CS 536 Fall 2008 - Homework 4
Due 12/09/2008 in class

Problem 1 (20pts) Suppose three active nodes — A, B, and C — are competing for access to a channel using slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

1. What is the probability that node A succeeds for the first time in slot 4 ? [5pts]
2. What is the probability that some node (either A, B, or C) succeeds in slot 2 ? [5pts]
3. What is the probability that the first success occurs in slot 4 ? [5pts]
4. What is the efficiency of this three-node system ? [5pts]

Problem 2 (20pts): In this problem, you will derive the efficiency of a CSMA/CD-like multiple access protocol. In this protocol, time is slotted and all adapters are synchronized to the slots. Unlike slotted ALOHA, however, the length of a slot (in seconds) is much less than a frame time (the time to transmit a frame). Let S be the length of a slot. Suppose all frames are of constant length $L = kRS$, where R is the transmission rate of the channel, k is a large integer. Suppose there are N nodes, each with an infinite number of frames to send. We also assume that $d_{prop} < S$, so that each node can detect a collision before the end of a slot time. The protocol is as follows:

- If, for a given slot, no node has possession of the channel, all nodes contend for the channel; in particular, each node transmits in the slot with probability p. If exactly one node transmits in the slot, that node takes possession of the channel for the subsequent $k - 1$ slots and transmits its entire frame.
- If some node has possession of the channel, all other nodes refrain from transmitting until the node that possesses the channel has finished transmitting its frame. Once this node has transmitted its frame, all nodes contend for the channel.

Note that the channel alternates between two states: the productive state, which lasts exactly k slots, and the nonproductive state, which lasts for a random number of slots. Clearly, the channel efficiency is the ratio of $k/(k + x)$, where x is the expected number of consecutive unproductive slots.

1. For fixed N and p, determine the efficiency of this protocol. [5pts]
2. For fixed N, determine the p that maximizes the efficiency. [5pts]

3. Using the p (which is a function of N) found in (b), determine the efficiency as N approaches infinity. [5pts]

4. Show that this efficiency approaches 1 as the frame length becomes large. [5pts]

Problem 3 (15pts) Suppose two nodes, A and B, are attached to opposite ends of a 1800 m cable, and that they each have one frame of 1,000 bits (including all headers and preambles) to send to each other. Both nodes attempt to transmit at time $t = 0$. Suppose there are five repeaters between A and B, each inserting a 20-bit delay. Assume that the transmission rate is 10 Mbps, and CSMA/CD with backoff intervals of multiples of 512 bits is used. After the first collision, A draws $K = 0$ and B draws $K = 1$ in the exponential backoff protocol. Ignore the jam signal and the 96-bit time delay.

1. What is the one-way propagation delay (including repeater delays) between A and B in seconds ? Assume the signal propagation speed is $2 \cdot 10^8$ m/sec. [5pts]

2. At what time (in seconds) is A's packet completely delivered to B ? [5pts]

3. Now suppose that only A has a packet to send and that the repeaters are replaced with switches. Suppose that each switch has a 40-bit processing delay in addition to a store-and-forward delay. At what time, in seconds, is A's packet delivered to B ? [5pts]

Problem 4 (25pts) While it is standard to represent messages and the CRC generator G in terms of bit strings, another popular representation based on polynomials is probably better for analysis and is explained below. Consider two bit strings 101 and 011, we can represent them as $x^2 + 1$ and $x + 1$ respectively. Notice that if the i-th bit position is a 1, then we have a x^i term in the polynomial. Adding these polynomials using normal arithmetic is $x^2 + x + 2$, but in our case, we use mod 2 arithmetic (EX-OR). Thus, we can get rid of the painful carries and thus will lead to $x^2 + x$ in mod 2 arithmetic as a result of adding $x^2 + 1$ and $x + 1$.

1. In this polynomial arithmetic, a bit error at positions i correspond to adding x^i to the original polynomial. If the CRC polynomial $G(x)$ has at least two terms, is it possible that this sum of the message and the bit error is divisible by $G(x)$? Explain your answer using polynomial arithmetic ? [5pts]

2. Show that odd bit error polynomials (that is number of bit errors is odd, e.g., 1 bit error polynomial will be x^i, 3 bit errors will be $x^i + x^j + x^k$ and so on) are never divisible by $x + 1$. [Hint: Use the reduction $x^i + x^j = x^i(1 + x^{(j-i)})$ so you really need to check for reduced polynomials. Substitute $x = 1$ in the polynomial E and then use proof by contradiction] [10pts]

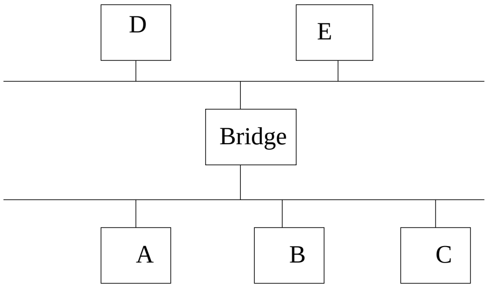
3. If the CRC generator polynomial is such that it is a multiple of $x + 1$, then can it catch all odd bit errors ? Justify. [5pts]

4. What do burst errors of length k starting at position i correspond to ? If $k \leq d$, where d is the degree of the polynomial, can we catch all k bit burst errors ? Justify. [5pts]

Problem 5 (10pts). It often happens that a node knows the higher layer address of another node and needs to know its Data Link address. Suppose someone builds an introduction service to do this, that works as follows. An intro server has a well known multicast address, say INTRO. A node X that wishes to know the Data Link address corresponding to higher level address H, sends a LAN frame with destination address INTRO and with its own source address X, but with H in the data portion of the frame. When the server gets the frame, it looks up the Data Link address corresponding to H (say Y). It then forwards the original frame to Y by changing the destination address from INTRO to Y . When Y gets the frame, Y knows Xs address from the source address and so can send a reply directly to X. When X gets such a reply, X also knows the Data Link address of Y. This protocol works fine on a LAN. But it can fail in an Extended LAN with transparent bridges.

1. Describe a topology and a scenario in which this protocol fails. [5pts]
2. How can you fix the introduction protocol to work in an Extended LAN? [5pts]

Problem 6 (10pts). A broadcast storm is an event that causes a flurry of messages. One implementation that caused broadcast storms was the Berkeley UNIX endnode IP implementation. In this implementation, an endnode attempts to forward a packet that it mysteriously receives with a network layer (IP) address that is different from itself. This is what you would do if you found a neighbors letter wrongly placed in your mailbox. However, this seemingly helpful policy can cause problems. Consider Figure 2 which shows 2 LANs connected by a bridge, with several IP endnodes on each LAN. There are no IP routers. All IP endnodes are configured to be on the same IP subnet. Suppose IP endnode A is incorrectly configured and incorrectly thinks its data link address is all 1s. The data link address of all 1s is the broadcast address: any packet sent to such an address is received by all stations on a LAN (it is the ultimate multicast address!).



1. What happens when another IP endnode B decides to send a packet to IP endnode A.? Assume that B initially does not have As data link address in its cache, and so must do the ARP protocol. Give the sequence of events. [5pts]
2. Suppose bridge B is replaced by an IP router. (Of course, the nodes have to be configured so that there are now two subnets.) The problem does not disappear but it does get a little better. Explain. [5pts]