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CS 3800
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Computer Networks: Assignment #1

1. Q1: Rate of the bottleneck link = $R_s$ bits/sec.
   Size of each packets = $L$ bits.
   Propagation delay $d_{prop}$ of both links are equal.
   a. When the bottleneck link is the first link of the packet A, then packet B is queued at the first link waiting for the transmission of packet A. This delay can be calculated by using the formula:
   $Transmission\ delay = \frac{Length\ of\ packet\ (L)}{Transmission\ rate\ (R)} = \frac{L}{R_s}$
   b. $R_c < R_s$ because then the router can forward bits quickly at a same speed while receiving them. Because both packets are sent back to back, the second packet at the input queue of the second link may arrive before the second link finishes the transmission of the first packet, which means $\frac{L}{R_s} + \frac{L}{R_s} + d_{prop} < \frac{L}{R_s} + \frac{L}{R_c} + d_{prop}$:
   The left hand side of the inequality is the time needed by the second packet to arrive at the input queue of the second link, and the right hand represents the time needed by the first packet to finish its transmission. When the second packet is sent $T$ seconds later, then the delay for the second packet at second link becomes:
   $$\frac{L}{R_s} + \frac{L}{R_s} + d_{prop} + T \geq \frac{L}{R_s} + \frac{L}{R_c} + d_{prop}$$
   $$\rightarrow \frac{2L}{R_s} + d_{prop} + T \geq \frac{L}{R_s} + \frac{L}{R_c} + d_{prop}$$
   $$\rightarrow \frac{L}{R_s} + d_{prop} + T \geq \frac{L}{R_c} + d_{prop}$$
   $$\rightarrow \frac{L}{R_s} + T \geq \frac{L}{R_c}$$
   $$\rightarrow T \geq \frac{L}{R_c} - \frac{L}{R_s}$$
2. Q2: Message is not segmented, the page size = message size $p_s = 8 * 10^6\ bits$
   Each link is 2 Mbps (ignore propagation, queuing, and processing delays)
   a. The transmission time required to send message from source host to first packet switch is $T_{link} = \frac{p_s}{R} = \frac{8*10^6}{2*10^6} = 4\ sec$. The total time to move message from source host to destination host through 3 links using store-and-forward switching is $T = \#\ of\ hops * T_{link} = 3 * 4 = 12\ sec$
   b. The message is segmented into 800 packets, with each packet being 10000 bits long. $T_{link} = \frac{p_s}{R} = \frac{1*10^4}{2*10^6} = 0.005\ sec = 5\ msec$. The time at which the second packet is received at the first switch is when the first packet is received at the

second switch. To transmit the first packet from source to the second switch, it is required to pass through one switch with two transmission links. $T = \#\, of\ hops * T_{link} = 2 * 5 = 10\, msec.$

c. The time required to move the first packet from source to destination through three transmission links is $T = \#\, of\ hops * T_{link} = 3 * 5 = 15\, msec.$ 799 packets will be received at destination host every 5 msec. The 800th packet will be received by $15\, msec + 799 * 5\, msec = 4010\, msec = 4.01\, sec.$ My answer in part (a) gave me 12 seconds, where we did not use segmentation. We can transmit almost three times faster using segmentation.

d. Using message segmentation not only reduces delay, but also gives each packet travel in its own path that reduces transmission time and load on a specific link in the network. It also saves time when retransmitting the message if only a lost packet has been lost (rather than a whole message).

e. Drawbacks of message segmentation include re-arrangement of packets in sequence at destination, consuming computation power of the destination system. Another drawback is that message segmentation requires more bandwidth as the message size increases due to the overheads.

3. Q3: 3 links and 2 switches between A and B
Host A adds 80 bits of header to each segment, forming packets of $L = 80 + S$

$$T_{delay} = \frac{L}{R} = \frac{80+S}{R} * number\ of\ links = \left(\frac{80+S}{R}\right) * 3$$

$$T_{total} = delay\ for\ first\ packet * 3 + \left(\frac{F}{S} - 1\right) * \frac{80+S}{R}$$

$$T_{total} = \left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right) \rightarrow \frac{dT_{total}}{dS} = 0$$

$$\rightarrow \frac{d}{dS}\left[\left(\frac{80+S}{R}\right)\left(\frac{F}{S} + 2\right)\right] = 0$$

$$\rightarrow \left(\frac{F}{S} + 2\right)\left(\frac{d}{dS}\left(\frac{80}{r}\right) + \frac{d}{ds}\left(\frac{S}{R}\right)\right) + \left(\frac{80+S}{R}\right)\left(\frac{d}{dS}\left(\frac{F}{s}\right) + \frac{d}{ds}(2)\right) = 0$$

$$\rightarrow \left(\frac{F+2S}{SR}\right) - \left(\frac{80+S}{R}\right)\left(\frac{F}{S^2}\right) = 0 \rightarrow 2S^2 - 80F = 0$$

$$\rightarrow\ S = \sqrt{40F}$$

4. Q4: Number of packets $N$, Length of each packets $L$, Rate of transmission $R$

a. Queuing delay for second packet is $\frac{L}{R}$, queuing delay for third packet is $\frac{2L}{R}$, queuing delay for Nth packet is $\frac{(N-1)L}{R}$:

Average queuing delay for n packets: $\frac{\frac{L}{R}+\frac{2L}{R}+\cdots+\frac{(N-1)L}{R}}{N} = \frac{\frac{L}{R}(1+2+\cdots+N-1)}{N}$

The sum of natural number formula is: $S_n = \frac{n(n+1)}{2}$ where we can replace (n with N-1) so we get the following formula:

$$\frac{\frac{L}{R}\left(\frac{N(N-1)}{2}\right)}{N} \rightarrow \frac{L*(N-1)*N}{2RN} \rightarrow \frac{L(N-1)}{2R}$$

b. The transmission of N packets require $\frac{LN}{R}$ seconds

Average queuing delay: $\frac{1}{N}\sum_{k=1}^{N}\frac{(N-1)L}{R}$

$$\rightarrow \frac{L}{R} * \frac{1}{N}\sum_{k=0}^{N-1} N$$

$$\rightarrow \frac{L}{R} * \frac{1}{N} * \frac{N(N-1)}{2}$$

$$\rightarrow \frac{L}{R} * \frac{N-1}{2}$$

$$\rightarrow \frac{(N-1)L}{2R}$$