CMPEN/EE 362 - HW1

Student Name: _____

Problem 1

Consider a source and a destination connected by N links (i.e., N-1 packet switches). Each link has capacity R bps, and propagation delay d seconds. Ignore processing delays and assume that initially all the buffers are empty.

a) Give a formula for the end-to-end delay of sending one packet of length L bits.
b) Generalize the formula for sending P packets of L bits each.
c) Now suppose the links (in the order from source to destination) have capacities $R_1 < R_2 < \ldots < R_N$, and propagation delays $d_1, d_2, \ldots, d_N$ (with arbitrary values). Give formula for the end-to-end delay of sending P packets of L bits each.
d) Repeat c), but assume that $R_1 > R_2 > \ldots > R_N$ (still arbitrary values for $d_1, d_2, \ldots, d_N$).

Problem 2

Consider an 8-car caravan, where the propagation speed is 100 km/hour, each car takes 1 minute to pass a toll both. The caravan starts in front of toll booth A, goes through toll booth B, and ends after passing toll booth C. Let d_{AB} and d_{BC} be the distance between A-B, and B-C.

a) Suppose $d_{AB} = d_{BC} = 10$ km. What is the end-to-end delay if the caravan travels together (i.e., the first car must wait for the last car after passing each toll booth)?
b) Repeat a), but assume the cars travel separately (i.e., not waiting for each other).
c) Repeat a) and b), but suppose $d_{AB} = d_{BC} = 100$ km.
d) Still suppose $d_{AB} = d_{BC} = 100$ km. Suppose toll booth B takes 10 minute to pass each car (A and C still takes 1 minute per car). Where is the first car when the second car passes B?
e) Still assume that toll booth B takes 10 minute to pass each car, and A and C each takes 1 minute per car. What is the maximum value of d_{BC} such that the first car has passed C when the second car passes B (d_{AB} is irrelevant here)?

Problem 3

Suppose users share a 9 Mbps link. Each user consumes 1.5 Mbps when transmitting, and only transmits with probability 0.2.

a) How many users can be supported using circuit switching?
b) Assume packet switching for the rest of the problem. What is the probability that 7 out of 10 users are transmitting?
c) What is the maximum number of users, such that the probability of exceeding the link capacity is no more than 0.01? Hint: Gradually increase the number of users and evaluate the probability of exceeding the link capacity for each value of this number.
d) What is the average link utilization under the maximum number of users computed in c), defined as $\frac{expected\ transmission\ rate\ on\ the\ link}{link\ capacity}$?

Problem 4

Refer to Chapter 1 P31 for definition of *message segmentation* (hint: this is analogous to letting the cars travel separately as opposed to traveling together in the caravan analogy). Suppose the source has a message of 1 Gbit to be sent to the destination via a 3-link path (through two packet switches). Each link has a capacity of 10 Mbps and a propagation delay of 0.1 seconds. Ignore queuing and processing delays.

a) What is the end-to-end delay to send the message without segmentation?
b) What is the end-to-end delay if the message is sent with segmentation into 500 packets, of 2 Mbit each?
c) Repeat a) and b) when there are 10 links (i.e., 9 packet switches) between the source and the destination.
d) Suppose now that each packet needs a header of 1 Kbit. Repeat the calculation in b) (for the 3-link case).
e) What are the benefits of message segmentation?
f) What are the drawbacks of message segmentation?

Problem 5

Suppose you are asked to design a highway control system where all the sensors share a 1 Mbps link to the control center. Each sensor transmits with probability 0.1. When it transmits, it can transmit either only numerical measurements at 0.1 Mbps, or both numerical measurements and video at 1 Mbps.

a) How many sensors can be supported using circuit switching if they transmit only numerical measurements? And what if they transmit both numerical measurements and video?
b) Assume that sensors only transmit numerical measurements. How many sensors can be supported using packet switching such that the probability of exceeding the link capacity is no more than 0.005?
c) Repeat b) but assume that sensors transmit both numerical measurements and video.
d) Compare b-c) with a), at which transmission rate (0.1 Mbps or 1 Mbps) the sensors benefit more from packet switching?