Problem Set 7

Due date: Wednesday, May 4

You will hand in your solution using SVN. Follow the instructions on Piazza to add and commit new files.

TCP Congestion

1. Consider a TCP system implementing slow start and congestion avoidance with fast retransmit and fast recovery. When a connection is setup the congestion window is initialized to one segment and the slow start threshold to 64 segments. To simplify the problem, assume that the timeout is equal to the RTT (an exact estimate) and specify time in units of RTT, such that one time slot is one RTT.

Packet transmissions are such that at each time slot the sender sends all packets in the congestion window. If ACK's are received in the next time slot, there is no timeout. In addition, to simplify matters either the entire window is acknowledged or none of its segments are acknowledged.

For a particular connection, ACK's are received in time slots 1-9, 11-18, 20-23, 25-45, and 47-50. Timeouts occur in slots 10, 19 and 24; in slot 46, three duplicate ACK's are received for the packets sent in time slot 45.

For the system described, plot both the congestion window and the slow start threshold (on the same graph) versus time (slots), between slots 0 and 50. The values for each slot are the ones that the CW and the threshold assume at the end of the slot. Remember to consider the differences between slow start and congestion avoidance with fast retransmit and fast recovery when changing the congestion window. Ignore the value of SWS.

Random Early Detection

2. Consider a RED gateway with MaxP = 0.06, and with an average queue length halfway between the two thresholds MinThreshold and MaxThreshold.

   a. Find the drop probability $P_{\text{count}}$, for count = 1 and count = 20

   b. Calculate the probability that none of the 20 packets are dropped. (Describe the method, and provide a numerical result approximate to the 4th decimal place)

TCP and Network Delay
3. Consider the following two causes of a 2-second network delay (assume ACKs return instantaneously).

   • One intermediate router with a 2-second outbound per-packet bandwidth delay and no competing traffic.

   • One intermediate router with a 100-ms outbound per-packet bandwidth delay and with a steadily replenished (from another source) 20 packets in the queue.

   a. How might a transport protocol in general distinguish between these two cases?

   b. Suppose TCP Vegas sends over the above connections, with an initial CongestionWindow of 3 packets. What will happen to CongestionWindow in each case? Assume BaseRTT = 2 second and \( \beta \) is one packet per second.

**Fair Queueing**

4. Suppose that the following packets arrivals:
   - Flow 1: A:5, B:4, C:6, D:7
   - Flow 3: J:1, K:5, L:1, M:1, N:6, O:5, P:4
   - Flow 4: Q:6, R:6, S:6, T:5

   Assume that at the current time, all the packets have arrived and are now sitting in the per-flow queues. The number after the colon is the size of the packet, so packet A is 5 units in size.

   a. List the order of departure of these packets under the packetized weighted fair queuing scheme, with equal weights for each flow. Break ties by going with the lowest-numbered flow.

   b. Now list the order of departure assuming that the four flows have weights 3, 1, 2, 1 respectively.

**TCP Slow Start**

3. Although slow start with congestion avoidance is an effective technique for coping with congestion, it can result in long recovery times in high-speed networks.

   a. Assume a RTT delay of 80 ms and a link with an available bandwidth of 1 Gbps and a segment size of 1024 bytes. Determine the window size needed to keep the pipe full and the time it will take to reach that window size after a timeout using the Jacobson Algorithm, assuming that the sender was transmitting at the full window before the timeout,

   b. Repeat for a segment size of 16 Kbytes. (Assume 1K = 1024)