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Computer Networks

→ Elements.. → Devices.
→ Hosts.
→ Cables.

→ Protocols. → HTTP.
→ SMTP.
→ VoIP.

→ IEEE documents all the protocols along with RFC.

→ Edge Network. / End System. (Hosts.)
- LAN.
- WLAN.
- Home Network.
- Bluetooth.

→ Core Network is the link. / links.

→ Core Network.
- Switches.
- Routers.
- Hubs.

→ **Packet Switches:-** Forward packets (chunks of data).

→ **Protocols:** Set of instructions, format.

→ **Network Edge:**

→ hosts: clients & servers.
→ servers often in data centers.

→ **Network core:**

→ interconnected routers.
→ network of networks.

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* link Transmission rate = link capacity = link bandwidth.

Q. → Residential Access Networks (Fiber, DSL, Cable).
→ Mobile Access Networks. (WiFi, 4G, 5G).

→ DSL : Digital Subscriber Lines.

→ Wireless access Networks.
  ↳ Wide-Area Access (5G, 4G, Mobile).
  ↳ Wireless Networks (WiFi).

→ Wired access Network.
  ↳ Cable-Based Network.
  ↳ DSL.
  ↳ ADSL.

→ Host : sends packets of data.
→ Packets of length L bits transmitted into access network at transmission rate R.

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

→ Bit.
→ Physical Link.
→ Guided Media. (Wired).
→ Unguided Media. (Wireless).

→ Forwarding → "switching".
  ↳ local.
  ↳ global.

Finally BingO!

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→ Router has a maintained table of the devices.
→ Router forwards the packet from the correct port after looking through its local forwarding table.

→ Local action works on Forwarding tables.
→ Global action works on Routing Algorithms.

Packet Switching

* Store & forward:- Entire packet must arrive at the router before it can be transmitted on next link

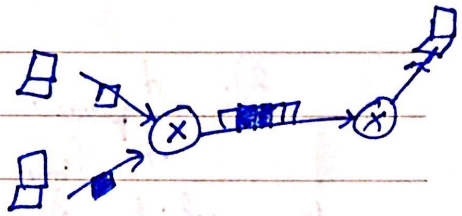
* One-hop numerical example:

→ L = 10 Kbits.
→ R = 100 Mbps.

⇒ One-hop transmission delay = $\frac{L}{R} = \frac{10}{100} = 0.1$ msec

Packet Switching

* Queuing:- Packets get queued on the router if the host to router bandwidth is greater than the bandwidth from router to destination host.



→ Packets can also be dropped (lost) if memory (buffer) in router fills up.
→ Causes Packet losses.

* Circuit-Switching:- Same as old telephone lines which were dedicated to a certain someone upon calling.

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→ FDM & TDM.

FDM → Frequency Division Multiplexing

TDM → Time Division Multiplexing.

→ Peering Link: B/w Two ISPs.

→ Exchange Point (IXP): Connects a bunch of ISPs together.

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*. Queue Delay:- Time of a packet to stay on the router before getting forwarded.

*. Packet Delays:-

Four types of delays present:

1). d_{proc} : Nodal Processing: (delay in forwarding table. lookup)
→ time taken for checking bit errors, determining output link etc.

2). d_{queue} : queuing delay:
→ Time from waiting in queue to the time at which the packet gets deployed on the transmission link.

3). d_{trans} : transmission delay:
→ Time taken by the packet to completely get on the transmission line. i.e $\frac{L}{R}$.

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4) d_{prop} : propagation delay.

→ d: length of physical link.
s: propagation speed (~ 2×10^8 m/sec).

$d_{prop} = d/s$.

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

→ Queuing Delay:

a: average packet arrival rate
L: packet length (bits).
R: link bandwidth.

$\frac{L \cdot a}{R}$: "traffic intensity" = arrival rate of bits / service rate of bits.

→ $\frac{L \cdot a}{R} \sim 0$: avg. queuing delay small.

$\Rightarrow 1$

→ $\frac{L \cdot a}{R} > 1$: avg. queuing delay large.

* Packet loss:-

→ Packet dropped due to low capacity of buffer.
→ Packets may be retransmitted back to the link or may be completely dropped.

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*. **Throughput :-**

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

- instantaneous : rate at a point.
- average : rate over longer period of time.

Q. F = 32 Mbs. (Million bits).
R_s = 2 Mbps.
R_c = 1 Mbps.

$R_c < R_s$ so, R_c cool. ← min. throughput.

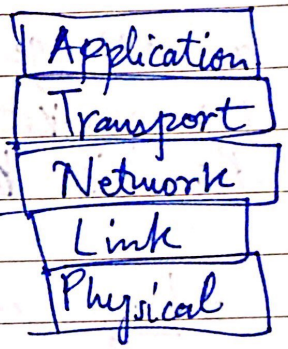
*. **Layered Internet Protocol Stack :-**

Raw message
- application : HTTP, SMTP.

Segment
- transport : TCP, UDP.

Datagram
- network : routing of datagrams from source to destination. (IP, routing protocols).

Frame
- link : data transfer between neighbouring network elements. (Ethernet, 802.11).



From book. R18 Pg 47

Packet of length = 1000 bytes.
Distance = d = 2,500 km.
Prop. Speed : $s = 2.5 \times 10^8$ m/s.
Transmission Rate = 2 Mbps.

Required :-

d_{prop} = ?

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Solution:-

(a). $D_{prop} = \frac{d}{s} = \frac{2500 \times 1000}{2.5 \times 10^8} = 0.01 sec.$

(b). $D_{prop} = \frac{d}{s}$.

R1a

Given Factors:

(a). $R_1 = 500$ kbps.
$R_2 = 2$ Mbps.
$R_3 = 1$ Mbps.

(b) $L = 4$ million bytes.
$= 4 \times 10^6 \times 8$.
$= 32 \times 10^6$ bits.

Required:-

(a). Throughput = ?

Solution-

(a). Throughput = min (R_1, R_2, R_3).
= min (500 kbps, 2 Mbps, 1 Mbps).
Throughput = 500 kbps. (R_1).

(b). $\frac{L}{R} = \frac{32 \times 10^6}{500 \times 10^3} = 64$ secs.

$\frac{L}{R}$ ← Throughput

(c). $\frac{L}{R} = \frac{32 \times 10^6}{1 \times 10^5} = 320$ secs

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Q5 Data:-

(a). Propagation Speed = S = 100 Km/hr.
Distance = d = 175 Km.
Service Time = 12 secs.

Required:-

End-to-end delay = ?

Solution:-

(Transmission Delay) Total Service Time = 12 x 10 = 120 sec. for one booth. till
= 120 x 3 = 360 sec.

∴ Propagation Delay = $\frac{d}{S}$

$= \frac{175}{360} = 0.48 \times 60 = 29.1$ mins.

Chap#2 Application Layer

→ First step is to create a network app.
→ The application layer is software-based.
→ There are 2 types of architectures:

→ Client-Server:-
Server has a permanent IP address, but a client has dynamic IPs.

→ Peer-to-Peer:-
Peers request service from other peers, provide service in return to other peers.

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* tcp compromises security as the ports remain open and are vulnerable when awaiting data

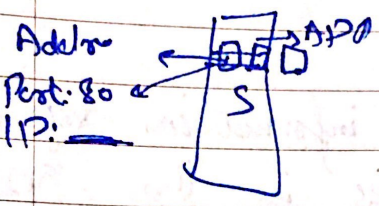
IP: Port

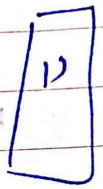
* Process:- Program running within a host.

* Sockets:-

Process sends / receives messages to/from its socket.

→ to receive messages, process must have identifier.





→ client process: initiates communication.

→ server process: process that waits to be contacted.

→ Open Protocols:-

defined in RFCs, everyone has access to protocol definition.

* Data Integrity (100% reliable data transfer)
* Timing (Low Delays).
* Throughput (effective Throughput).
* Security (Encryption, data integrity).

* Web & HTTP:-

→ HTTP uses TCP.
→ HTTP is "stateless". (Cookies do that!)
→ Persistent & Non-Persistent HTTP.

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→ RTT (Round-Trip Time).

→ Non-Persistant HTTP: Multiple time connection open & close for multiple files. 2RTT + file download time

HTTP(1.1) → Persistant HTTP: One time connection opens & stays open. TLS provides the necessary security for open connection.

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*. Cookies :-

Server stores client information by client id sent through the cookies in the response header.

→ Used for keeping session active.

---

*. Web Caches :-

Goal: Satisfy client requests without involving origin server.

*. Conditional GET :-

Goal: Don't send object if cache has up-to-date cached data.

→ Head-of-Line Blocking (HOL).

→ SMTP & HTTP for Email.

---

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Data:- Access link rate = R = 154 Mbps.
RTT = 2 sec. (Internet delay).
L = 100 K bits.
a = 15 sec.

Required:-

(1) Access Link Utilization = ?
(2) LAN Link Utilization = ?
(3) End-End Delay = ?

Solution:-

(1) $A.U = \frac{a.L}{R} = \frac{15 \times 10^5}{154 \times 10^6}$.

Access Link Utilization = 0.0097.

(2) $LAN\ L.U = \frac{a.L}{R} = \frac{15 \times 10^5}{1 \times 10^9}$.

(R ← Mbps)

$= 0.0015$.

(3) End-End Delay = Internet Delay + Access Link Delay + LAN Delay.

$= 2 + \frac{L}{R}$ | $= 2 + 0.00064$.

$= 2 + \frac{1 \times 10^5}{154 \times 10^6}$ | $= 2.00064$ sec.

Finally BingO!

day/date

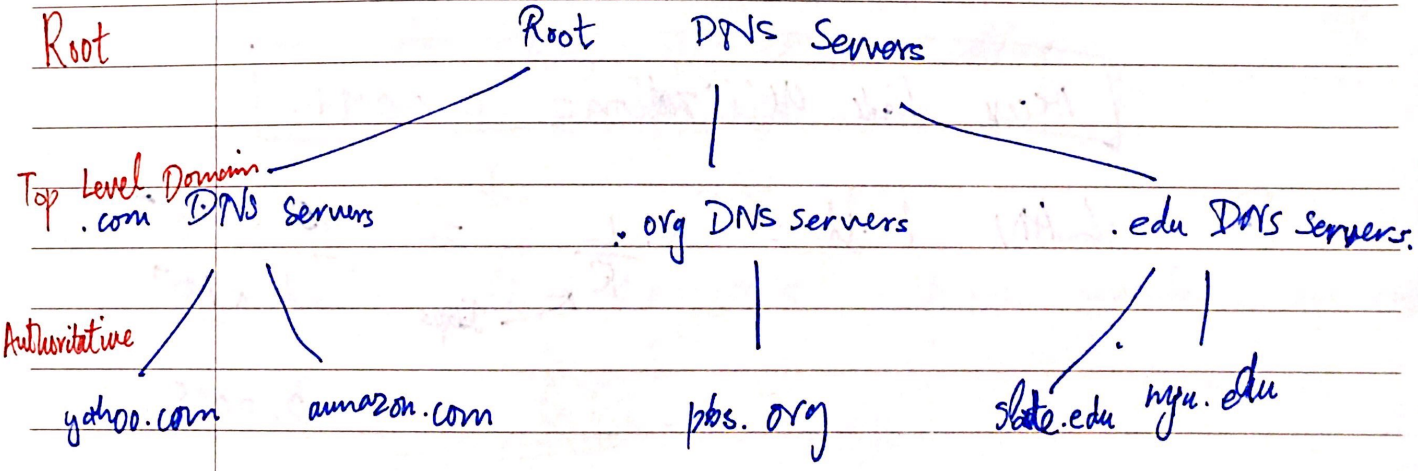
→ 40% cache hit.
→ 60% cache miss.

New traffic intensity = I = (0.0097) × 0.6.
= 0.00582.

End-End Delay = (Internet Delay) × 0.6 + (Access delay) × 0.4

✱. Domain Name System (DNS):-

→ Works on application layer.
→ Resolved by edge systems (host networks).
→ hostname - to - IP - address translation.



→ ICANN (Internet Corporation for Assigned Names and Numbers) manages root DNS domain.

→ Two methods to resolve DNS:-

→ Iterated Query.
→ Recursive Query.

AI Quiz: Pak Map. Karachi → Gilgit using shortest path. BFS/DFS

day/date

→ Caching DNS Information.

→ DNS Records:-

RR format: (name, value, type, ttl).

type: A
- name is hostname.
- value is IP Address.

type: NS
- name is domain
- value is hostname of authoritative name server for domain

type: CNAME
- aliasing.
- name is alias name
- value is reale name

type: MX
- value is the name of SMTP mail servers associated with name.

→ DNS protocol messages.

---

*. Server:-

→ Time to send one copy: F/μ_s.
→ Time to send N copies: NF/μ_s.

*. Client:-

→ d_{min} = min client download rate.
→ min. client download time: F/d_{min}.

time to distribute F to N clients using P2P approach

$$D_{P2P} > \max\{F/\mu_s, F/d_{min}, NF/(\mu_s + \Sigma u_i)\}$$

day/date Dynamic, Adaptive Streaming over HTTP P22 : H.W.

* Bit Torrent:-

→ Tracker: tracks peers participating in torrent. (server)

→ Torrent: group of peers exchanging chunks of a file.

* Video Coding:

→ Spatial.
→ Temporal.

→ CBR.
→ VBR.

→ Content Distribution Networks (CDNs).