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Q 2) Size of message = 100 Kb
Meta-data per packet = 100 bytes / Packet

⇒ processing and propagation delays = 0

a) 1 Packet

⇒ Packet size = $10^5 + 10^2$ bytes
$P = (10^5 + 10^2) \times 8$ bits

⇒ T for a link = $\frac{\text{Size}}{\text{Bandwidth}}$

⇒ Total-time = $t_1 + t_2 + t_3$ (link1, link2, link3)

$= \frac{P}{400 \times 10^6} + \frac{P}{100 \times 10^6} + \frac{P}{200 \times 10^6}$

$= \frac{P}{10^6 \times 10^2}\left(\frac{1}{4} + 1 + \frac{1}{2}\right)$

$= \frac{7}{4} \times \frac{(10^5 + 10^2) \times 8}{10^6 \times 10^2}$

$= \frac{14 \times 10^2 (1001)}{10^6 \times 10^2}$

$$= \frac{14014}{10^6}$$

$$= 0.014014 \text{ s}$$

$$= 14.01 \text{ ms}$$

b) 10 packets :

⇒ For multiple packets we can say that, they travel one by one, i.e., 1 packet per link at a time.

⇒ Packet size $= 100 + \frac{10^5}{10} = (10^2 + 10^4) \times 8$ bits

⇒ $P = 80800$ bits

Transmission delay for $L_1 = \frac{P}{400 \times 10^6} = \frac{80800}{400 \times 10^6}$ (202)

$$= 202 \text{ μs}$$

Transmission delay for $L_2 = \frac{P}{100 \times 10^6} = \frac{80800}{10^8}$

$$= 808 \text{ μs}$$

Transmission delay for $L_3 = \frac{P}{200 \times 10^6} = \frac{404}{200 \times 10^6}$

$= 404 \mu s$

⇒ For transmission :

→ Link 1 will take 202 μs
→ link 2 will take 808 μs
→ link 3 will take 404 μs

⇒ we can say that t_2 is taking more time and if some packet is there on t_2 then other should wait on t_1 and the packet who completes t_2 doesn't have to wait for packet taking t_3 time because $t_3 < t_2$. Hence we can say that for transferring 1st packet it will take $t_1 + t_2 + t_3$ time and rest of the time will be (total packet-1) $\times (t_2)$.

So, For 10 packets,

Total time $= 202 + 404 + (10)(808)$

$= 8686 \mu s$

c) For 50 packets,

⇒ Packet size $= 100 + \frac{100 \times 10^3}{50} = 2100 \times 8$ bits

Delays : $L_1 = 42$ us

$L_2 = 168$ us

$L_3 = 84$ us

Total time $= t_1 + t_3 + (\text{total-packets}) \times t_2$

$= 42 + 84 + 50 \times 168$

$= 8526$ us

d) for 100 packets.

Packet size $= 100 + \frac{100 \times 10^3}{100} = 1100 \times 8$ bits

Delays : $L_1 = 22$ us

$L_2 = 88$ us

$L_3 = 44$ us

Time $= 22 + 44 + 100 \times 88 = 8866$ us

⇒ Hence, 50 packets will take least time.

Q3) length = 10 kms

bandwidth = 100 Gb/s

speed = $\frac{2}{3} \times 3 \times 10^8$ m/s

a) propagation delay :

Time taken by first packet to reach the end

$$= \frac{10 \times 10^3 \text{ m}}{\frac{2}{3} \times 3 \times 10^8 \text{ m/s}}$$

$$= 50 \text{ us}$$

b) Max. no. of bits R_1 can send

= Bandwidth × Propagation delay

$= 100 \times 10^9 \times 50 \times 10^{-6}$

$= 5 \times 10^6$ bits

c) Bit width of the data = $\frac{\text{distance}}{\text{no. of bits in that distance}}$

$= 10 \times 1000$ m

$$\frac{}{5 \times 10^6}$$

$$= 2 \text{ mm/bit}$$

Q4) RTT = 10 ms

Size of web page = 1 KB

a) HTTP 1.0 (non-persistent)

HTTP response time:

$$\sum_{i=1}^{n} (RTT_{\text{initial connection}} + RTT_{\text{requests}} + \text{transmission time})_{\text{objects}}$$

=) Let 't' be transmission time for objects 1 KB

a) Total-time = 2 RTT $\times n$ + Total trans. time

= 2 x 11 x RTT + (1 KB + 10 x 100 KB) x t

(Package + 10 objects)

= 2 x 11 x 10 ms + 1001 t

= 220 ms + 1001 t

b) HTTP 1.1 (persistent)

Total time = RTT + $\sum^{n}$ (RTT + life transmiss)

connec. $i=1$ (req + file trans.) objects

$= (1+11)\ RTT + \text{total trans. time}$

$= 12\ RTT + 100\ t$

$= 120\ ms + 100\ t$

c) HTTP 2.0 (persistent + Pipelined)

data frames of 1 KB

total time $= RTT + \underset{\text{webpage}}{RTT} + \underset{\text{object}}{RTT} + \text{file trans.}$

$= (1+1+1)\ RTT + 100\ t$

$= 30\ ms + 100\ t$