HW #7

ELEN E4710 - Intro to Network Engineering Due 4/25/2002
Spring 2002 Prof. Rubenstein

Homework must be turned in at the beginning of class on the due date indicated above. CVN students have one additional day. Late assignments will not be accepted.

1. A sender S and receiver R use the Selective-Repeat protocol to communicate reliably across a network that drops or corrupts packets in each direction (from S to R and also from R to S) with probability p. Assume that the loss process is Bernoulli and that the sender never times out early (i.e., the sender does not retransmit a packet while a previous copy is heading to the receiver using the Selective-Repeat protocol or an acknowledgment for a previous transmission is on its way back to the sender).

   (a) Compute the expected number of times the sender transmits a particular packet (i.e., packet i for any i).

   (b) If the window size used by the protocol is w, and it takes time τ for a packet to be received and acknowledged when no loss or corruptions take place, give an upper bound on the maximum rate of the protocol. Explain why your result is an upper bound (hint: *at most* w packets can be transmitted at any given time).

2. Assume S and R communicate in a networking environment similar to that in problem 1. The reliable data transfer protocol used is Go-back-N, where packets that are received out of order are dropped by the receiver (i.e., packet $i + 1$ is accepted only if packet i has already been receieved). Assume the sender and receiver communicate in rounds where each round, the sender sends the w packets that are currently in its window.

   (a) Assuming ACKs are never lost, compute the expected number of packets accepted by the receiver each round.

   (b) Suppose the receiver responds each round by sending a single ACK (at the end of the round) indicating the largest sequence number it has accepted, and that this ACK is lost with probability p. Let R be a r.v. that equals the number of packets accepted by the receiver between the time the sender receives acknowledgments. Let N be the number of rounds that take place until the sender receives an acknowledgment. Compute $E[R]$ and $E[N]$.

   (c) (Extra Credit) The expected number of transmissions per round is $E[R]/E[N]$ (and not $E[R/N]$). Why?

3. Consider a reliable data transfer protocol that transfers data using a window of size w in an environment in which packets can be lost, but cannot be reordered. The protocol uses a sequence numbering scheme that goes from 0 to $n-1$, such that packet representing the ith segment of data is assigned sequence number $i \pmod{n}$. If n is too small, the receiver might mistake one data packet for another. For instance, if $n < w$, then the receiver might mistake packet n (which has sequence number 0) as a retransmission of packet 0, which also has sequence number 0, as both packets could be in the window at the same tim. Show that a receiver can make such an error when

   (a) The protocol is Selective Repeat and $n = 2w - 1$.

   (b) Go-Back-N (assume the receiver discards any packets that cause a gap in the received sequence) and $n = w$.

4. A sender wishes to perform reliable communication with two receivers simultaneously. Upon receiving a packet, a receiver sends an ACK if the packet is received uncorrupted. Otherwise, it sends a NAK if the packet is corrupted. A receiver's acknowledgment can be corrupted as well. Each receiver's acknowledgment arrives at the sender as an uncorrupted ACK independently with probability p (i.e., After sending a packet to a receiver, the sender "knows" with probability p that the receiver successfully received the packet.) Assume that the sender can determine from which receiver an arriving acknowledgment belongs to (e.g., it can make the determination from the source address of the acknowledgment packet.)

   (a) Is it sufficient to have just two sequence numbers (i.e., just using sequence numbers 0 and 1 for packets) as is sufficient in the single-receiver case? Explain how two can be used or give a counter-example showing that two is not sufficient.

   (b) Consider the reliable transmission of a *single* packet over a series of rounds. The following lists three algorithms used by the sender to handle receiver acknowledgments. In each algorithm, at the start of each round, if the sender's state indicates that some receiver has not acknowledged receipt, then the sender retransmits the packet to *both* receivers. The round ends with the sender receiving and processing feedback from the receivers. For each of the following algorithms, indicate whether or not the algorithm is correct (i.e., that it always reliably delivers the packet to both receivers.) If not, give a scenario where it fails. If it is correct, do both of the following: draw the finite state machine for the sender that indicates its state during the transmission of the packet. Also, let R_i be a random variable that equals the number of rounds required to reliably deliver the packet to both receivers. Compute $E[R_i]$.

      i. A single bit is initially set to 0, and is set to 1 when an uncorrupted ACK is received from *either* receiver within a round. The sender stops transmitting the packet once the bit is set to 1.

      ii. A single bit is initially set to 0, and is set to 1 when uncorrupted ACKs are received from both receivers in a single round. The sender stops transmitting once the bit is set to 1.

      iii. 2 bits are used, one for each receiver. Both bits are initially set to 0. When an uncorrupted ACK is received from a receiver, that receiver's bit is set to 1. The sender stops transmitting once both bits are set to 1.