CN ASSIGNMENT#01

NABIRA KHAN 23K-0914

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NOTE: SUBMISSION VIA IPAD ALLOWED, CONFIRMED WITH SIR FARRUKH SALIM

QUESTION #01 a) pg 41 - section 1.4.3, b) pg 39 - section 1.4.2

packet of length L
link 1 transmission rate R1 , propagation delay D1
link 2 transmission rate R2 , propagation delay D2
negligible processing delay.

a) $d_{end-end} = \frac{L}{R1} + D1 + \frac{L}{R2} + D2 + D_{queue} + D_{proc} = \frac{L1}{R1} + D1 + \frac{L2}{R2} + D2$ (assuming negligible Dqueue & Dproc)

$\frac{L}{R1}$ ⟶ transmission delay on first link (time to push packets on to link)
D1 ⟶ propagation delay on first link (time for signal to travel physical link from one node to next)
$\frac{L}{R2}$ ⟶ transmission delay on second link (time to push packets on to link)
D2 ⟶ propagation delay on second link (time for signal to travel physical link from one node to next)
Dqueue ⟶ queueing delay encountered at router (time packets wait in buffer for transmission, depends on router congestion)
D proc ⟶ processing delay in router (time to examine packet header) ⟶ negligible (0)

first you pay time to transmit bits to the first link, then they propagate to the router, the router, after queuing / processing, transmits onto link 2 paying L/R2, then the bits propagate to destination.

b) • if R2 << R1, L/R2 >> L/R1, so the second links transmission delay dominates the end-to-end delay.
• packets will arrive at the router faster than the router can forward them causing queueing at router. Dqueue ↑ further increasing total delay
• link 2 becomes a bottleneck and controls throughput, dominates latency, link 1's contribution becomes negligible

QUESTION #02 a) pg 14,15 - section 1.2.1, b) pg 15 - section 1.2.1

a) DSL (Digital Subscriber Line)
• runs over existing telephone lines (twisted pair, copper)
• each home has a dedicated line to the DSLAM at ISP's central office
• the line to each home is point-to-point, so max rate applies to physical pair
• frequency division multiplexing separates data & voice
• advantage ⟶ no sharing with neighbours, 100 Mbps is per subscriber over their dedicated copper pair (limited by distance & noise)

HFC (Hybrid Fiber-Coaxial)
• ISP uses fiber backbone up to neighbourhood, then coaxial cable shared among multiple homes
• frequency bands separated (TV, internet)
• shared medium, users compete for bandwidth, 100 Mbps is the peak rate available over the shared access medium.

b) On HFC, the shared coax segment near node has many active users at peak times, bandwidth is split among active users, contention & queuing increases so individuals experience slowdowns.
• On DSL, each individual has dedicated last-mile copper pair, so neighbours activity does not directly influence your own, thus customer avoids shared-node contention.

QUESTION #03 a) pg 52 ⟶ fig 1.24, b) pg 47 - section 1.5, c) slides

a) APPLICATION LAYER (HTTP header)
Key Info: request line & headers, URLs (e.g ⟶ GET /path HTTP/1.1)
Role: identifies resource requested, carries application semantics (which page, cookies for session state, user agent), controls how server should respond.
TRANSPORT LAYER (TCP header)
Key Info: source port & destination port (and sequence number)
Role: ensures reliable, ordered delivery via sequence nums to correct process by multiplexing to right application process on endpoints (ports)
NETWORK LAYER (IP header)
Key Info: source & destination IP addresses, time-to-live (TTL)
Role: end-to-end addressing and routing across networks, routers use destination IP to forward packet, TTL prevents loops
LINK LAYER (ethernet frame header)
Key Info: source & destination MAC address
Role: node-to-node delivery over physical link, error detection, hardware addressing for next hop.

b) examines Network (IP) header, checks destination IP + TTL, decrements TTL, looks up next hop in routing table, may check IP header checksum.
• ignores Transport (TCP) and Application (HTTP) headers: irrelevant for routing.
• uses Link header only on arrival / departure (to check frame destination, error bits)

c) Advantage: efficient pipelining of multiple packets, congestion control can adapt + error recovery as only lost / error segment retransmitted
Disadvantage: increased per-packet overhead as segmentation multiplies headers which can increase queueing delay and processing delay across routers causing higher router load.

QUESTION #04 a) pg 27 - section 1.3.2, b) pg 23,28 - section 1.3.1

a) link capacity = 1 Gbps
each active user = 100 Mbps
max users = $\frac{1 \times 10^9}{100 \times 10^6}$ = 10 users

b) users transmit in bursts, not all active simultaneously
• statistical multiplexing: resources are shared only when needed
• this allows > 10 users without guaranteed failure, since inactive users free bandwidth for others

QUESTION #05 a) pg 48, section 1.4.1, b) pg 57 - section (1.6), c) slides

a) car ⟶ packet
driver ⟶ host sending packet
intersections ⟶ routers / switches
roads ⟶ link between nodes
final destination ⟶ destination host IP

analogy ⟶ driver reads address, follows signs at intersections; routers read destination IP and consult routing tables to forward the packet toward destination final destination ⟶ destination host IP

analogy ⟶ driver reads address, follows signs at intersections; routers read destination IP and consult routing tables to forward the packet toward destination

b) • maps to network/routing layer (layer 3) when the fake sign causes misrouting of vehicles through wrong intersections
• corresponds to network layer attack (IP spoofing / routing manipulation/poisoning)

c) integrity ⟶ routing info altered

QUESTION #06 a) pg 48 - section 1.4.1, b) pg 38, para 1-3

P5 propagation speed = 100 km/hour

a) length = 175 km
tollbooth service time = 12 secs / car
caravan passes 3 tollbooths in total
caravan = 10 cars

$t_{prop} = \frac{dist}{speed} = \frac{175 km}{100 km/hr} = 1.75 km/h$

$1.75 \times 60 = 105$ minutes

service per car = $\frac{12 \ secs}{60} = 0.2$ mins per car

for 10 cars ⟶ $t_{per \ toll} = 10 \times 0.2 = 2$ mins

for 3 tollbooths ⟶ $t_{tolls} = 3 \times 2 = 6$ mins

$d_{end-end} = t_{prop} + t_{tolls} = 105 + 6 = 111$ mins

1 hr 51 mins

b) caravan = 10 cars
$t_{prop} = 105$ mins
service per car = 0.2 mins
for 8 cars ⟶ $t_{per \ toll} = 8 \times 0.2 = 1.6$ mins
for 3 tolls ⟶ $t_{toll} = 3 \times 1.6 = 4.8$ mins
$d_{end-end} = 105 + 4.8 = 109.8$ mins

1 hr 49 mins 8 s

P6 hosts A & B pg 46 onwards for all parts, 1.4 section
link Rate = R
distance = m meters
propagation speed = s m/s
packet size = L

a) $d_{prop} = \frac{m}{s}$

b) $d_{trans} = \frac{L}{R}$

c) $d_{end-end} = \frac{L}{R} + \frac{m}{s}$

d) at d_{trans}, the sender just finishes transmitting the last bit onto the link, so the last bit is just leaving A and has not yet propagated far down the link

e) if $d_{prop} > d_{trans}$, propagation is slower than transmission, at d_{trans}, first bit is still in transit located a distance $s \cdot d_{trans}$ from A (not yet reached B)

f) if $d_{prop} < d_{trans}$, propagation is faster than transmission, at d_{trans}, the first bit has already reached / arrived at B before the entire packet finished transmitting.

g) $s = 2.5 \times 10^8$
L = 1500 bytes
R = 10 Mbps
$d_{prop} = d_{trans}$
$\frac{d}{s} = \frac{L}{R}$

$\frac{m}{2.5 \times 10^8} = \frac{1500 \times 8}{10 \times 10^6}$
$m = (2.5 \times 10^8) \times 0.0012$
m = 300 000 m
m = 300 km

P18 slides
NOTE: using the last hop RTT because they measure the true end-to-end delay to destination host, which is what we want

domain ⟶ google.com

TIME	DESTINATION RTTS (LAST)		
7:30 PM	104 ms	99 ms	99 ms
10:30 PM	104 ms	50 ms	50 ms
11:30 PM	42 ms	48 ms	51 ms

domain ⟶ stylo.plc

TIME	DESTINATION RTTS (LAST)		
7:30 PM	139 ms	144 ms	111 ms

domain → stylo.pk

TIME	DESTINATION RTTS (LAST)		
7:30 PM	139 ms	144 ms	111 ms
10:30 PM	117 ms	136 ms	101 ms
11:30 PM	114 ms	99 ms	101 ms

FOR STYLO

a) means at each of the 3 hours → $\frac{139+144+111}{3}$, $\frac{117+136+101}{3}$, $\frac{114+99+101}{3}$

= 131.33 ms, 118 ms, 104.67 ms

standard deviations at each of the 3 hours → $\sqrt{\frac{(7.667)^2+(12.667)^2+(-20.33)^2}{3}}$, $\sqrt{\frac{(-1)^2+(18)^2+(-17)^2}{3}}$, $\sqrt{\frac{(9.33)^2+(-5.667)^2+(-3.667)^2}{3}}$

= 14.52 ms, 14.31 ms, 6.65 ms

b)

HOUR	HOPS
7:30	8
10:30	8
11:30	8

→ the paths never changed between the times

c) No. of ISP networks = 3

yes, the largest delays occurred at peering interfaces between adjacent ISPs.

FOR GOOGLE

a) means at each of the 3 hours → $\frac{104+99+99}{3}$, $\frac{104+50+50}{3}$, $\frac{42+48+51}{3}$

= 100.67 ms, 68 ms, 47 ms

standard deviations at each of the 3 hours → $\sqrt{\frac{(3.333)^2+(-1.667)^2+(-1.667)^2}{3}}$, $\sqrt{\frac{36^2+(-18)^2+(-18)^2}{3}}$, $\sqrt{\frac{(-5)^2+1^2+4^2}{3}}$

= 2.36 ms, 25.46 ms, 3.74 ms

b)

HOUR	NO. ROUTER
7:30	10
10:30	12
11:30	12

yes the path changed between the times (different exit point)

c) No. of ISP networks = 5

yes, the largest delays occurred at peering interfaces between adjacent ISPs.

P24 50 terabytes of data → $(50 \times 10^{12}) \times 8 = 4 \times 10^{14}$ bits   slides

100 Mbps dedicated link → $t = \frac{4 \times 10^{14}}{100 \times 10^6} = 4 \times 10^6$ seconds

convert to days → $\frac{4 \times 10^6}{3600 \times 24} = 46.296$ days

FedEx overnight = 1 day

1 <<< 46.296 days ∴ FedEx faster.

P31 message = 10^6 bits   pg 46 onwards + slides

each link R = 5 Mbps

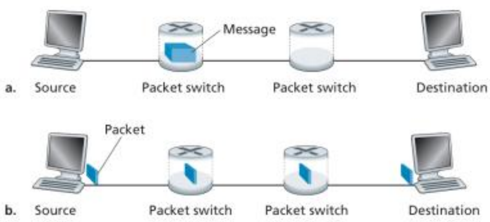

Figure 1.27 ♦ End-to-end message transport: (a) without message segmentation; (b) with message segmentation

a) no message segmentation

3 links

$d_{trans(whole\ msg)} = \frac{L}{R} = \frac{10^6}{5 \times 10^6} = 0.2\,s = 200\,ms$

time to move msg from source to first switch → 200 ms

with store-and-forward: each link must transmit the entire msg before next link starts sending it

3 links, hence → $t_{total} = 3 \times 200\,ms = 600\,ms$

b) message segmented into 100 packets

each packet 10,000 bits long

$t_{packet} = \frac{L}{R} = \frac{10000}{5 \times 10^6} = 0.002\,s = 2\,ms$

time for first packet to reach first switch = 2ms

time when second packet is fully received at first switch

packet 1 from source to switch1 → $t = 0$ to $t = t_{packet}$

packet 2 from source to switch1 → $t = t_{packet}$ to $t = 2t_{packet}$

∴ packet 2 will be received at switch 1 at $t = 2t_{packet} = 2 \times 2ms = 4ms$

c) first packet to traverse 3 links → $3 \times t_{packet} = 3 \times 2ms = 6ms$

once pipeline fills, one packet per t_{packet} → $(100-1) \times t_{packet} = 99 \times 2ms = 198\,ms$

total = 6 + 198 = 204 ms to move entire msg with segmentation

600 ms to move entire msg without segmentation

$\frac{600}{204}$ = 2.941 times faster with segmentation

d) ADDITIONAL REASONS

- error recovery efficiency, retransmit only lost/error-prone packet
- multiplexing, interleaves packets from many flows, better utilization, fairness, and responsiveness for short flows
- small packets can traverse quickly without waiting behind a huge message, lower per-packet latency

e) DRAWBACKS

- multiplexing ; interleaves packets from many flows , better utilization, fairness, and responsiveness for short flows
- small packets can traverse quickly without waiting behind a huge message, lower per-packet latency

e) DRAWBACKS
- increased header overhead as each packet carries its own headers (IP/TCP/UDP) , reduced payload efficiency
- higher processing load , more packets ⟶ more interrupts, processing, routing/forwarding
- more packets ⟶ greater probability of packetloss
- receiver complexity + buffering , must reassemble , handle out-of-order delivery , allocate reassembly buffers , increases memory

BONUS QUESTION slides

10 GB file = 80×10^9 bits
8 hops in path (routers)
packet size = 1500 bytes = 1500 x 8 = 12000 bits
$d_{proc} = 0$
d_{queue} = different for each hop
$d_{prop} = 2 \times 10^8$ m/s

Hop #	From Node	To Node	Link Type	Distance (approx)	Propagation Speed (in medium)	Transmission Rate (Bandwidth)	Typical Queueing Delay (per hop)	TRANSMISSION DELAY $= \frac{L}{R}$	PROPAGATION DELAY $= \frac{d}{s}$
0	Ayesha's PC	Home Router	Ethernet Copper Cable	10 m	2.0 x 10^8 m/s	1 Gbps	0.1 ms	$= \frac{12000}{1\times10^9} = 0.012$ ms	$= \frac{10}{2\times10^8} = 0.1$ms
1	Home Router	Local ISP (KHI)	Fiber Optic (Metro)	5 km	2.0 x 10^8 m/s	1 Gbps	0.5 ms	$= \frac{12000}{1\times10^9} = 0.012$ ms	$= \frac{5\times10^3}{2\times10^8} = 0.025$ ms
2	Local ISP (KHI)	National ISP (KHI)	Fiber Optic (Terrestrial)	800 km	2.0 x 10^8 m/s	100 Gbps	0.2 ms	$= \frac{12000}{100\times10^9} = 0.00012$ ms	$= \frac{800\times10^3}{2\times10^8} = 4$ ms
3	National ISP (KHI)	Landing Station	Fiber Optic (Terrestrial)	200 km	2.0 x 10^8 m/s	100 Gbps	0.2 ms	$= \frac{12000}{100\times10^9} = 0.00012$ ms	$= \frac{200\times10^3}{2\times10^8} = 1$ ms
4	Karachi Landing	Submarine Cable (EMERGENT)	Fiber Optic (Submarine)	6,500 km	2.0 x 10^8 m/s	50 Tbps (per fiber pair)	2 ms (congested)	$= \frac{12000}{50\times10^{12}} = 2.4\times10^{-7}$ ms	$= \frac{6500\times10^3}{2\times10^8} = 32.5$ ms
5	UK Landing	National ISP (LHR)	Fiber Optic (Terrestrial)	150 km	2.0 x 10^8 m/s	100 Gbps	0.3 ms	$= \frac{12000}{100\times10^9} = 0.00012$ ms	$= \frac{150\times10^3}{2\times10^8} = 0.3$ ms
6	National ISP (LHR)	London Data Center	Fiber Optic (Metro)	20 km	2.0 x 10^8 m/s	100 Gbps	0.1 ms	$= \frac{12000}{100\times10^9} = 0.00012$ ms	$= \frac{20\times10^3}{2\times10^8} = 0.1$ ms
7	London DC Router	Server (LHR)	Ethernet Copper Cable	50 m	2.0 x 10^8 m/s	10 Gbps	0.05 ms	$= \frac{12000}{10\times10^9} = 0.0012$ ms	$= \frac{50}{2\times10^8} = 2.5\times10^{-4}$
						SUM	3.45ms	38.37530 ms	0.00025ms

a) $d_{end\text{-}end} = d_{trans} + d_{proc} + d_{queue} + d_{prop}$

$= 0.025680412 + 0 + 3.45 + 38.37530$
$= 41.85 \text{ ms} = 0.04185 \text{ s}$

b) Number of packets ⟶ $N = \frac{80\times10^9}{12000} = 6,666,666.6$
$\approx 6,666,667$ packets

single packet travel time across all nodes : 0.04185s
since its a multilink path , we need to find bottleneck
bottleneck = 1 Gbps (smallest bandwidth)
now we will find $t_{bottleneck}$ (time to transmit one packet across link)
$t_{bottleneck} = \frac{\text{packet size}}{\text{bottleneck rate}} = \frac{12000}{1\times10^9} = 1.2\times10^{-5}$ s

NOTE ⟶ first packet : no bottleneck
rest : bottleneck because of pipeline

$\therefore T_{total}$ for 10GB file $= 0.04185 + (6,666,667 - 1) \times 1.2\times10^{-5}$
$= 80.42$ s