HW #4 Solutions

CSEE 4119 - Computer Communication Networks — Due 10/18/2016
Fall 2016 — Prof. Rubenstein

1. A connection is using a window-based reliability protocol with a window of size N. The lowest-sequenced packet in the receiver's window has sequence number s. What are the ranges of the lowest sequence number in the sender's window?

   Answer: The receiver has received all packets up to $s-1$ but not packet s. The sender could not have possibly received an ACK for packet s, hence s must still be in the sender's window, making the lowest sequence number less than $s+1$. Similarly, since the receiver received packet $s-1$, packet $s-N-1$ can no longer be in the sender's window (else the sender could not have sent packet $s-1$).

   Thus, the lowest sequence number in the sender's window can range from $s-N$ to s. If the sender has received acknowledgments for all packets up to $s-1$, the window is at s. It is also possible that the last packet for which the sender received acknowledgment is $s-N-1$. In this case, the N packets $s-N, s-N+1, \cdots, s-1$ have all been sent and received, but if none are acknowledged, the sender's window is stuck containing $s-N$.

2. Suppose a network drops data packets with probability p, and suppose there is a round trip time of T from source to destination and back.

   (a) If ACKs are never dropped, what is the expected number of times a given packet is transmitted using selective repeat with window size N?

   Answer: A packet will need to be transmitted on average $1/(1-p)$ times until it is received. Since each packet is ACK'd individually, this is the expected number of transmissions.

   (b) Same as above, except ACKs are also dropped with probability p.

   Answer: A packet is retransmitted if either it or its ACK are dropped. p should be replaced with $2p-p^2$, i.e., the probability that either the packet or the ACK is dropped, making the answer $1/(1-2p+p^2)$.

   (c) Same as part (a), except compute an upper bound for Go-Back-N. Do this by assuming that when a packet enters the window, none of the $N-1$ preceding packets have yet been received.

   Answer: Consider the packet that is lost the most within this window, and needs to be transmitted j times. Then the last packet will be transmitted j times as well. Hence, the probability that the last packet is transmitted more than j times is the probability that *some* packet in the window is lost more than j times. This makes the solution

   $$\sum_{j=0}^{\infty}(1-(1-p^j)^N)$$

   .

3. Suppose each packet that is received and ACK'd requires a fixed time T to complete, and there is no reordering of data packet arrivals, and there is no ACK loss. Consider Selective Repeat and Go-Back-N, each implemented with the same window size, N.

(a) Which will deliver data faster to the client?

Answer: They deliver at the same rate. One needs to watch the movement of the sender window. Whenever Go-Back-N moves the window from position x to y, it means that prior to x being received, all packets $x+1, \cdots, y-1$ were already received. Hence, they would have all been ACK'd as well in selective repeat so selective repeat's window would keep up with Go-Back-N. Similarly, when selective repeat moves the window forward from x to y, it means the same thing (all packets $x+1, \cdots, y-1$ were already received), so GBN would also move the window the same distance.

(b) If there is ACK loss, which has a higher rate?

Answer: Go-Back-N: when the ACK is received that moves the window, it moves the maximum distance, whereas Sel-repeat might only move it partially due to some missing ACKs.

4. Use Little's Law to solve the following problem: Selective Repeat is used with a window-size of N in a network where data packets are lost with probability p. Suppose the time it takes the sender receive an ACK for a delivered packet averages to T seconds, and the time to "timeout" upon not receiving an ACK for a packet is τ seconds. If data is delivered at a rate of λ packets / second, how many packets in the window are on average already received and acknowledged?

(a) Assume ACKs are not lost.

Answer: Let X be the number of packets in the window not yet acknowledged. Then, by Little's law, $E[X] = \lambda E[S]$ where S is the time a sender waits for a given transmission. Packets lost (with probability p spend time τ on average, and those not lost (probability $1-p$) spend time T on average. Hence the overall average time spent is $p\tau + (1-p)T$. Applying Little's Law, we get that $E[X] = \lambda(p\tau + (1-p)T)$. The average number of packets already received and acknowledged is $N - E[X] = N - \lambda(p\tau + (1-p)T)$.

(b) Assume ACKs are also lost with probability p.

Answer: In this case, instead of the probability of not receiving a transmission being p, it is $2p - p^2$, changing the solution to $N - E[X] = N - \lambda((2p-p^2)\tau + (1-2p+p^2)T)$.