HW #3

COMS W4119 - Computer Networks — Due Feb 22, 2006 (revised)
Spring 2006 — 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. Suppose the sequence numbering scheme used in a reliable transport protocol uses the packet sequence number modulo s. Let w be the size of the window for the protocol. Assume there is no packet reordering. Prove

   - $s \geq 2w$ for selective repeat and Go-Back-N when the client buffers packets received out-of-order (due to loss, not reordering in the network).
   - $s > w$ for Go-Back-N when the client drops any packet received out-of-order.

   The following steps will help guide you through the proof. For all steps, we will prove the result by contradiction. Assume that the sender and receiver get "mixed up" and some packets get improperly ACK'd. Let i be the smallest numbered packet sent by the sender that exhibits such a mix-up, and let ℓ be the sequence number of this packet. Note that your proofs **should not** substitute numerical values for i, ℓ, or w.

   (a) Case $s = 2w$ where out-of-order packets are buffered. Suppose i is sent and the receiver sends an ACK thinking the packet is $i - 2w$. Explain why this cannot happen.

   (b) Again, case $s = 2w$ where out-of-order packets are buffered. Suppose i is sent and the receiver sends an ACK thinking the packet is $i + 2w$. Explain why this cannot happen.

   (c) Case $s = w + 1$ where out-of-order packets are not buffered. Suppose i is sent and the receiver sends an ACK thinking the packet is $i - w + 1$. Explain why this cannot happen.

   (d) Again, case $s = w + 1$ where out-of-order packets are not buffered. Suppose i is sent and the receiver sends an ACK thinking the packet is $i - w - 1$. Explain why this cannot happen.

   (e) Give a short (1 or 2 sentence) explanation why the above proof holds not only for the case where $s = 2w$ ($s = w + 1$), but also for all cases where $s \geq 2w$ ($s > w$).

2. Give an example in a network where packets are lost and delayed, but not reordered where:

   (a) $s = 5$ and $w = 3$ using selective repeat (or Go-Back-N with buffering out-of-order received packets), where the sender and receiver get "mixed up".

   (b) $s = 5$ and $w = 5$ using Go-Back-N without buffering out-of-order received packets, where the sender and receiver get "mixed up".

3. A sender multicasts data to two receivers, numbered 1 and 2. Since the sender is always multicasting, each transmission by the sender always goes toward both receivers. However, that transmission can be arbitrarily delayed (but not reordered), and can be lost at either of the receivers or at both. Suppose the receivers implement the alternating bit protocol discussed in class, where the ACK from a receiver indicates not only the sequence number (0 or 1) but also the identity of the receiver (1 or 2). If packets can be lost or delayed but not reordered, draw the sender's finite state machine to communicate with these two receivers. Use the following action and response functions:

   - $r_i(j)$: sender receives an ACK from receiver i with sequence number j.
   - $S(j)$: multicast a new packet with sequence number j.
   - $\sigma(j)$: re-multicast the previous packet with sequence number j.

   Hint: your state machine will need to keep track of when only one of the receivers has ACK'd the packet the sender is currently trying to deliver to both receivers.

4. Suppose an LDPC code is constructed over N data symbols. Suppose k symbols have already been decoded and the coding buffer is empty (the receiver has no codewords formed from any missing data symbols).

   Suppose a codeword of degree ℓ is received. What is the probability that this codeword can be decoded immediately to provide an additional data symbol to the receiver.

5. Suppose the packet loss is Bernoulli (i.e., packets are lost independent of previous losses) with probability p. Suppose Reed-Solomon packet-level FEC is employed to protect k packets, where $n - k$ additional "repair" packets are generated. All n packets are sent only once.

   (a) Suppose n could be infinite. What is the expected (average) number of data plus repair packets that are sent to recover the k data packets.

   (b) Suppose n is finite. What is the probability that the data is recovered.