CS 421: COMPUTER NETWORKS **SPRING 2004**

FINAL
May 21, 2004
160 minutes

Name: ______________________________

Student No: ____________________________

1)

a) Consider a 1 Mbits/sec channel with a 20 msec one-way propagation delay, i.e., 40 msec roundtrip delay. We want to transfer a file of size 6000 Bytes. Each packet carries a header of 40 Bytes long and the maximum number of data bytes in a packet is 960 Bytes. When there is data to be transmitted, each packet contains the maximum number of bytes. Assume that ACK packets are of 125 Bytes long and there is a processing delay of 1 msec after a packet is fully received at the receiver until the transmission of the corresponding ACK is started. Selective Repeat protocol is used with a window size of N = 5 packets.

   i. (6 pts) Assume there are no transmission errors and no lost packets or ACKs. How much time is required to complete the transfer of the whole file and receive the final ACK at the sender?

   ii. (6 pts) Now assume that every 6^{th} packet crossing the forward channel is lost while ACKs are not lost or corrupted. How much time is required to complete the transfer of the whole file and receive the final ACK at the sender?

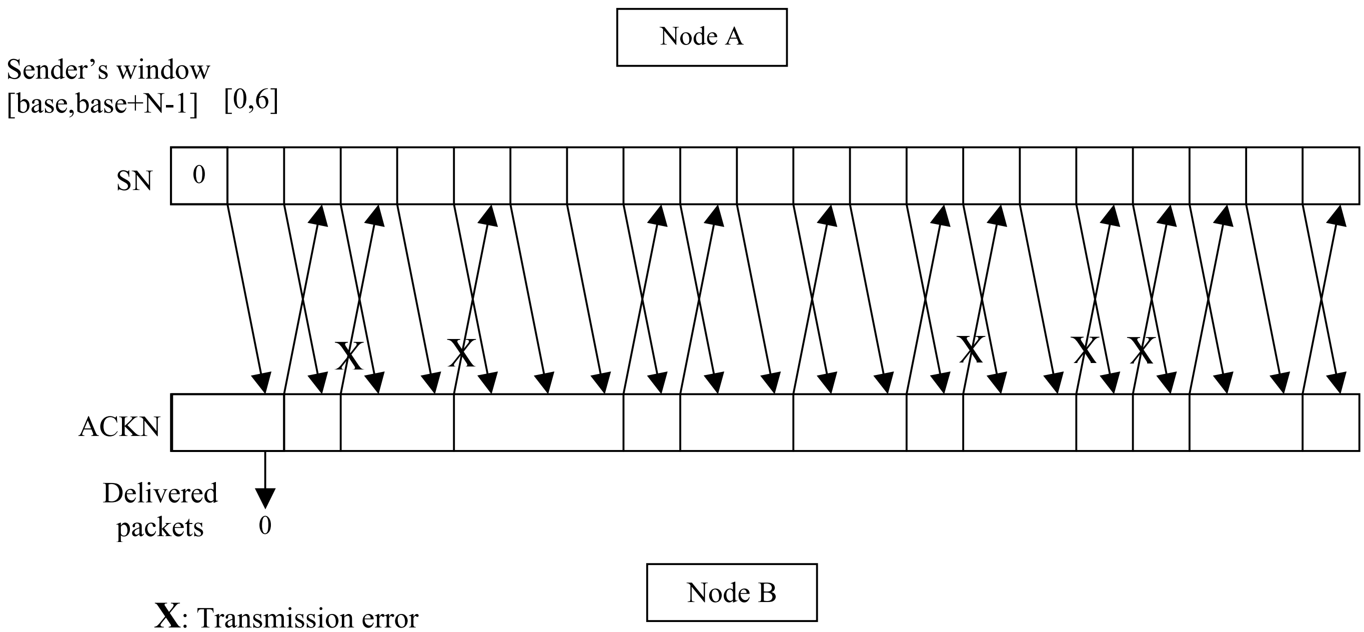
b) Suppose a TCP connection experiences round-trip times (RTT) of 10 msec for 80% of its packets, and 100 msec for 20% of its packets. Suppose no packets are actually lost. Assume that the estimated RTT (according to the exponential weighted moving average) is equal to the true (ensemble) average of RTT, i.e., EstimatedRTT = average value of RTT = E[SampleRTT].

   i. (5 pts) Assume that the timeout is set to **2 (two)** times the estimated RTT (as in the original version of TCP), i.e., TimeOut = 2 x EstimatedRTT. What fraction of the packets will be assumed lost by the TCP sender?

   ii. (6 pts) Currently used versions of TCP estimate both the mean and the mean deviation as we discussed in the class (the mean deviation is the average absolute distance of RTT samples from the estimated RTT), and sets the timeout to the estimated mean (estimatedRTT) plus **4 (four)** times the estimated deviation (devRTT), i.e., TimeOut = EstimatedRTT + 4 x devRTT. Assume that the TCP connection uses this new method, and the estimated RTT and deviation are equal to their true (ensemble) values, i.e., EstimatedRTT = E[SampleRTT] and devRTT = E[|SampleRTT-EstimatedRTT|]. What fraction of the packets will be assumed lost by the TCP sender?

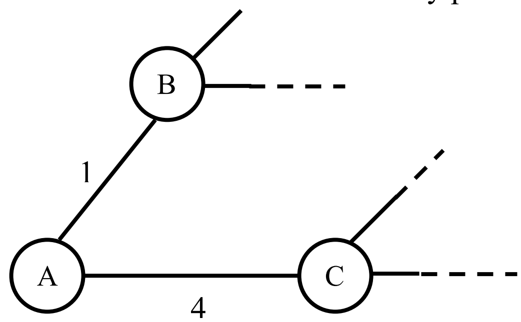
c) (6 pts) Even if the network is not congested, and the sending and receiving processes can write and read data arbitrarily fast, there is a limit to the throughput that TCP can provide. If the round trip delay is 100 msec, what is the maximum rate at which user data (not counting TCP and lower layer headers) can be transferred? (*Hint:* Field(s) and their lengths in the TCP header that you *may* need in answering this question are: Checksum (2 Bytes), Receive Window (2 Bytes), Sequence Number (4 Bytes), Urgent data pointer (2 Bytes).)

d) (10 pts) Consider the use of Go-Back-7 protocol for communication from Node A to Node B. Assume that when the sender reaches at the end of the window, i.e., all packets in the window are sent but not ACK'd, the sender goes to the beginning of the window and retransmits all packets in the window, as if the timeout occurred. In the following figure, indicate the sequence number (SN) for packets sent from A to B, the ACK number (ACKN) for packets sent from B to A, the times and SN of the packets at B delivered to the application layer, and the window kept at A. **Note that packets received during the transmission of another packet will be immediately processed, but the corresponding action, e.g., update of SN/ACKN, will take effect with the start of transmission of the next packet.**



2)

a) Consider the 3-node network fragment shown below which uses distance vector routing. As shown in the figure, node A has only two attached neighbors, B and C, with link costs of 1 and 4, respectively. B has a minimum-cost path to a destination network D of cost 5 and C has a minimum-cost path to D of cost 3. Node D and the paths from B and C to D are not shown in the figure. Assume that all link costs in the network have strictly positive integer values.



i) (4 pts) In the table below show A's routing table.

Destination	Cost	Next Router
B		
C		
D		

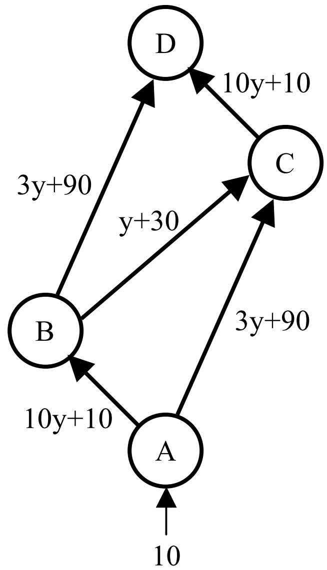
ii) (3 pts) Let c(X,Y) represent the link cost between nodes X and Y. Give a link-cost change for either c(A,B) or c(A,C) such that A **will** inform its neighbors of a new minimum-cost path to D.

iii)(3 pts) Give a link-cost change for either c(A,B) or c(A,C) such that A **will not** inform its neighbors of a new minimum-cost path to D.

b) (8 pts) You are the network administrator for University of "Best Students" (UBS), which owns the Class B address 172.118.0.0. UBS has a total of 11 departments: 5 departments each with 5000 hosts, and the remaining 6 each with 2500 hosts. Show in the following table how you will use subnetting to assign IP addresses to each department.

Department	# of hosts	Network number	Subnet Mask
1	5000		
2	5000		
3	5000		
4	5000		
5	5000		
6	2500		
7	2500		
8	2500		
9	2500		
10	2500		
11	2500		

c) Consider the 4-node network shown below. The delay on each link is illustrated in the figure as a function of the traffic carried over that link (y denotes the amount of traffic carried over a link). Node A has an incoming traffic with rate 10 packets/sec, which is destined for node D. Suppose node A routes each packet along the shortest path which is calculated at the time when the packet is to be routed, i.e., individual optimality is used.



i) (5 pts) First consider the network **without** link (B,C). Find the long-term average packet flow rates along the paths A-B-D and A-C-D when individual optimality is used. Calculate the average delay per packet from A to D for all packets routed from A to D.

ii) (8 pts) Now suppose link (B,C) (which becomes the fastest link in the network) is built with the recommendations of some "not-so-knowledgeable" network engineers. Find the long-term packet flow rates along the paths A-B-D, A-C-D and A-B-C-D when packets are routed along the shortest paths, i.e., individual optimality is used. Calculate the average delay per packet from A to D for all packets routed from A to D.

iii) (Bonus 8 pts) Based on your answers in parts i) and ii) above, do you observe any peculiarities? (This phenomenon is known as Brass' paradox in routing based on shortest paths, and it shows why proper network engineering is crucial for network performance.) **Partially correct answers will not be graded.**

3)

a) (6 pts) Explain why CSMA/CD cannot be used directly in wireless networks. **(Use at most three sentences.)**

b) (7 pts) Suppose the data bit sequence 110010010 is to be transmitted using the generator sequence 100000111. Compute the CRC bits and the transmitted bit sequence.

c) (6 pts) Consider a 100 Mbits/sec Ethernet segment having a length of d km with no repeaters. Assuming that the minimum frame size is 64 Bytes and that the propagation speed is $2.5\text{x}10^8$ m/sec, what is the maximum cable length d that can be supported for proper operation of the CSMA/CD protocol?

d) Consider a pair of stations A and B on a 10 Mbits/sec Ethernet. Suppose nodes A and B are involved in a collision which is the second collision for A and fourth collision for B. After the collision is detected (we assume that both nodes detect the collision exactly at the same time), both nodes calculate their backoff times according to the binary exponential backoff algorithm.

i) (6 pts) What is the probability that A will transmit before B in the next retransmission after the above collision?

ii) (5 pts) What is the probability that there will be another collision in the next retransmission after the above collision?