CS244A: An Introduction to Computer Networks

Problem Set #3: Due 12 noon, Wednesday March 12, 2008.

Your solution should be handed to Ann Coulthard in Gates 351 or posted under her door.

Show your reasoning clearly. If your reasoning is correct, but your final answer is wrong, you will receive most of the credit. If you just show the answer without reasoning, and your answer is wrong, you may receive no points at all. Hand in your solution on separate paper.

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1. **(30 points) TCP Congestion Control.** To control congestion, TCP varies the window size, *W*, depending on the current congestion in the network. In this question, we're going to assume a simplified model of TCP (ignoring, for example, slow-start) that follows two rules to control congestion:

   Rule 1: When a packet is successfully acknowledged: $W \to W + 1/W$.

   Rule 2: When a packet is dropped: $W \to \frac{W}{2}$.

   a. Sketch the evolution of *W* as a function of time, assuming that exactly one packet is dropped every time *W* reaches a maximum value, $\hat{W}$. Mark the axes of your graph as accurately as you can.

   b. Based on your sketch, derive an approximate expression for the throughput of a TCP flow as function of *p* (the loss probability) and *RTT* (the round-trip-time, which we will assume is constant). Explain your answer intuitively in words. Does it make sense?

   c. Explain how your result is changed if we also take into account how *RTT* changes with *W*.

2. **(20 points) Slotted ALOHA**. Problem P7 on Page 503 of Kurose and Ross.

3. **(20 points) CSMA/CD.** This question explores an *alternative* to CSMA/CD which attempts to decrease the minimum packet size, without expanding the network. We normally require for CSMA/CD that:

   $$TRANSP > 2\ PROP \qquad (1)$$

   a. Why is it important for a transmitting station to be able to detect a collision before it completes transmission?

   b. If we know that there is a minimum propagation time between adjacent nodes, $PROP_{MIN}$, how can we change equation (1) to decrease *TRANSP*, yet still allow a station to uniquely determine which packet collided? Determine the new relationship between *PROP* and *TRANSP*. Explain your new equation.

4. **(20 points) Token Passing Networks.** N computers are connected to the same shared bus network. Access to the bus is controlled by the Token Bus protocol. This protocol operates like the "release after transmission" (RAT) Token Ring protocol discussed in class. When computer C_i receives the token, it may hold the token while it transmits one packet. The computer then passes the token to the next computer on the bus, C_{i+1}. When the token reaches the computer C_N at the end of the bus, it is passed back to computer C_1 at the other end of the bus. We'll assume that: (i) the distance between each computer equals l meters, (ii) the speed of propagation along the bus is c m/s, (iii) it takes *PROP* seconds for a bit to propagate from C_1 to C_N, (iii) the average transmission time of a packet is *TRANSP* seconds, and (iv) the time taken to transmit the token is negligible.

   a. Find an expression for the efficiency of the Token Bus network when every computer has a packet to transmit. Express your answer in terms of N and $a = \dfrac{PROP}{TRANSP}$.

   b. Now consider an identical network in which the computers are numbered differently. Starting from one end of the bus, the computers are labeled: $C_1, C_3, C_5, \ldots, C_N, \ldots, C_6, C_4, C_2$. The distance between each computer is l meters. The token is passed between computers in the same order as before; i.e. when computer C_i receives the token, it may hold the token while it transmits one packet, then passes the token to computer C_{i+1}. When the token reaches computer C_N, it is passed back to computer C_1. *PROP* is now defined to be the propagation delay between C1 and C_2. Assuming that the number of computers, N, is an odd number, and that N is large, find the efficiency of this network. Has the efficiency increased or decreased? Explain your answer.

   c. Compare the efficiency of the Token Bus network in part (b), with the efficiency of a RAT Token Ring network: When N is large, how many times more efficient is the RAT Token Ring network than our Token Bus network? Express your result as a function of a. Briefly explain your result.

5. **(20 points) Noise.** We hire you as a consultant to help us design a digital library in which books are scanned, stored digitally and made available to users of the web. The library will contain ten million books; we will assume that each book contains 400 white pages containing black text. The text on each page covers 6"x6" and we will represent the text area using 300 dots per inch (dpi) vertically and horizontally. We will represent 1 "dot" with 1 bit and will not use any data compression techniques. We assume that 1,000 users access the library simultaneously and that they request a new page once per minute. The bandwidth

of the channel connecting the library to the side world is 100MHz, and has a capacity that is limited by Gaussian noise.

a. How many bytes of data storage are required on the disk?

b. What data rate is required to connect the library to the Internet?

c. What is the minimum signal to noise ratio that could possibly be tolerated on the channel? Express the signal to noise ratio as both a ratio and in dB.

d. We analyze the link, and find that it has a bit error rate (BER) of 10^{-9}. What packet size is required to ensure that the packet error rate (PER) is less than 10^{-5}. State any assumptions you make.

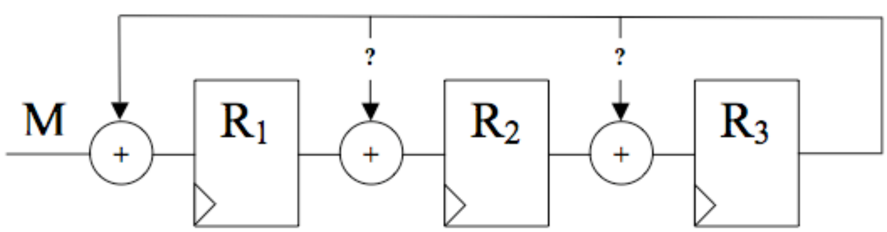
6. **(15 points) Elasticity Buffer.** An elasticity buffer is used to store bits arriving at a network interface. If the receiving station uses a 128-bit elasticity buffer and the clocks of the transmitter and receiver have a minimum frequency of 9.999MHz and a maximum frequency of 10.001MHz, then:

a. What is the tolerance of the clocks in parts-per-million?

b. How long can packets be without overflowing the elasticity buffer?

c. How long must the inter-packet gap be so as to guarantee that we drain the elasticity buffer before the next packet arrives?

7. **(15 points) CRC Calculation**. Consider the CRC circuit shown in the figure below:



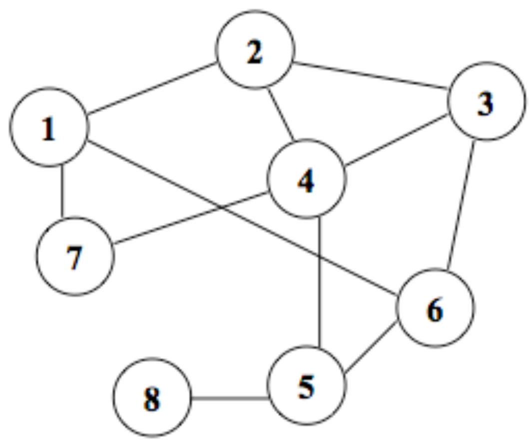
Time	**Output of Register R_1**	**Output of Register R_2**	**Output of Register R_3**	…
0	0	0	0	
1				
2				
3				
…				

a. Currently, the circuit is incomplete. You must draw the complete circuit so that it will correctly calculate a CRC with a generator of $G(x) = x^3 + 1$.

b. Copy and fill in the table in the figure to show the evolution of the circuit as it calculates the CRC value for the incoming message: M = 1101101. Make sure you evaluate and write down the remainder, *R*. (**Hint:** First, perform the long-division in the same way I did in class. Then watch how the circuit mimics the long-division, row-by-row).

c. Does this generator detect all single bit errors? Explain your answer.

8. **(20 points) Spanning Tree Algorithm.** Consider the switched Ethernet network topology with eight Ethernet switches shown below. The Ethernet switches use the spanning tree protocol. They switch off ports so as to create a spanning tree with switch "1" as the root of the tree.



a. Assume that all the Ethernet switches are powered on at exactly the same time, and exchange a message with each other every 5 seconds. How long before every switch knows that switch "1" is the root of the tree? Explain your answer.

b. Draw a new topology that shows the resulting spanning tree.

c. On a copy of the old topology, clearly mark which switch ports are turned off (for forwarding).

d. If a host connected to switch "8" sends a packet to a host connected to switch "7", which switches does the packet pass through on its way?

e. A few minutes after the algorithm has converged, the link between switches "1" and "2" breaks. If spanning tree control messages are sent every 5 seconds, how long before a new spanning tree is formed? Assume that if a switch doesn't receive a spanning tree control message from its neighbor for 10 seconds, it assumes its neighbor (or the link connecting them) has failed.