CMSC 440 - Homework Assignment #1 - Solution

Due Date: Sunday Feb. 12th, 2023 - 11:59pm

Questions:

You are required to answer the following questions from the attached document:

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Question
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Problem 1.2

At time N*(L/R) the first packet has reached the destination, the second packet is stored in the last router, the third packet is stored in the next-to-last router, etc. At time N*(L/R) + L/R, the second packet has reached the destination, the third packet is stored in the last router, etc. Continuing with this logic, we see that at time N*(L/R) + (P-1)*(L/R) = (N+P-1)*(L/R) all packets have reached the destination.

Problem 1.3

a) A circuit-switched network would be well suited to the application, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session without significant waste. In addition, the overhead costs of setting up and tearing down connections are amortized over the lengthy duration of a typical application session.

b) In the worst case, all the applications simultaneously transmit over one or more network links. However, since each link has sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur. Given such generous link capacities, the network does not need congestion control mechanisms.

Problem 1.4

a) Between the switch in the upper left and the switch in the upper right we can have 4 connections. Similarly we can have four connections between each of the 3 other pairs of adjacent switches. Thus, this network can support up to 16 connections.

b) We can *4* connections passing through the switch in the upper-right-hand corner and another *4* connections passing through the switch in the lower-left-hand corner, giving a total of *8* connections.
c) Yes. For the connections between A and C, we route two connections through B and two connections through D. For the connections between B and D, we route two connections through A and two connections through C. In this manner, there are at most 4 connections passing through any link.

Problem 1.6

a) $d_{prop} = m / s$ seconds.
b) $d_{trans} = L / R$ seconds.
c) $d_{end-to-end} = (m / s + L / R)$ seconds.
d) The bit is just leaving Host A.
e) The first bit is in the link and has not reached Host B.
f) The first bit has reached Host B.
g) $m = \frac{L}{R} s = \frac{120}{56 \times 10^3} \left(2.5 \times 10^8\right) = 536$km.

Problem 1.8

a) 20 users can be supported.

Problem 1.10

The first end system requires L/R_1 to transmit the packet onto the first link; the packet propagates over the first link in d_1/s_1; the packet switch adds a processing delay of d_{proc}; after receiving the entire packet, the packet switch connecting the first and the second link requires L/R_2 to transmit the packet onto the second link; the packet propagates over the second link in d_2/s_2. Similarly, we can find the delay caused by the second switch and the third link: L/R_3, d_{proc}, and d_3/s_3.
Adding these five delays gives

$$d_{end\text{-}end} = L/R_1 + L/R_2 + L/R_3 + d_1/s_1 + d_2/s_2 + d_3/s_3 + d_{proc} + d_{proc}$$

To answer the second question, we simply plug the values into the equation to get 6 + 6 + 6 + 20+16 + 4 + 3 + 3 = 64 msec.

Problem 1.20

Throughput = $min\{R_s, R_c, R/M\}$

Problem 1.23

Let's call the first packet A and call the second packet B.

a) If the bottleneck link is the first link, then packet B is queued at the first link waiting for the transmission of packet A. So the packet inter-arrival time at the destination is simply L/R_s.

b) If the second link is the bottleneck link and both packets are sent back to back, it must be true that the second packet arrives at the input queue of the second link before the second link finishes the transmission of the first packet. That is,

   $L/R_s + L/R_s + d_{prop} < L/R_s + d_{prop} + L/R_c$

   The left hand side of the above inequality represents the time needed by the second packet to *arrive at* the input queue of the second link (the second link has not started transmitting the second packet yet). The right hand side represents the time needed by the first packet to finish its transmission onto the second link.

   If we send the second packet T seconds later, we will ensure that there is no queuing delay for the second packet at the second link if we have:

   $L/R_s + L/R_s + d_{prop} + T >= L/R_s + d_{prop} + L/R_c$

   Thus, the minimum value of T is $L/R_c - L/R_s$.

Problem 1.25

a) 160,000 bits
b) 160,000 bits
c) The bandwidth-delay product of a link is the maximum number of bits that can be in the link.
d) the width of a bit = length of link / bandwidth-delay product, so 1 bit is 125 meters long, which is longer than a football field
e) s/R

Problem 1.31

a) Time to send message from source host to first packet switch $= \frac{8\times10^6}{2\times10^6}\sec = 4\sec$ With store-and-forward switching, the total time to move message from source host to destination host = $4\sec\times 3\ hops = 12\sec$

b) Time to send 1st packet from source host to first packet switch = . $\frac{1\times10^4}{2\times10^6}\sec = 5\ m\sec$. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times 5m\sec = 10\ m\sec$

c) Time at which 1st packet is received at the destination host = $5\ m\sec\times 3\ hops = 15\ m\sec$. After this, every 5msec one packet will be received; thus time at which last (800th) packet is received = $15\ m\sec + 799 * 5m\sec = 4.01\sec$. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).

d)

i. Without message segmentation, if bit errors are not tolerated, if there is a single bit error, the whole message has to be retransmitted (rather than a single packet).

ii. Without message segmentation, huge packets (containing HD videos, for example) are sent into the network. Routers have to accommodate these huge packets. Smaller packets have to queue behind enormous packets and suffer unfair delays.

e)

i. Packets have to be put in sequence at the destination.

ii. Message segmentation results in many smaller packets. Since header size is usually the same for all packets regardless of their size, with message segmentation the total amount of header bytes is more.

Problem 1.33

There are *F/S* packets. Each packet is S=80 bits. Time at which the last packet is received at the first router is $\frac{S+80}{R}\times\frac{F}{S}$ sec. At this time, the first F/S-2 packets are at the destination, and the F/S-1 packet is at the second router. The last packet must then be transmitted by the first router and the second router, with each transmission taking $\frac{S+80}{R}$ sec. Thus delay in sending the whole file is $delay = \frac{S+80}{R}\times(\frac{F}{S}+2)$

To calculate the value of S which leads to the minimum delay,

$$\frac{d}{dS}delay = 0 \Rightarrow S = \sqrt{40F}$$