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R-18 Given that :

Packet length; $L = 1000$ bytes
$= 1000 \times 8$ bits
$= 8000$ bits

Distance, $d = 2500$ km $= 2500 \times 10^3$ m

Propagation speed, $S = 2.5 \times 10^8$ m/s

Transmission Rate, $R = 2$ Mbps $= 2 \times 10^6$ bps

Propagation delay, $= \frac{d}{s} = \frac{2500 \times 10^3}{2.5 \times 10^8} = 0.01$ S
$= \cancel{100ms}$ 10 ms.

Transmission " $= \frac{L}{R} = \frac{8000}{2 \times 10^6} = 0.004$ S
$= 4$ ms

Total delay $= (10+4)$ ms $= 14$ ms.

Propagation delay does not depend on packet length but transmission delay does.

Transmission rate depends on transmission delay, not on propagation delay.

R-19 (a) Given,

$R_1 = 500$ kbps

$R_2 = 2$ Mbps

$R_3 = 1$ Mbps $= 1000$ kbps

The bottleneck is the link with lowest rate.

So, the throughput is 500 kbps.

(b) Given,

File size $= 4$ million bytes

$= 4 \times 10^6 \times 8$ bits.

$= 32 \times 10^6$ bits

here, throughput $= 500$ kbps $= 500 \times 10^3$ bps

$\therefore$ Transferring time $= \dfrac{\text{File size}}{\text{throughput}}$

$= \dfrac{32 \times 10^6}{500 \times 10^3}$

$= 64$ sec. (Ans)

(c) R_2 is reduced to 100 kbps.

$\therefore$ throughput $= 100$ kbps. $= 100 \times 10^3$ bps.

now, time to transfer $= \dfrac{\text{File size}}{\text{throughput}}$

$= \dfrac{32 \times 10^6}{100 \times 10^3}$

$= 320\ s.$

$\therefore$ With the reduced throughput, it will take 320secs to transfer the file.

P5 (a) Given.

Propagation Speed, $S = 100\ km/h$

Difference, $d = 175\ km$

The caravan is of 10 cars and is passing through 2 toll booths before finishing just after the 3rd toll booth.

Now,

Propagation delay, $= \frac{d}{S} = \frac{175}{\frac{100}{60}} = 105$ mins.

Car no $= 10$; each car needs 12 sec to pass.

Transmission delay on 1st to 3rd toll booth

$= 10 \times 12 \times 2 = 4$ mins.

End-to-End delay $= (105 + 4)$ mins

$= 109$ mins.

(b) Transmission delay for 8 cars: $8 \times 12 \times 2 = 3.2$ mins

$\therefore$ End-to-End delay $= (105 + 3.2)$ mins

$= 108.2$ mins. (Ans).

P-6 (a) The propagation delay is the time it takes for a bit to travel from host A to host B across the link. It depends on the distance between two hosts & propagation speed of the signal

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

m = ~~difference~~ distance between 2 hosts.

s = propagation speed.

(b) The transmission delay is the time it takes to push a bit of the packet onto the link. It depends on packet size(L) & transmission rate (R).

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

(c) The total End-to-End delay is the sum of the transmission delay & the propagation delay.

End-to-End delay $= d_{trans} + d_{prop}$

(d) At time $t = d_{trans}$, the last bit of the packet has just been fully transmitted onto the link by host A. this means the last bit has just left host A & is starting to propagate along the link but it has not reached host B yet.

(e) If d_{prop} is greater than d_{trans}, the propagation time is longer than the time it takes to transmit the packet. At time $t = d_{trans}$ the first bit of the packet is still in transit but has not yet reached host B. It is somewhere on the link between host A & B.

(f) If $d_{prop} < d_{trans}$:

the propagation time is shorter than the time it takes to transmit the package. At time $t = d_{trans}$, the first bit of the packet has already reached host B, while the rest of the packet is still being transmitted by Host A.

(8) Given,

$s = 2.5 \times 10^8$ m/s

$L = 1500$ bytes $= 1500 \times 8$ bits

$R = 10$ Mbps $= 10 \times 10^6$ bps

Now,

$$d_{prop} = d_{trans}$$

$$\frac{m}{s} = \frac{L}{R}$$

$$\Rightarrow \frac{m}{2.5 \times 10^8} = \frac{1500 \times 8}{10 \times 10^6}$$

$$\Rightarrow m = 300 \text{ km} \quad \text{(Ans)}.$$

P-7 Given,

bit rate, $R = 64$ kbps

$= 64 \times 10^3$ bits

$S = 56 \times 8 = 448$ bits

$R = 10$ Mbps $= 10 \times 10^6$ ~~k~~bps

Propagation delay $= 10$ ms.

$$d_{packetization} = \frac{\text{Packet size}}{\text{Bit rate}} = \frac{448}{64 \times 10^3} = 7 \text{ ms}.$$

$$d_{trans} = \frac{L}{R} = \frac{448}{10 \times 10^6} = 0.0448 \text{ ms}.$$

$\therefore$ Total delay $= (7 + 0.0448 + 10)$ ms

$= 17.0448$ ms (Ans).

P-8 (a) Given,

Total Bandwidth $= 10$ mbps
$= 10 \times 10^3$ kbps

Bandwidth per user $= 200$ kbps

$\therefore$ No. of user $= \frac{10 \times 10^3}{200} = 50$ users.

(b) In packet switching, a user transmits only 10% of the time.

So, the probability : $P_{trans} = 0.10$. (Ans).

(c) Given, $P_{trans} = 0.10$

total user, $N = 120$.

$\therefore$ Probability that exactly n users are transmitting

is $P = \binom{120}{n}(0.10)^n (0.90)^{120-n}$ [using binomial distribution].

(Ans)

(d) Probability of 51 or more user:

$$P = \sum_{n=51}^{120} \cancel{P(51)} (0.10)^{51} (0.90)^{120-51}$$

$$= \frac{120!}{51!\,(120-51)!} \times (0.10)^{51} \times (0.90)^{69}$$

$$= 1.75 \times 10^{-20}$$ (Ans)

P-10 Given,

Packet size, $L = 1500$ bytes $= 1500 \times 8$ bits.

Propagation speed $s_1 = s_2 = s_3 = 2.5 \times 10^8$ m/s

Transmission rate $R_1 = R_2 = R_3 = 2.5$ Mbps $= 2.5 \times 10^6$ bps

Processing delay, $d_{proc} = 3 \times 10^{-3}$ s. $= 3$ ms

Lengths, $d_1 = 5000$ km $= 5000 \times 10^3$ m

$d_2 = 4000$ km $= 4000 \times 10^3$ m

$d_3 = 1000$ km $= 1000 \times 10^3$ m.

For link 1:

$$d_{trans1} = \frac{1500 \times 8}{2.5 \times 10^6} = 4.8 \text{ ms.}$$

$$d_{prop_1} = \frac{5000 \times 10^3}{2.5 \times 10^8} = 20 \text{ ms.}$$

$$d_{trans1} = d_{trans2} = d_{trans3} = 4.8 \text{ ms}$$

For link 2:

$$d_{prop2} = \frac{4000 \times 10^3}{2.5 \times 10^8} = 16 \text{ ms}$$

For link 3:

$$d_{prop3} = \frac{1000 \times 10^3}{2.5 \times 10^8} = 4 \text{ms}$$

$\therefore$ Total delay $= [(4.8 \times 3) + (2 \times 3) + (20 + 16 + 4)]$ ms

$= (14.4 + 6 + 40)$ ms

$= 60.4$ ms (Ans).

P-14 (a)

Total delay = Queueing delay + Transmission delay

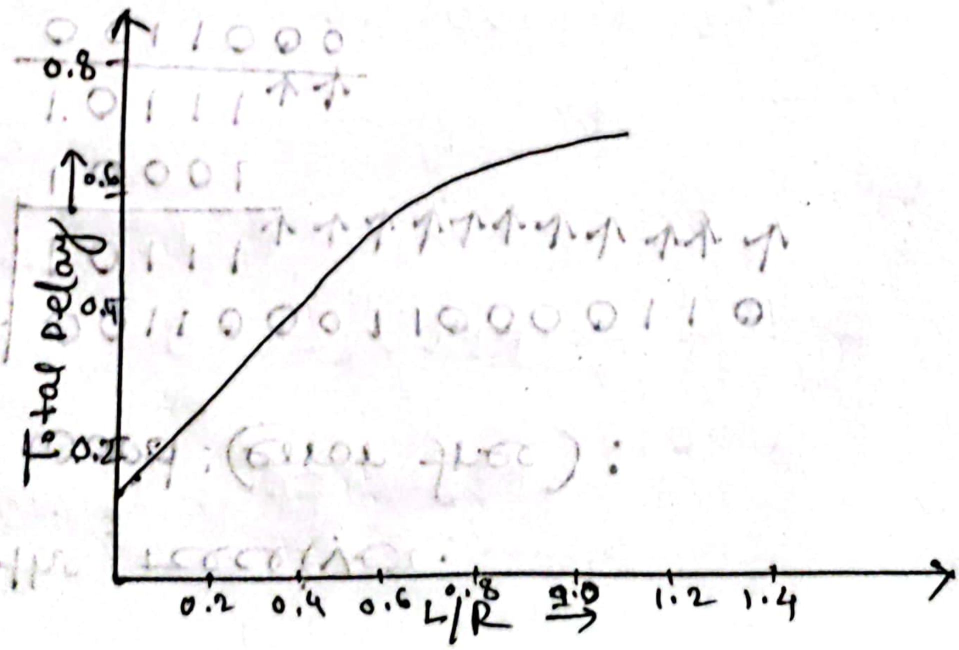
$$= \frac{I \cdot L}{R(1-I)} + \frac{L}{R}$$

$$= \frac{\cancel{I \cdot L} + L - \cancel{IL}}{R(1-I)}$$

$$= \frac{L}{R(1-I)} \quad \text{(Ans)}.$$

(b) Plot of delay as a function of L/R.

Here, total delay $= \dfrac{L}{R(1-I)} = \dfrac{L}{R} \times \dfrac{1}{(1-I)}$.



P-15

We know,

Transmission delay, $d_{trans} = \frac{L}{R}$

Let's assume, all packets have the same size.

& transmission rate is denoted by μ.

$$\therefore d_{trans} = \frac{1}{\mu}$$

Similarly, Queueing delay, $d_{queue} = \frac{\rho}{\mu(1-\mu)}$

$$\therefore \text{Total delay} = \frac{1}{\mu} + \frac{\rho}{\mu(1-\rho)} \qquad \Bigg| \; \rho = \frac{a}{\mu}$$

$$= \frac{1}{\mu} + \frac{\frac{a}{\mu}}{\mu\left(1-\frac{a}{\mu}\right)}$$

$$= \frac{1}{\mu} + \frac{\frac{a}{\mu}}{\cancel{\mu}\left(\frac{\mu-a}{\cancel{\mu}}\right)}$$

$$= \frac{1}{\mu} + \frac{a}{\mu(\mu-a)}$$

$$= \frac{\cancel{\mu} - \cancel{a} + \cancel{a}}{\cancel{\mu}(\mu-a)}$$

$$= \frac{1}{\mu-a} \quad \text{(Ans)}$$

P-16 Given,

The avg. no. of packets, $N = 100$

" " queuing delay, $d_{queue} = 20ms = 0.02\,s$.

Transmission rate, $\mu = 100$ packets/s.

$\therefore d_{trans} = \frac{1}{\mu} = \frac{1}{100} = 0.01\,s$.

$\therefore$ total delay, $d = (0.02 + 0.01)\,s$

$= 0.03\,s$.

Using Little's formula:

$N = a.d$

$\Rightarrow a = \frac{N}{d}$.

$\therefore a = \frac{100}{0.03} = 3333.33$ packets/sec.

(Ans).

P-23: According to fig 1.19 (a):

1st link $d_{trans} = \frac{L}{R_s}$

d_{prop} = Propagation delay.

Total delay for 1st packet:

$t_1 = \frac{L}{R_s} + 2d_{prop}$

Time for the 2nd packet:

$t_2 = t_1 + \frac{L}{R_s} = \left(\frac{L}{R_s} + 2d_{prop}\right) + \frac{L}{R_s}$

$$\Rightarrow t_2 = 2\frac{L}{R_s} + 2d_{prop}.$$

$\therefore$ Inter-arrival time $= t_2 - t_1 = \left(2\frac{L}{R_s} + 2d_{prop}\right) - \left(\frac{L}{R_s} + 2d_{prop}\right)$

$$= \frac{L}{R_s} \text{ (Ans).}$$

(b) Yes, it is possible for the 2nd packet to queue at the input queue of the 2nd link if $R_c \leq R_s$.

Explanation:

If the transmission rate of 2nd link: $R_c \leq R_s$; the first link can send packet faster than the 2nd link can transmit to the client. If the 2nd packets arrives at the 2nd link while the first packet is still being transmitted, it will have to wait in the queue.

To ensure no queuing occurs, T must be $T \geq \frac{L}{R_c}$. That means the server needs to wait at least L/R_c seconds before sending the packets.

P-25 Given,

Distance, $d = 20{,}000$ km.

Transmission rate, $R = 5$ Mbps $= 5 \times 10^6$ bits/sec.

Propagation speed, $s = 2.5 \times 10^8$ ms^{-1}

(a) $d_{prop} = \frac{d}{s} = \frac{20000 \times 10^3}{2.5 \times 10^8} = 0.08$ s

∴ Bandwidth-delay product $= R \times d_{prop}$
$= (5 \times 10^6 \times 0.08)$
$= 400000$ bits.

(b) Maximum no. of bits in the link at any time is equal to the bandwidth-delay product:

max. bits $= 400000$ bits.

(c) The bandwidth-delay product represents the amount of data that can be "in transit" in the network at any given time. It indicates how much data can be sent into the network before receiving an acknowledgement.

(d) Time to send 1 bit $= \frac{1}{R} = \frac{1}{5 \times 10^6}$ s

Width of a Bit $= s \times \frac{1}{5 \times 10^6}$

$= (2.5 \times 10^8) \times \frac{1}{5 \times 10^6}$

$= 50$ meters (Ans).

(e) General Expression for the width of a bit :

Width of a Bit $= s \times \frac{1}{R} = \frac{s}{R}$ (Ans).

P-26 Given,

Distance $= 4000$ km

Propagation speed (s) $= 3 \times 10^8$ m/s (speed of light)

$\therefore$ ~~Word~~ width of a bit $= 4000 \times 10^3$ m.

$\Rightarrow \frac{s}{R} = 4000 \times 10^3$

$\Rightarrow R = \frac{3 \times 10^8}{4000 \times 10^3}$

$= 75$ Mbps. (Ans)

P-27 Given,

$R = 500 \times 10^6$ bps.

$d = 4000$ km

$s = 3 \times 10^8$ m/s

File size = 800000 bits.

ⓐ $\therefore d_{prop} = \frac{d}{s} = \frac{4000 \times 10^3}{3 \times 10^8} = 0.0133$ s.

$\therefore$ Bandwidth - Delay Product $= 500 \times 10^6 \times 0.0133$

$= 6666667$ bits (Ans)

ⓑ Max. no. of bits = 6666667 bits.

ⓒ Width of a bit $= \frac{s}{R}$

$= \frac{3 \times 10^8}{500 \times 10^6}$

$=$ 0.6 meters. (Ans)

P-28 Given,

(a) File size: 50 terabytes $= 50 \times 10^{12}$ bytes
$= 50 \times 8 \times 10^{12}$ bits.

Transmission rate, $R = 100 \times 10^6$ bps.

$\therefore$ Time $= \frac{\text{file size}}{R} = \frac{50 \times 8 \times 10^{12}}{100 \times 10^6}$ s
$= 4000000$ s
$= 1111$ hours.

Ans

(b) Given, Packet size $= 40000$ bits
Distance, $d = 4000$ km.
Prop. speed, $s = 3 \times 10^8$ m/s

$\therefore d_{prop} = \frac{d}{s} = \frac{4000 \times 10^3}{3 \times 10^8} = 13.33$ ms.

Transmission time $= \frac{40000}{100 \times 10^6} = 0.0004 = 0.4$ ms.

$\therefore$ RTT $= 2 \times d_{prop} + 0.4 = (2 \times 13.33 + 0.4)$ ms
$= 27.06$ ms.

Total time $= (20 \times 27.06)$ ms
$= 0.54$ s. Ans

(c) Comparison:

- Continuous transmission time (a) : 1.111 hours. (continuously sending the file without waiting for acknowledgement).
- (b): 0.54 s. (with 20 packets, each was acknowledged before sending the next.).

P-29: Given,

- $R = 10\,Mbps = 10 \times 10^6$ bps
- $d = 35786$ km
- $s = 2.4 \times 10^8$ m/s.

(a) $\therefore d_{prop} = \frac{d}{s} = \frac{35786 \times 10^3}{2.4 \times 10^8} = 0.149$ s.

$= 149$ ms. (Ans)

(b) Bandwidth delay product $= R \times d_{prop}$

$= 10 \times 10^6 \times 0.149$

$= 1490000$ bits.

(c) Bits transmission in 1 min $= (10 \times 10^6 \times 60)$ [1 min = 60 s].

$= 600000000$ bits

$= 75$ MB. (Ans).

P-31

(a) Message size = 10^6 bits

$R = 5\text{Mbps} = 5 \times 10^6$ bits/sec.

$\therefore t_{first} = \frac{10^6}{5 \times 10^6} = 0.2$ s

$t_{total} = 3 \times 0.2 = 0.6$ sec.

(b) Sending with segmentation.

Packet size = 10^6 bits/100 = 10000 bits

$N = 100$.

$\therefore t_{packet} = \frac{10000}{5 \times 10^6} = 0.002$ s.

$t_{first\_seg} = 3 \times 0.002 = 0.006$ s.

$t_{tot\_seg} = 0.006 + (99 \times 0.002) = 0.006 + 0.198$

$= 0.204$ sec.

(c) Without segmentation = 0.6 sec.

With segmentation = 0.204 sec

(d) Reasons to use message segmentation:

1. Reduced delay : segmentation reduces time to transit a message.
2. Error Control : If a single packet is lost, only that packet is needed to be transmitted again
3. Efficient use of bandwidth.

(e) Drawbacks:

1. Reassembly complexity: The destination must reassemble packets in the correct order, which increases processing complexity.
2. Header complexity overhead: Each packet needs its own header that causes an overhead.
3. Packet loss: If packets are lost, the receiver may need to wait for missing packets which leading to delay.