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Question 8:

(a)
(b)

Question 1.

(a)
$\frac{L}{R} \times N$

(b)
$P \times \frac{L}{R} + \frac{L}{R} \times (N - 1)$
$P \times \frac{L}{R}$ for transmitting all packets, and $\frac{L}{R} \times (N - 1)$ to transmit the last packet through all switches.

Question 2.

(a)
$d_{\text{prop}} = \dfrac{m}{s}$

(b)
$d_{\text{trans}} = \dfrac{L}{R}$

(c)
$d_{\text{end-to-end}} = \dfrac{m}{s} + \dfrac{L}{R}$

(d)
Right after starting of the host link

(e)
Still in the link. $d_{\text{trans}} \times s$ meters into the link.
(f)
In the host B

(g)
$d_{\text{prop}} = \dfrac{m}{s} = \dfrac{m}{2.5 \times 10^8\ m/s}$
$d_{\text{trans}} = \dfrac{120 \text{ bits}}{56\ 000 \text{ bits/s}} = \dfrac{3 \text{ bits}}{1\ 400 \text{ bits/s}}$

Then if $d_{\text{prop}} = d_{\text{trans}}$, we have

$$\begin{aligned}
\frac{m}{2.5 \times 10^5\ m/s} &= \frac{3 \text{ bits}}{1\ 400 \text{ bits/s}} \\
m \times 1400 \text{ bits/s} &= 3 \text{ bits} \times 2.5 \times 10^8\ m/s \\
m &= \frac{3 \text{ bits} \times 2.5 \times 10^8\ m/s}{1400 \text{ bits/s}} \\
m &\approx 535\ 714.2857\ m
\end{aligned}$$

Question 3.

(a)
$\dfrac{3 \times 10^6 \text{ bits/s}}{150 \times 10^3 \text{ bits/s}} = 20$

(b)
10%

(c)
Binomial Distribution: $P = \binom{n}{x} p^x (1-p)^{n-x}$

$$\begin{aligned} x &= n \\ n &= 120 \\ p &= \frac{1}{10} \end{aligned}$$

So $P(X = n) = \binom{120}{n} (0.1)^n (0.9)^{120-n}$

(d)
Binomial Distribution: $P = \binom{n}{x} p^x (q-p)^{n-x}$

Want probability of $x = 21,\ x = 22,\ \cdots\ ,\ x = 119,\ x = 120$

$$\begin{aligned} P(X \geq 21) &= \sum_{n=21}^{120} \binom{120}{n} 0.1^n (0.9)^{120-n} \\ &\approx 0.00794 \end{aligned}$$

Question 4.

(a)

$$\begin{aligned}\text{Transfer Time} &= \frac{\text{Transfer Size}}{\text{Bandwidth}} \\ &= \frac{1.5 \times 2^{20} \text{ bits}}{10 \times 10^{6} \text{ bits/second}} \\ &= 1.2582912 \text{ seconds}\end{aligned}$$

$$\begin{aligned}\text{Total time} &= \text{Handshake} + \text{Transfer Time} \\ &= (2 \times 80 \times 10^{-3} \text{ seconds}) + (1.2582912 \text{ seconds}) \\ &= 1.4182912 \text{ seconds}\end{aligned}$$

(b)

$\dfrac{1.5 \times 2^{20} \text{ bytes}}{1 \times 2^{10} \text{ bytes}} = 1\ 536 \text{ packets}$

$$\begin{aligned}\text{Time for one packet} &= \text{Transfer Time} \\ &= \frac{1 \times 2^{10} \times 8 \text{ bits}}{10 \times 10^{6} \text{ bits/second}} \\ &= 0.0008192 \text{ seconds}\end{aligned}$$

$$\begin{aligned}\text{Total time} &= \text{Handshake} + 1\ 536 \times \text{Time for one packet} + 1\ 535 \text{ RTT} \\ &= (2 \times 80 \times 10^{-3} \text{ seconds}) + 1\ 536 \times 0.0008192 \text{ seconds } + 1\ 535 \times \left(80 \times 10^{-3} \text{ seconds}\right) \\ &= 124.2182912 \text{ seconds}\end{aligned}$$

(c)

$\dfrac{1.5 \times 2^{20} \text{ bytes}}{1 \times 2^{10} \text{ bytes}} = 1\ 536 \text{ packets}$

$$\frac{1\ 536 \text{ packets}}{20 \text{ packets/RTT}} = 76.8 \text{ RTT} = 76 \text{ RTT}$$

$76 \text{ RTT} \times 80 \times 10^{-3} \text{ seconds/RTT} = 6.08 \text{ seconds}$

$$\begin{aligned}\text{Total time} &= \text{Handshake} + \left(76 \text{ RTT} \times 80 \times 10^{-3} \text{ seconds/RTT}\right) \\ &= \left(2 \times 80 \times 10^{-3} \text{ seconds}\right) + 6.08 \text{ seconds} \\ &= 6.24 \text{ seconds}\end{aligned}$$

(d)

$$\frac{1.5 \times 2^{20} \text{ bytes}}{1 \times 2^{10} \text{ bytes}} = 1\ 536 \text{ packets}$$

Sum of powers of 2 is the biggest binary number $= 2^n - 1$

for $n = 10$, the sum of powers of 2 is 1023.
for $n = 11$, the sum of powers of 2 is 2047.
Therefore, there is going to be 10 RTT.

$$\begin{aligned}\text{Total time} &= \text{Handshake} + 10 \text{ RTT} \times 80 \times 10^{-3} \text{ seconds/RTT} \\ &= \left(2 \times 80 \times 10^{-3} \text{ seconds}\right) + 0.8 \text{ seconds} \\ &= 0.96 \text{ seconds}\end{aligned}$$

Question 5.

$$\text{Propogation Delay} = \frac{\text{Distance}}{\text{Propogation Speed}}$$

$$\text{Transmission Delay} = \frac{\text{Size}}{\text{Bandwidth}}$$

Setting them equal for 100-byte packets, we have

$$\frac{\text{Distance}}{\text{Propogation Speed}} = \frac{\text{Size}}{\text{Bandwidth}}$$

$$\frac{50 \times 10^3 \text{ m}}{2 \times 10^8 \text{ m/s}} = \frac{100 \times 8 \text{ bits}}{\text{Bandwidth}}$$

$$\text{Bandwidth} \times (50\ 000 \text{ m}) = (2 \times 10^8 \text{ m/s}) \times (800 \text{ bits})$$

$$\text{Bandwidth} = \frac{(2 \times 10^8 \text{ m/s}) \times (800 \text{ bits})}{50\ 000 \text{ m}}$$

$$= 3\ 200\ 000 \text{ bits/s}$$

Setting them equal for 512-byte packets, we have

$$\text{Bandwidth} = \frac{(2 \times 10^8 \text{ m/s}) \times (512 \times 8 \text{ bits})}{50\ 000 \text{ m}}$$

$$= 16\ 384\ 000 \text{ bits/s}$$

Question 6.

(a)

For the shortest RTT, we would want to transmit only 1 bit, so we can ignore transmit delay.

$$\begin{aligned}
\text{RTT} &= 2 \times \text{Propagation} \\
&= 2 \times \frac{\text{Distance}}{\text{Propagation speed}} \\
&= 2 \times \frac{55 \times 10^9 \text{ meters}}{3 \times 10^8 \text{ meters/second}} \\
&= 366 + \frac{2}{3} \text{ seconds}
\end{aligned}$$

(b)

$$\begin{aligned}
\text{delay} \times \text{bandwidth} &= 366 + \frac{2}{3} \text{ seconds} \times 128 \times 10^3 \text{ bits/second} \\
&= 46\ 933\ 333 + \frac{1}{3} \text{ bits} \\
&= 46\ 933\ 333 \text{ bits}
\end{aligned}$$

(c)

$$\begin{aligned}
\text{Transfer time} &= \frac{\text{RTT}}{2} + \frac{\text{Transfer size}}{\text{Bandwidth}} \\
&= \frac{1}{2}\left(366 + \frac{2}{3}\right) \text{ seconds} + \frac{5 \times 8 \times 2^{20} \text{ bits}}{128 \times 10^3 \text{ bits/second}} \\
&= 511 + \frac{1}{75} \text{ seconds} \\
&= 511.01\overline{3} \text{ seconds}
\end{aligned}$$

Question 7.

(a)

$$\begin{aligned}\text{Transmit time} &= \frac{\text{Size}}{\text{Bandwidth}} \\ &= \frac{5\ 000 \text{ bits}}{1 \times 10^9 \text{ bits/second}} \\ &= \frac{1}{200000} \text{ seconds} \\ &= 5 \times 10^{-6} \text{ seconds} \\ &= 0.000005 \text{ seconds}\end{aligned}$$

Since there is 1 router, there is 2 links to pass through.

$$\begin{aligned}\text{Transfer Time} &= 2 \times \text{Propogation} + 3 \times \text{Transmit} \\ &= 2 \times \left(10 \times 10^{-6} \text{ seconds } + 5 \times 10^{-6} \text{ seconds}\right) \\ &= 3 \times 10^{-5} \text{ seconds} \\ &= 0.00003 \text{ seconds}\end{aligned}$$

(b)

For 3 switches, there will be 4 links.

$$\begin{aligned}\text{Transfer Time} &= 4 \times \text{Propogation} + \text{Transmit} \\ &= 4 \times \left(10 \times 10^{-6} \text{ seconds}\right) + 5 \times \left(10^{-6} \text{ seconds}\right) \\ &= 6 \times 10^{-5} \text{ seconds} \\ &= 0.00006 \text{ seconds}\end{aligned}$$

(c)

$$\text{Transmit time}_{5\ 000} = 5 \times 10^{-6} \text{ seconds}$$

If a switch can retransmit after 128 bits, it will only be effective for the last 2 switches. so we have:

$$
\begin{aligned}
\text{Transmit time}_{128} &= \frac{\text{Size}}{\text{Bandwidth}} \\
&= \frac{128 \text{ bits}}{1 \times 10^9 \text{ bits/second}} \\
&= \frac{1}{7812500} \text{ seconds} \\
&= 1.28 \times 10^{-7} \text{ seconds} \\
&= 0.000000128 \text{ seconds}
\end{aligned}
$$

$$
\begin{aligned}
\text{Transfer Time} &= 4 \times \text{Propogation} + 3 \times \text{Transmit time}_{128} + \text{Transmit time}_{5\ 000} \\
&= 4 \times \left(10 \times 10^{-6} \text{ seconds}\right) + 3 \times \left(1.28 \times 10^{-7} \text{ seconds}\right) + 5 \times 10^{-6} \text{ seconds} \\
&= \frac{5673}{125000000} \text{ seconds} \\
&= 0.000045384 \text{ seconds} \\
&= 4.5384 \times 10^{-5} \text{ seconds}
\end{aligned}
$$

Question 8.

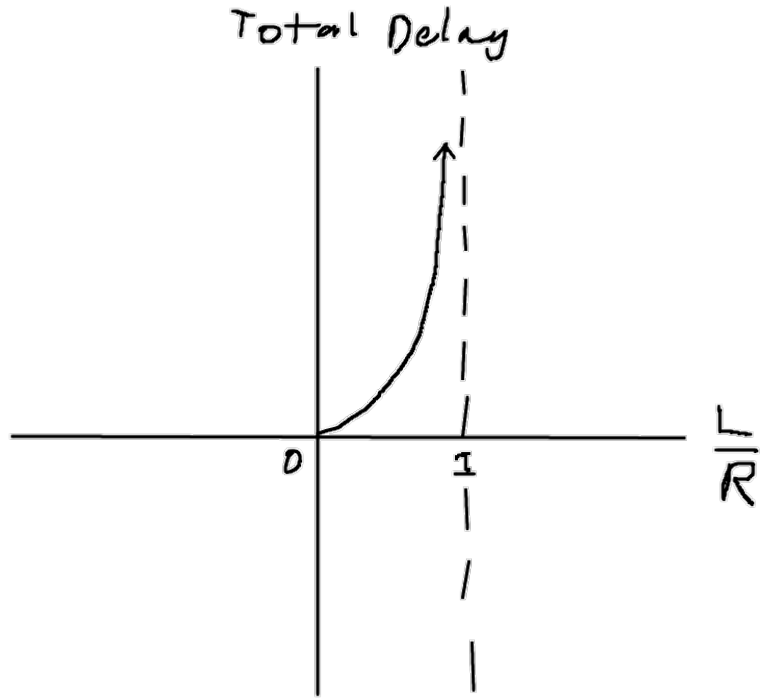
(a)

$$\text{Total Delay} = \text{Queuing delay} + \text{Transmission delay}$$

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

(b)
Substituting $x = \frac{L}{R}$, we have:

$$\begin{aligned}
\text{Total delay} &= \frac{IL}{R(1-I)} + \frac{L}{R} \\
&= \frac{x^2 a}{1 - xa} + x \\
&= \frac{x^2 a}{1 - xa} + \frac{x(1 - xa)}{1 - xa} \\
&= \frac{x^2 a + x(1 - xa)}{1 - xa} \\
&= \frac{x^2 a + x - x^2 a}{1 - xa} \\
&= \frac{x}{1 - xa}
\end{aligned}$$


Total Delay
0
1
L
R