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CHAPTER # 01

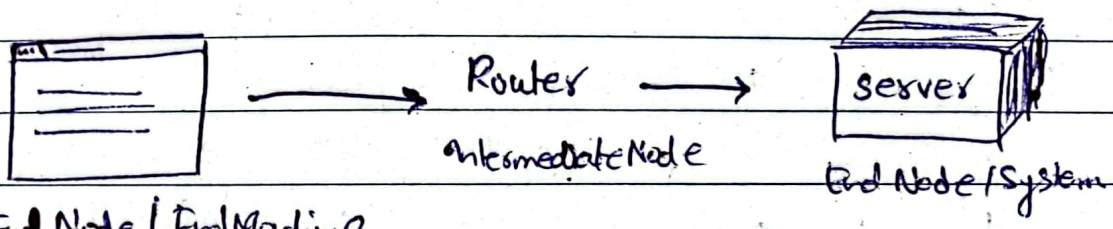
→ Internet is a computer network that interconnects billions of computing devices throughout the world. (a infrastructure that provides services to applications)

→ Internet = Interconnected Network

→ All the devices connected to internet are called host or end systems

→ End systems are connected together by a network of communication links and packet switches

→ Different links transmit data at diff rates, this transmission rate is measured in bits/second



End Node / End Machine
Client / Host Machine

→ When one end system has data to send to other end system, the sender segments the data and adds header bytes to each segment. The resulting package of information is called packets. These packets are then reassembled by recieven. The process is called packet switching. (each packet is given unique address)

→ Types of packet switching
① Routers (used in network core)
② Link-layer switches (used in access networks)

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→ The sequence of communication links & packet switches traversed by a packet from the sending to recieving end systems is known as route or path through the network.

→ End systems access the Internet thru Internet Service Provider (ISPs)

→ Each ISP is in itself a network of packet switches and communication links.

→ End systems, packet switches and other pieces of Internet run protocols that control sending and recieving of info within the Internet.

→ Transmission Control Protocol (TCP) & Internet Protocol (IP) are two most imp protocols.

↳ specifies the format of that packets that are sent & rec

→ The internet's principal protocols are collectively known as TCP/IP.

→ Internet Standards are developed by Internet Engineering Task Force (IETF).

→ The IETF std documents are called requests for comments.

downstream → refers to flow of data from server → end user like downloading data.

upstream → refers to flow of data from end user → server like uploading

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→ An application involving multiple end systems that exchange data with each other are called distributed applications.

→ End systems attached to the internet provide a socket interface that specifies how a program running on one end system asks the internet infrastructure to deliver data to a specific destination program.

↳ set of rules that sender must follow to deliver data

▷ PROTOCOLS :

"A protocol defines the format and the order of messages exchanged b/w two or more communicating entities, as well as the actions taken on the transmission and/or reciept of a message or other event."

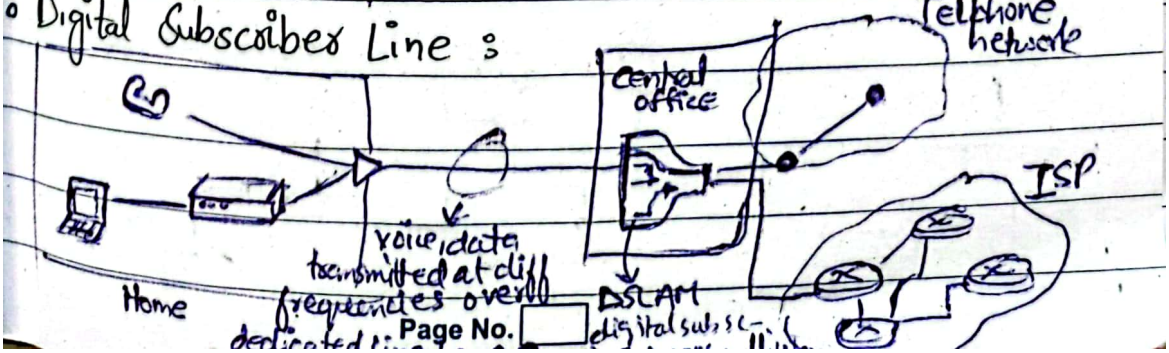
▷ NETWORK EDGE :

→ End systems are referred to as hosts because they host application programs.

→ End systems → clients (desktop, laptop, smartphones)
→ servers (powerfull machines to store & distribute web pages)

→ they are also asymmetric

◦ Digital Subscriber Line :



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transmission rate depends upon distance b/w the home & Central Office

→ DSLAM (Digital Subscriber Line Access Multiplexer) receives the signals and breaks the signal into two. If it is a voice data then it is sent to telephone network or else to the ISP.

o Cable Internet Access: There are more consumers than providers → asymetric (means they transmit data faster in downstream than upstream) 40 Mbps - 1.2 Gbps downstream transmission rate, & 30 - 100 Mbps upstream.

→ It is a broadband internet service that delivers high speed internet using hybrid fiber coaxial cable network.

It provides faster speeds as compared to DSL.

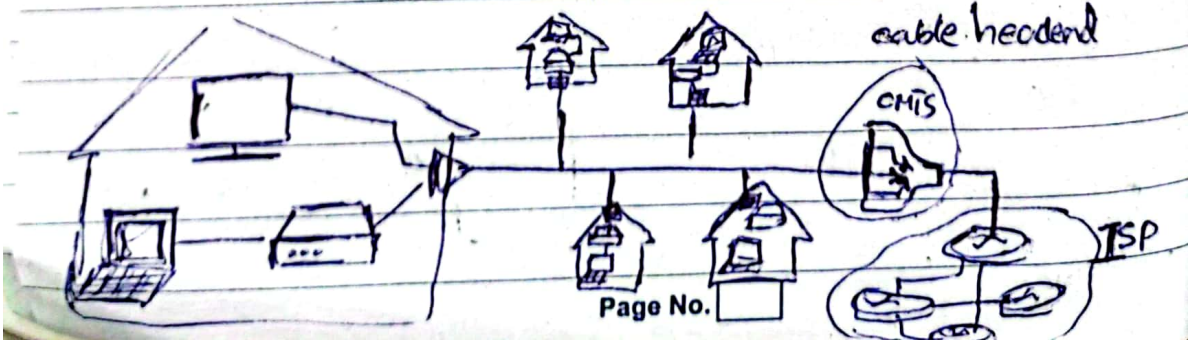
It typically shares bandwidth among multiple users in a neighbourhood.

→ Cable internet access requires special modems, called cable modems.

→ The cable modem termination system (CMTS) is similar to DSLAM → turning analog signal sent from the cable modems in many downstream homes back to digital format.

→ Cabel modem divides the HFC network into two channels, a downstream & an upstream channel.

→ A downstream channel is typically allocated a higher transmission rate than upstream.



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→ Fiber to the home (FTTH) provides more higher speeds than DSL or cable

→ Wirless access network → Shared wireless access network connects end system to router via base station aka "access point"
↳ Wireless local area Network (WLANs)
↳ Wide-area cellular access network

→ Enterprise Network
↳ Used by organizations, companies and universities

→ Data Center Networks :
↳ High bandwidth links (10s to 100s Gbps) connect hundreds to thousands of seavers together, and to Internet

▷ PHYSICA MEDIA :
→ Physical Media falls into two categories
↳ Guided Media → The waves are guided along a solid medium such as a fiber-optic cable, a twisted pair copper wire or a coaxial cable.
↳ Unguided Media → The waves propagate in the atmosphere and in outerspace, such as in a wireless LAN or a digital satellite channel

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- bits : propagates between transmitter / reciever pair

- Twisted Pair Copper wire :
  - ↳ Consist of two insulated copper wire each about 1mm thick, arranged in a regular spiral pattern
  - ↳ A wire pair constitute a single communication link.
  - ↳ Unshielded Twisted Pair (UTP) is commonly used for computer networks within a building
    - ↳ Data rates for LANs using twisted pair range from 10 Mbps – 10 Gbps, dependends on thickness of wire & distance b/w transmitter & reciever

- Coaxial Cable :
  - ↳ Coaxial Cable can be used as a guided shared medium.
  - ↳ A no. of end systems can be connected directly to the cable, with each of the end systems recieving whatever is sent by other end systems.
  - ↳ bidirectional

- Fiber Optics :
  - ↳ An optical fiber is a thin, flexible medium that conducts pulses of ~~light~~ light, with each pulse representing a bit.

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↳ They are immune to electromagnetic interference, have very low signal attenuation upto 100 km, and are very hard to tap.

↳ High Speed operation: (10's – 100's Gbps)

↳ low error rate

• Wireless Radio:

↳ Signal carried in various "bands" in electromagnetic spectrum

↳ No physical wire

↳ The characteristics of radio channel depend significantly on the propagation enviornment

↳ Shadow Fading: which dec the signal strength as the signal travels over a distance and around/through obstructing objects

↳ Multipath Fading: due to signal reflection off of interfering objects

↳ interfesence: due to other tranemissions and electromagnetic signals

• Satellite Radio Channels:

↳ A communication satellite links two or more Earth-based microwave transmitter/recievers, known as ground stations

↳ Two types of satellites are used

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① Geostationary Satellite :
↳ Remains permanently above the Earth one same spot at 36,000 km
↳ This huge distance causes substantial signal propagation delay of 280ms.

② Low Earth Orbiting (LEO):
↳ They are placed much closer to Earth & revolves around the Earth like a Moon.
↳ And communicates each other as well as with ground stations.

▷ NETWORK CORE :
↳ In a network application, end system exchange messages (text msg, audio, video, email etc) with each other
↳ Sender breaks message into small chunks called packets & each travels through a communication link and packet switches.
↳ A src is sending a packet of L bits over a link with transmission rate R bits/sec, then

→ Link capacity or link bandwidth

$$\text{packet transmission delay} = \frac{\text{time needed to transmit L-bit packet into link}}{} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}} \quad \text{sec}$$

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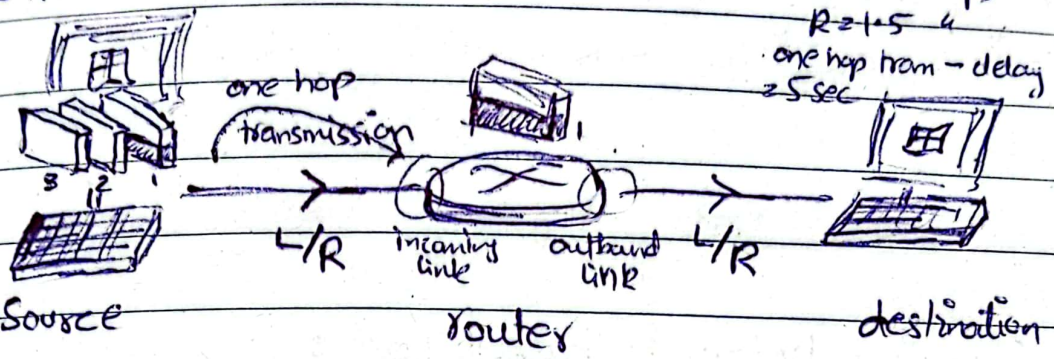
- Store & Forward Transmission :
  - ↳ Packet switches use store-and-forwarding transmission, meaning that the packet switch/router must recieve the entire packet before it can begin to transmitt the first bit of the packet onto the outbound link



- ↳ Transmission Time For One Packet
  - Transmission time for a packet of size L bits over a link of rate R:
    - ↳ L/R sec for the source → router
    - ↳ Another L/R sec for router → dest
    - ↳ Total delay = 2L/R

- ↳ Mulliple Packets Transsmisson (no. of packets = 3)
  - ↳ At L/R, the 1st packet reaches router
  - ↳ At 2L/R, 1st reaches dest & 2nd reaches router
  - ↳ At 3L/R, 2nd reaches dest & 3rd " "
  - ↳ At 4L/R, 3rd reaches dest
  - ↳ Total 4L/R

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↳ General Formula for N-links

↳ For N links, the end-to-end delay for one packet is:

$$d_{end\text{-}to\text{-}end} = N \times L/R$$

↳ If forwarding starts as soon as bits arrive, the delay could be L/R instead of N×L/R
But packets need to "recieve, store & process" the entire packet before forwarding

- Queuing Delay & Packet Loss:

↳ Output Buffers: (Queues)

→ Each packet switch has multiple output buffers for its attached links.

→ Buffer store packets waiting to be transmitted onto a busy link

↳ Queuing Delays:

→ If a packet arrives when the link is busy, it must wait in the output buffer.

→ This queuing delay varies based on network congestion (network cong- occurs when the demand for network resources exceeds the available capacity leading to delays & packet loss)

↳ Packet Loss:

→ Buffers have limited space; if they are full,

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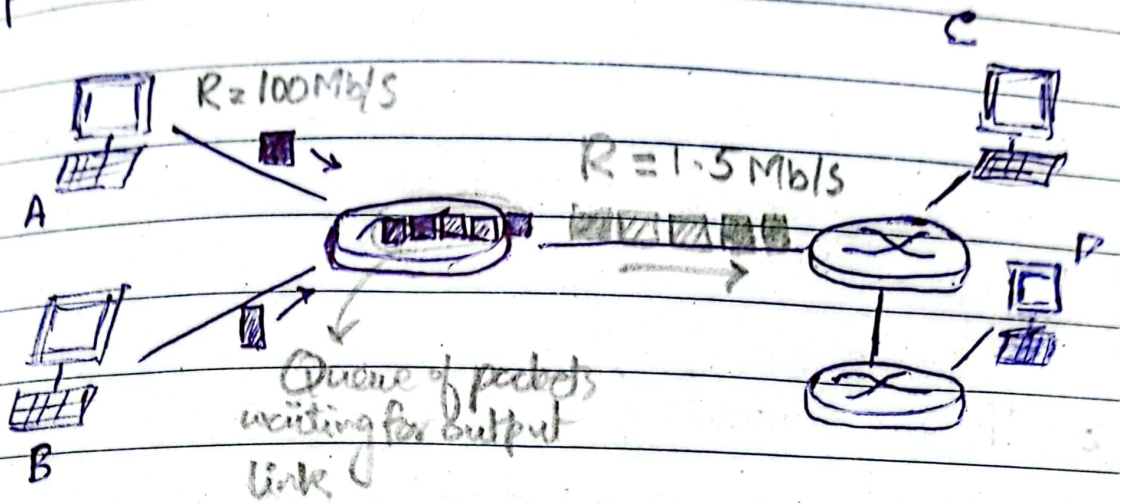
the incomming packet or one of the already-queued packets will be dropped.



↳ Host A & B send packets to Host D via a router
↳ The router connects to a 15 Mb/s link while receiving data at 100 Mb/s from both hosts.
↳ If arrival rate > 15 Mb/s, packets queue up, causing congestion.

- Packet Forwarding & Routing:

↳ Each end system in internet has a unique IP address
↳ The destination IP address is included in the packet header.
↳ Router forward packets based on their forwarding tables

- Forwarding Tables

↳ Maps destination address (or portions of them) to outbound links

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↳ The router examines the packet's destination address and selects the appropriate outbound link.

→ Internet has a number of special routing protocols that are used to automatically set the forwarding tables.

Circuit Switching :

↳ Two primary approaches for data transmission over a network.

① Packet Switching : Doesnot reserve resources; packets share resources dynamically

② Circuit Switching : Reserve resources (buffers, link transmission rate) for entire session

↳ Example : Telephone Network

→ Requires establishing a connection before communication

→ Switches maintain connection state for the duration of communication

→ Reserves a constant transmission rate in network links for guaranteed data transfer.

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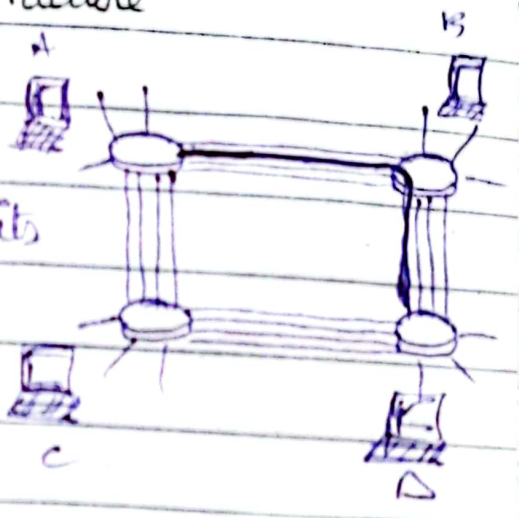
↳ Circuit Switched Network Structure

- Consist of circuit switches interconnected by links, each link supporting multiple circuits
- A network with 4 circuits switches & 4 circuits per link



- Dedicated end to end connection b/w two host (eg: A & D)
- if a link has 1 Mbps transmission rate & 4 circuits, each connection gets 250 Kbps

↳ Comparasion

→ Circuit switching has dedicated resources, no congestion delays, guaranteed transmission rate

→ Packet switching has no reserved resources packets may suffer queuing delay in congested links

Best effort delivery without transmission guarantees

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o Multiplexing in Circuit Switched Networks

o Frequency-Division Multiplexing (FDM):

→ Divides the frequency spectrum of a link into seperate bands for each connection

→ Each connection gets a dedicated frequency band for the duration of the session

→ Example: Telephone network allocates 4KHz per connection; FM Radio stations use 88-108M range

o Time-Division Multiplexing (TDM):

→ Divides time into frame, each containing fixed time slots

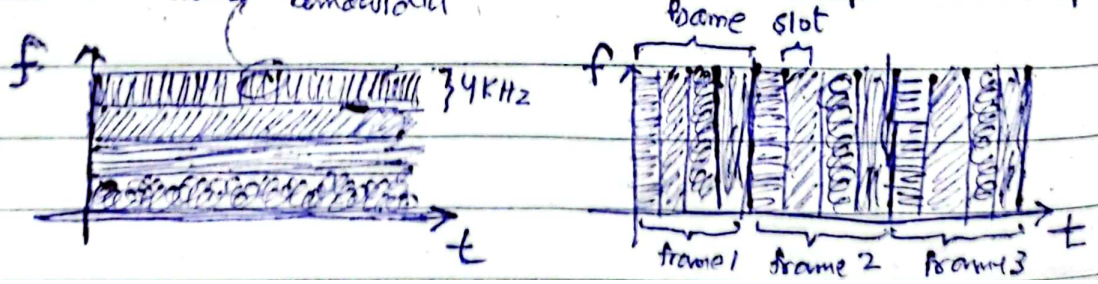
→ A dedicated time slot is assigned to each connection in every frame.

→ Example: If a link transmits 8000 frames/sec with 8-bit/slots then

transmission rate of a circuit = frame rate × Bits per slot

= 8000 × 8

= 64,000 bps = 64 Kbps



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- Inefficiency Due to Idle Resources:
  - ↳ Resources (frequency bands or time slots) remain unused during silent periods in conversations
  - ↳ Example: In a telephone call if a person stops talking, the allocated circuit remains idle
- Complexity of Circuit setup:
  - ↳ Requires end-to-end circuit establishment before data transmission
  - ↳ Needs complex signaling software to cordinate switch operations.

→ Packet switching provides more efficent resource utilization by dynamically sharing network capacity

Q: How long it takes to send a file of 640,000 bit from Host A to B over a circuit switched network Suppose that all links in the network use TDM with 24 slots and have a bit rate of 1.536 Mbps. Also it takes 500 msec for the connection to establish.

File size = 640,000 bits

Total link bit rate = 1.536 Mbps (for this capacity of a frame)

No. of time slots = 24

Circuit estab. time = 500msec

→ As there are 24 time slots so there are 24 circuits & each circuit have trans-rate 64Kbps

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Each circuit gets an equal share of the total link bandwidth

$$\text{Transmission Rate per circuit} = \frac{1.536 \text{ Mbps}}{24}$$

$$= 64 \text{ Kbps}$$

$$\text{Transimission Time} = \frac{\text{File Size}}{\text{Trans-Rate}} = \frac{640{,}000}{64{,}000}$$

$$= 10 \text{ seconds}$$

Total time = 10 sec + 0.5 sec = 10.5 sec

→ Because every link in the circuit operates at 64Kbps, adding more links doesnot incre. transmission time, it remains 10sec, no matter how many link the data travels through

Circuit Switching	Packet Switching
• Reserves a dedicated circuit (bandwidth) for the entire duration of communication	• No dedicated circuit; resources are shared dynamically
• Inefficent, as bandwidth remains reserved even during silent periods	• More efficent, as bandwidth is used only when data is transmitted

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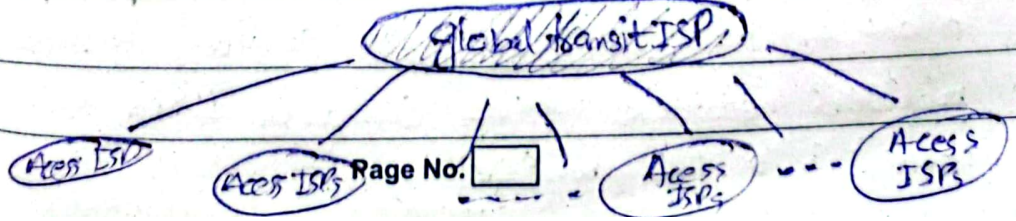
• Supports a limited no. of users due to fixed allocation	• Supports more users due to dynamic bandwidth sharing
• Fixed & predictable delay since a dedicated path is established	• Variable delay due to queuing & network congestion
• Data transmitted into continuous stream	• Data is broken into packets and transmitted independently

INTERNET STRUCTURE :

- Access ISPs : End systems (PCs, phones, servers) connect to the internet through Access ISPs using technologies like DSL, cable, WIFI etc. Universities and companies can also act as ISPs.
  → Access ISPs alone cannot connect all systems globally. They must interconnect, forming a network of networks.

- Network Structure 1: A single global transit ISP connects all Access ISPs, but this costly and impractical. (Q ek global ISP hundreds of thousands of Access ISPs ko connect nhi kr sakti)



Acess ISPs pays global ISPs for network connection there here AcessISP is customer and gl — ISP provider

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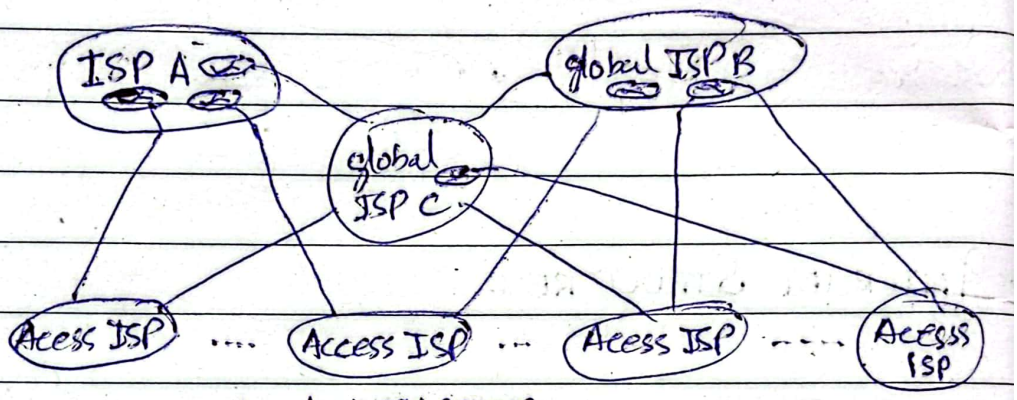
- Network Structure 2 : When one global ISPs make profit then multiple competitors emerges, this reducess cost for Acess ISPs and improving connectivity.
  → The global ISPs themselves must be interconnect to maintain connectivity



- Network Structure 3 : A 3-tier system develops :
  - Tier-1 ISPs (eg : AT&T, NTT, Sprint) interconnect globally (they donot pay anyone)
  - Regional ISPs : connects to Tier-1 ISPs. They also connect themselves (pays)
  - Acess ISPs : Connect to regional or directly to Tier-1 ISPs (pays)

- Network Structure 4 :
  - PoP (Point of Presence) : A PoP is simply a group of one or more routers (at same location) in the provider's network where customer ISPs can connect into the provi

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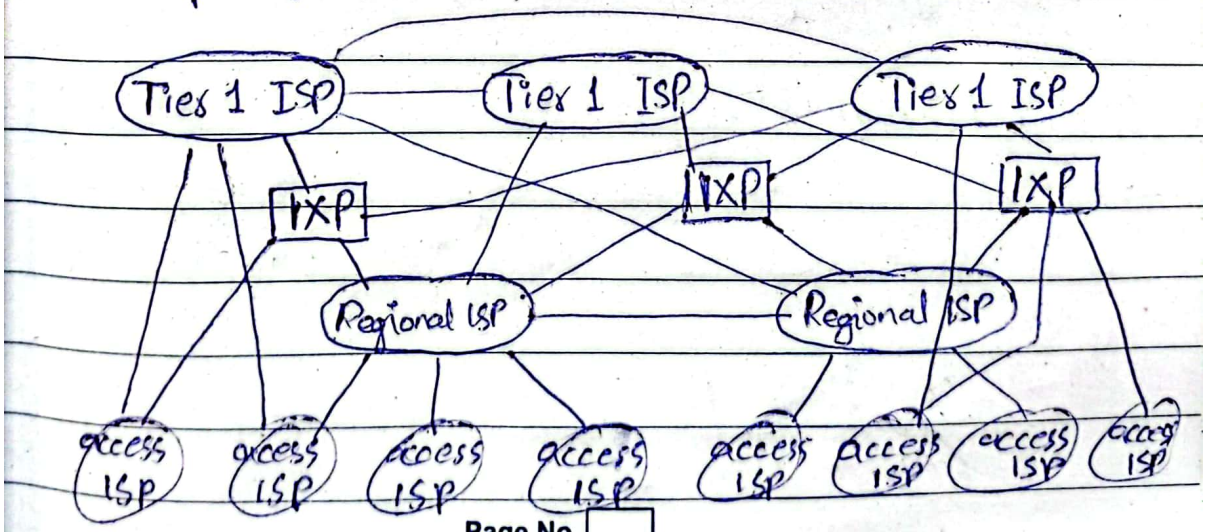
- Multihome : Any ISP (except for tier-1 ISPs) may choose to multi-home, that is, to connect to two or more provider ISPs, so an ISP may multihome with two regional ISP so that in case of ~~one failure~~ failure of one ISP, connection remains active.
- Peering : ISPs in same heirarchy connects with each other so they directly exchange traffic without paying intermediaries. And they donot pay each other.
- IXPs (Internet Exchange Point) : Physical locations where multiple ISPs peer.

- Network Structure 5 :
  - Content Provider Network : (eg: Google, Facebook) bypass upper-tier ISPs by directly connecting to lower-tier ISPs and IXPs, reducing costs and improving service control.



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▷ DELAYS IN PACKET SWITCH NETWORK :

→ A packet can be transmitted on a link only if there is no other packet currently being transmitte on the link and if there are no other packets preceding it in the queue; if the link is currently busy or if there are other packets already for the link, the newly arriving packet will then join the queue.

- Processing Delay :
  → The time required to examine the packet's header and determine where to direct the packet is part of the processing delay.
  ↳ This also include other factors, such as the time needed to check for bit-level errors in the packet that occured in transmitting the packet's bit from upstream node to routers.

- Queuing Delay :
  → At the queue, the packet experiences a queuing delay as it waits to be transmitted onto the link

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- Transmission Delay:

→ The amount of time required to push (that is, transit) all of the packet's bit into the link.
Transmission delay = L/R (L = length of bit, R = transmission rate)

- Propagation Delay:

→ Once a bit is pushed into the link, it needs to propagate to routers. The time req to propagate from begining of the link to routers is prop delay.

→ The propagation speed depends on the physical medium of the link.

→ Propagation delay = Distance b/w routers / Prop. speed of link

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

- Queuing Delay:

→ The time a packet spends waiting in a queue before transmission

→ Factors affecting queuing delay:
① Traffic arrival rate ② Transmission rate
③ Nature of traffic (periodic vs bursty)

→ Traffic Intensity → La/R
L = Packet size (bits), a = Packet arrival rate (packets/sec)
R = Link transmission rate (bits/sec)

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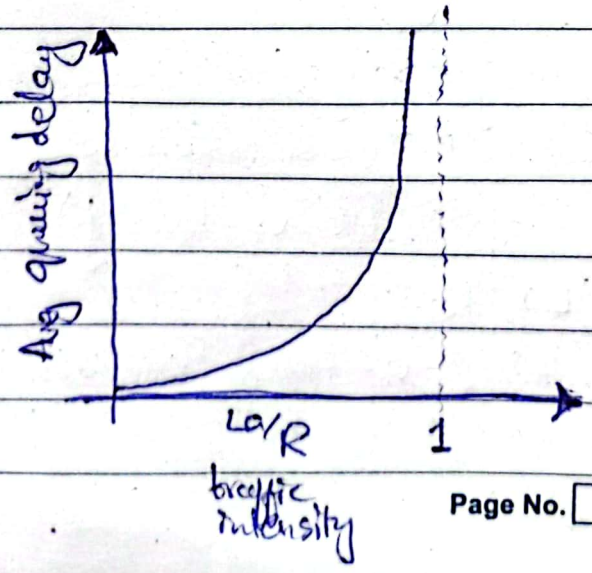
- if $La/R > 1$ (Queue builds indefinitely)
- if $La/R < 1$ (Delay depends on traffic arrival pattern)

- Periodic Arrival:
  - ↳ if packet arrives exactly every L/R sec, there is no queuing delay (empty queue)
  - ↳ if packets arrive in bursts, queuing delay incr.

if N packets arrive every (L/R)N seconds
1st packet → no delay
2nd packet → L/R ses delay
3rd packet → 2x L/R sees delay
⋮
nth " → (n-1) L/R ses delay

→ When traffic intensity La/R is $\simeq 0$, queing delay is minimal (low traffic)
→ When it approaches 1, queing delay grows exponentially



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• End-To-End Delay :

↳ Total delay from src → destination

↳ let there are N-1 routers from src → destination then,

$$d_{end-end} = N\,(d_{proc} + d_{trans} + d_{prop})$$

→ tracert (windows) is a cmd that helps us get the IP of all the router in path from src → destinatio

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End-to-End Delay :

- Total delay from src → destination
- let there are N-1 routers from src → destination

Here

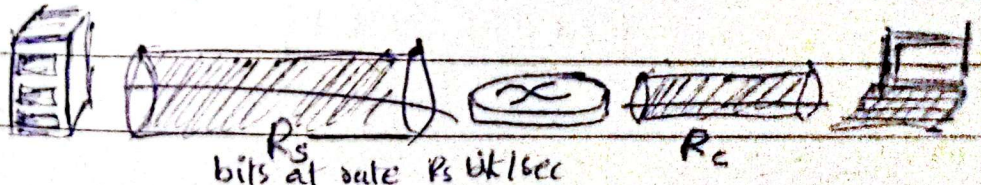
$$d_{end-end} = N(d_{proc} + d_{trans} + d_{prop})$$

→ tracert (windows) is a cmd that helps us get the IP of all the router in path from src → destination

• Throughput :

→ Rate (bits / time unit) at which bits are being sent from sender to reciever.

- instantaneous : rate at a given point in time
- average : rate over long period of time
  - ↳ if file consist of F bits and transfer takes T sec for Host to recieve all F bits then avg thr- = F / T (bit/sec)



Rs < Rc → so throughput will be Rc

throughput will be minimum (Rs, Rc)

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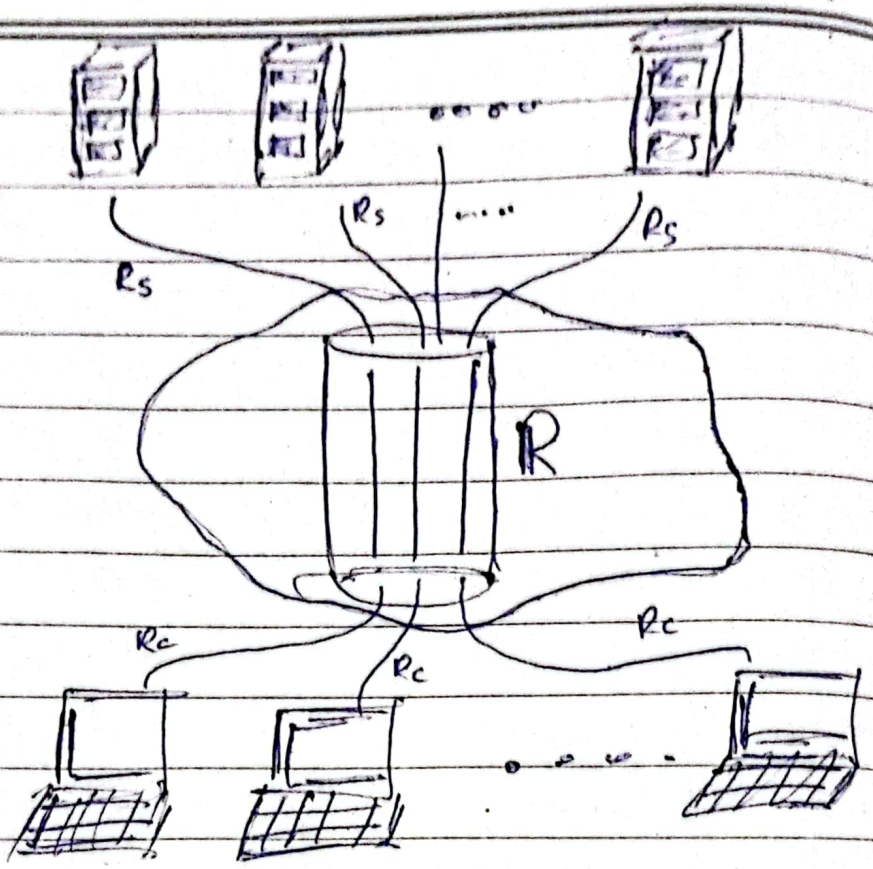

per connection end-to-end throughput:
minimum (R_c, R_s, $R/10$)

R_s = 2Mbps , R_c = 1 , R = 5 Mbps , n = 10

So now throughput will be or we can say the bottleneck

$$\min\left(2\text{Mbps}, 1\text{ Mbps}, \frac{5\text{Mbps}}{10}\right)$$

$$= 500\text{ kbps}$$

→ link on end-end path that constrains end-end throughput.

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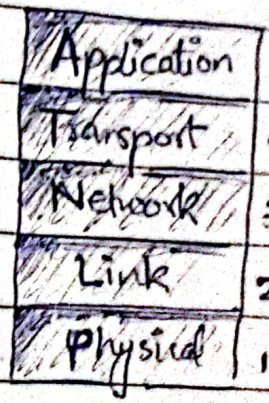
Five Layer Internet Protocol Stack

→ Computer network follows layered architecture.
→ Each layer implements a service
→ Modularity makes it easier to update system components
→ One layer may duplicate lower layer functionality.
→ A functionality at one layer may need info that is present only in another layer.
→ These are called protocols stack or TCP/IP Protocol Stack



① Application Layer :

- Protocols → HTTP, SMTP, DNS, FTP
- PDU (Protocol Data Unit): Message
- A application Layer is distributed over multiple end system with the application in one end system using the protocol to exchange packets of info with the application in another end system.

② Transport Layer :

- Protocols → TCP, UDP
- PDU → Segment
- This layer transports app.-layer msgs b/w app. endpoints

connection oriented service to its app service include guaranteed delivery of msgs
→ connection less service to its app
Unreliability

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(3) Network Layer :

- Protocol → IP protocol, routing protocol
- PDU → datagrams or IP datagram
- The Transport-layer protocol (TCP or UDP) in a src host passes a transport-layer segment and destination address to the network layer.
- The Network Layer then provides the service of delivering the segment to the transport-layer in dest addr.
- The IP Protocol defines the fields in datagram as well as how the end system & routers acts on these fields.
- The routing protocol determines the routes that datagram takes blw src & dest.

"To find out the best path to send the datagram to destination in a network layer is called routing"

- Routers are also called 3 layered devices

(4) Link Layer :

- Protocol ⇒ Ethernet, WiFi, DOCSIS, PPP
- PDU → Frames
- One frame passes through diff router to reach from src → dest

• Switches are layer 2 devices

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• Therefore to move a packet (frame) from one node (host/routes) to next one in the route, the Network Layer uses link layer's services
• At the dest node the link then passes packet to network layer.
• There ~~are~~ may ~~be~~ diff protocol running on the links b/w the ~~route~~ nodes in the route.
• Like one layer uses Ethernet, other link might use WiFi & so on.
•

⑤ Physical Layer:

• The job of this layer is to move individual bits within the frame from one node to next.
• The protocol layer are link dependent, like Ethernet have diff, WiFi have diff & so on.
• Protocol → Ethernet
  - 10BASE-T (Twisted Pair)
  - 100BASE-FX (Fiber optics)

WiFi
  - IEEE 802.11 Family

Bluetooth
  - IEEE 802.15.1

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→ When a packet is transfer from one layer to another each layer, a packet has to type of fields:

header fields → The metadata for the msg

payload field → A packet from the layer above

→ Har layer apna header attach krta hai apne upper wale layer k data k sath or age send krdeta hai

→ Router pas sirf teen tsha k layers implement hoti hai → Network, Link & physical

→ Switches par → Link & physical

→ Endsystems → all 5 layers

→ Link-layer switches donot recognize IP Addresses as they cannot implement IP Protocol as it is layer 3 protocal. They recognize Ethernet addres

"SECURITY"

o Malware

↳ Short form of malacious software

↳ Intentionally designed to cause harm to computer, server, client or CN.

↳ It can disrupt operations, steal sensitive data

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- **botnet:** is a network of computers or other internet-connected devices that have been infected by malware and are remotely controlled by a malicious actor know as "bot herder". The compromised devices "bots" can be used to perform malocious activities.

→ The malware is self replicating [once it infects one host, from that it seeks entry into other hosts].

- **Denial-Of-Service (DoS) Attack:**

"This attack aims to make a computer, network, or service unavailable to its intended users by overwhelming it with a flood of illegitimate requests."

→ This overloads the system's resources, preventing legitimate req from being processed.

Types of DOS Attacks:

① **Vulnerability Attak:**

→ This involves sending a few well-crafted messages to a vulnerable applications or OS running on a targeted host. If the right seq of ~~target~~ packet is sent to a vulnerable application or OS, they service may stop / crash.

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(2) Bandwidth flooding: Flood of data packets

→ The attacker sends a deluge of packets to the targeted-host so many packets that the target's access link becms clogged (blocked), preventing legitimate packets from reaching the server.

(3) Connection Flooding:

→ The attacker establishes a large no. of half-ope or fully open TCP connections at the target host. The host stops accepting legitim connections.

- Distributed DOS (DDOS):

→ Enhanced version of DOS, where attack is conducted using multiple compromised devices distributed across various locations.

→ The botnet generates a high volume of traffic congesting the target's network.

- Packet Sniffing:

→ A packet sniffer is a tool used to capture, analyze and monitor network traffic.

→ It can intercept & log packets that pass through a network, providing valuable info

Date _____ Day _____

about data being transmitted
Example: WireShark

- IP Spoofing:
→ It is a technique used by a hacker to gain unauthorized access to computers, by sending
→ messages with fake IP Address.
↳ To solve this, we will need end-point authentication that is, mechanism that will allow us to determine with certainity if a message originates from where we think it does.

▷ ISO / OSI Reference Model

Presentation: Allow Applications to interpret meaning of data eg: encryption, compression

Session: Sychronization, checkpointing recovery of data exchange.

Internet Stack missing these layers!