (This time is d_{proc})

d_{proc} : Nodal processing
- check bit error
- determines o/p link

d_{queue} : Queueing delay
- time waiting at o/p link for transmission
- depends on no. of packets present in queue

d_{Trans} : Transmission delay
- L → packet length (bits)
- R → link transmission rate

d_{prop} : propagation delay
- d : length of physical link
- S : propagation speed

$d_{Trans} = \frac{L}{R}$

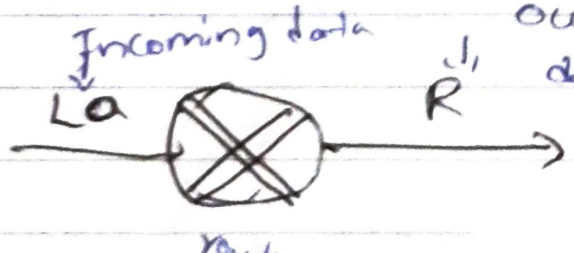
$d_{prop} = d/s$

d_{Trans} & d_{prop} are very different

Packet loss:-
- Queue is full then packet is loss.

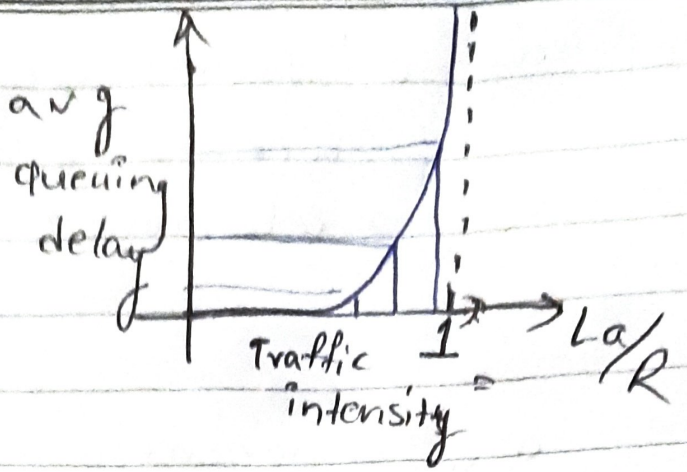
If we use TCP protocol → lost packet will be retransmitted. UTP protocol → lost packet won't be retransmitted.

a : avg time packet arrival rate
L : packet length (bits)
R : link bandwidth (bit-transmission rate)



$\frac{L \cdot a}{R}$ = Traffic intensity = $\frac{\text{arrival rate of bits}}{\text{service rate of bits}}$

for small increase in 'La' larger increase in Queining delay.



~~Traceroute~~

Traceroute program:-

delay measurement from Source to destination ~~router~~

Other delay:-

① End system wanting to transmit a packet into a shared medium may purposefully delay its transmision

② packetization delay:-

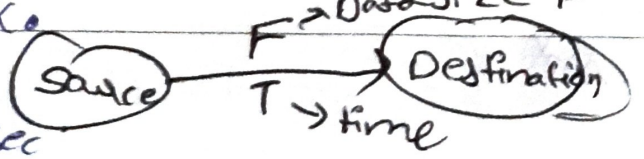
↳ present in ~~over~~ voice-over IP (VoIP) applications.

↳ The sending side must fill a packet with encoded digital speech before passing the packet to the internet

↳ Time to fill a packet is called the Packetization delay

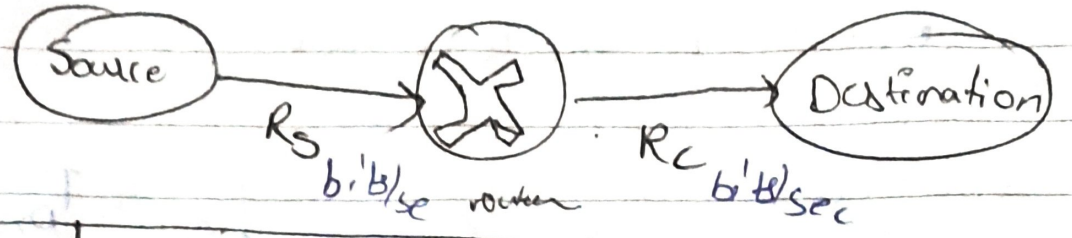
Throughput:- performance perameter of the Network.

Throughput = F/T = bits/sec



Throughput :- Rate at which bits are being sent from Sender to receiver

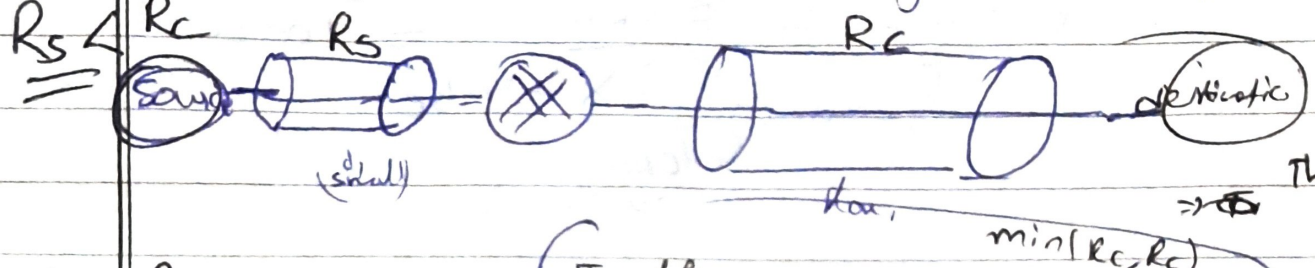
There are multiple routers in b/w source & destination.



$$\text{Throughput} = \min(R_s, R_c)$$

Instantaneous :- rate at given point in time

average :- rate over longer period of time.



$R_c > R_s$

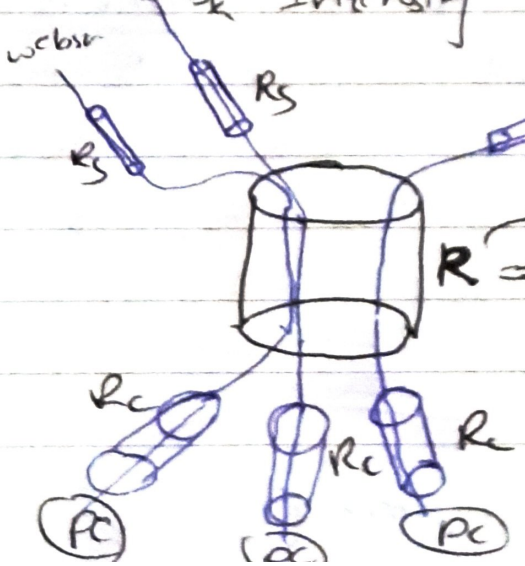
Traffic Intensity = $\frac{R_s}{R_c} < 1$ (good)

$\min(R_c, R_c)$

Throughput = R_c

Traffic Intensity = $\frac{R_s}{R_c} > 1$ (bad)

↳ Queueing delay is more



Throughput = $\min(R_c, R_s, \frac{R}{10})$

Q) Find Total nodal delay for a packet of 150kB transmitted at 150 Mb/sec speed over a distance of 300km in satellite link?

Sol) Total nodal delay = $T_{proc} + T_{queue} + T_{trans} + T_{prop}$

$$T_{trans} = \frac{L}{R} = \frac{150 \times 1000 \times 8 \text{ bit}}{150 \times 10^6 \text{ bit/sec}} = 8\text{m sec}$$

$$T_{prop} = \frac{d}{s} = \frac{300\text{km}}{3 \times 10^8 \text{m/sec}} = 1\text{m sec}$$

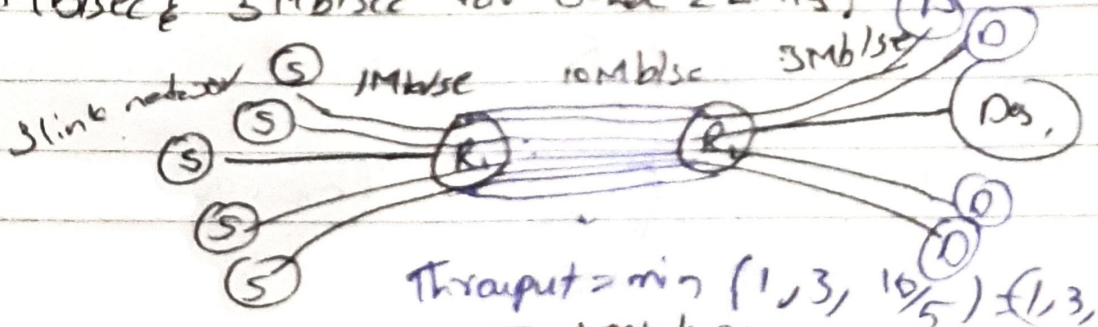
d → distance
s → speed (air, satellite → 3×10^8 m/sec)

T_{proc} & $T_{queue} = 0$ (as it is not mentioned)

∴ Total nodal delay = 0 + 0 + 8m + 1m
= 9m sec

Q) what is the overall throughput in a 3 link network with the middle link shared b/w Susas & having a bandwidth of 10Mb/sec, while data rates of 1Mb/sec & 3Mb/sec for other 2 Links?

Sol)



Throughput = min (1, 3, 10/5) = (1, 3, 2)
= 1Mb/sec