Homework 1 Due Date[*]: 10:00am 01/29/2020 Cutoff Deadline[**]: 10:00am 01/31/2020

[*]Late penalty will apply for past-due late submission; [**]Submission will NOT be accepted after the cutoff deadline

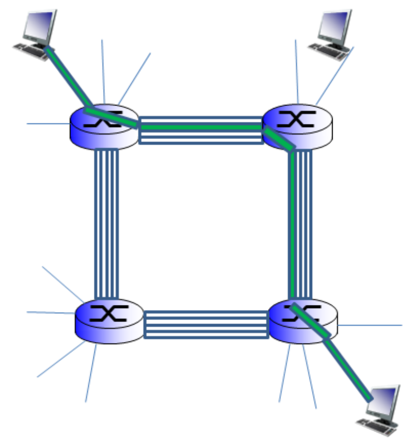
Submission: handwritten hardcopy at the beginning at the class (email to wzhu1@msudenver.edu must be used for late submission and the submission time is the moment when the email arrives at the instructor's inbox.)

PLEASE ORGANIZE YOUR WORK IN THE SEQUENCE GIVEN IN THE ASSIGNMENT!!!

Problem A. Consider a packet of length L which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link i, for i = 1, 2, 3. The packet switch delays each packet by d proc. Assuming no queuing delays, in terms of d_i , s_i , R_i , (i = 1,2,3), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,000 bytes, the propagation speed on all three links is 5.0×10^8 m/ s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to- end delay?

Problem B. A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway (50%) done being transmitted on this outbound link and three *other* packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 800 bytes and the link rate is 2 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length L (in bits), the transmission rate is R, x bits of the currently-being-transmitted packet have been transmitted, and n *other* packets are waiting in the queue?

Problem C. Consider the given circuit-switched network. Recall that there are 4 circuits on each link. Label the four switches A, B, C and D, going in the clockwise direction.



a. What is the maximum number of simultaneous connections that can be in progress at any one time in this network?
b. Suppose that all connections are between switches A and C. What is the maximum number of simultaneous connections that can be in progress?
c. Suppose we want to make four connections between switches A and C, and another four connections between switches B and D. Can we route these calls through the four links to accommodate all eight connections?

(hints for P4 (a): You may want to maximize the connections by assuming that each connection is only required to be between two adjacent switches, for example, between A and B or B and C or C and D or D and A)

Problem D. (requirements: please include the appropriate formula with numbers given by the problem statement in your solution as well as the final numeric values. If you like, you may also annotate how you calculate those values like via Calculator, Excel, Java programming, etc. You do NOT need to provide any details of your method like your java codes or excel scripts.)

Suppose users share a 1.5 Mbps link. Also suppose each user requires 100 kbps when transmitting, but each user transmits only 5 percent of the time. (See the discussion of packet switching versus circuit switching in Section 1.3.)

a. When circuit switching is used, how many users can be supported?
b. For the remainder of this problem, suppose packet switching is used. Find the probability that a *given* user is transmitting.
c. Suppose there are 100 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution.)
d. Find the probability that there are 16 or more users transmitting simultaneously. (keep significant digits till the *ten-millionth* position)

Problem E. In modern packet- switched networks, including the Internet, the source host segments long, application- layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as message segmentation. Figure 1.27 illustrates the end- to- end transport of a message with and without message segmentation. Consider a message that is 8×10^6 bits long that is to be sent from source to destination in Figure 1.27. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

a. Consider sending the message from source to destination without message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store- and- forward packet switching, what is the total time to move the message from source host to destination host?
b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

(more on next page!!!)

c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.
d. In addition to reducing delay, what are reasons to use message segmentation?
e. Discuss the drawbacks of message segmentation.

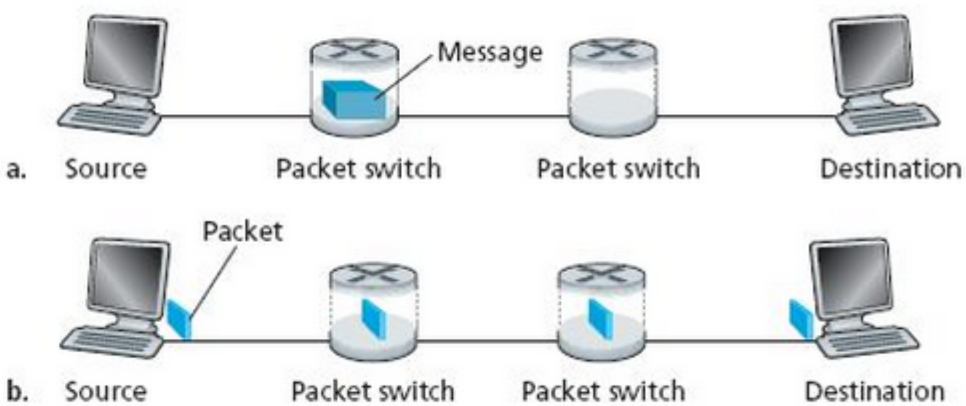


Figure 1.27 ♦ End-to-end message transport: (a) without message segmentation; (b) with message segmentation