COMP 431 — INTERNET SERVICES & PROTOCOLS

Spring 2020

Homework 6, April 3

Due: 10:30 am, April 14

Note: Late solutions for this assignment ***cannot*** be accepted.

Note:

- Please typeset your answers and submit on Gradescope.
- Please include detailed steps and explanations.

1. Suppose Host C runs a web server on port 80. Assume that the server uses persistent HTTP connections and is currently receiving requests from Clients A and B.
   a) Provide possible source and destination port number for:
      1) Segments sent from A to C
      2) Segments sent from B to C
      3) Segments sent from C to A
      4) Segments sent from C to B
   b) Are all of the responses being sent through the same socket at Host C?
   c) If A & B are different hosts, is it possible that the source port numbers in the segments from A to C is the same as that from B to C?
   d) If A & B are the same host, is it possible that the source port numbers in the segments from A to C is the same as that from B to C?

2. Can a 1-bit error go undetected with TCP checksum? Can a 2-bit error go undetected with TCP checksum?

3. Assume that Client A wants to simultaneously send packet to Clients B and C (all are on different hosts). A is connected to B and C via a broadcast channel (a packet sent by A is carried by the channel to both B and C). Assume that the broadcast channel connecting A, B, and C can independently lose and corrupt packets (e.g., a packet sent from A might be correctly received by B, but not by C). Design a stop-and-wait-like protocol for reliably transferring packets from A to B and C, such that A will not get new data from the upper layer until it knows that both B and C have correctly received the current packet. Provide Finite State Machine descriptions for A and C (the state machine for B would be essentially the same as for C). Also provide a description of the packet formats used.

4. Consider a sender that uses the Selective Repeat protocol. Assume that the medium does not reorder messages. Assume that the sender has a window size of N=4 and a sequence number range of 1024. Now suppose that a time t, the next in-order packet that the receiver is expecting has a sequence number of k. Answer the following (with justifications):
   a) At time t, what are the possible sets of sequence numbers inside the sender's window?
   b) At time t, what are the possible values of the ACK field in all possible messages currently propagating back to the sender?

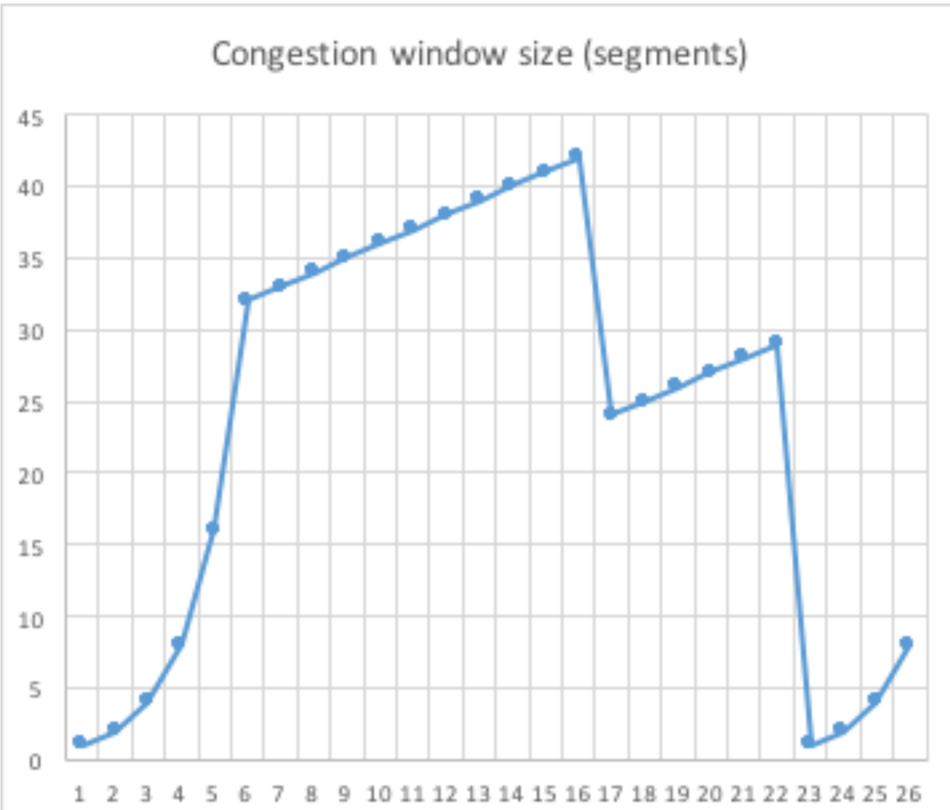
5. Consider the procedure used in TCP for estimating the RTT of a connection. Suppose that $x = 0.1$. Let SampleRTT_1 be the most recent RTT sample, and let SampleRTT_2 through SampleRTT_4 be the next 3 most recent samples. For a given connection, suppose four ACKs have been returned and that the four RTT samples previously mentioned have been generated. Express EstimatedRTT in terms of the four sample RTTs. Next, generalize your expression for n sample RTT values. If you then let n approach infinity in the general formula, comment on why this averaging procedure is called an "exponential moving average."

6. Consider two hosts A and B that use one of the 3 protocols – TCP (without any delayed ACK), Go-Back-N, or Selective Repeat. Assume that the retransmission timeout values used by all three protocols are sufficiently long such that 5 consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving Host B and the sending Host A, respectively. Suppose Host A sends 5 data segments to Host B and the second segment is lost. In the end, each of the three protocols ensures that all 5 segments have been correctly received by Host B.

   a) For each of the three protocols – how many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their sequence numbers?

   b) If the timeout values are much longer than 5 RTTs, then which protocol successfully delivers all five data segments in the shortest time interval.

7. Consider the following plot of congestion window size versus transmission round. Assume TCP Reno is being used, answer with justification the following questions:



   a) Identify the time intervals when Slow Start is operating.

   b) Identify the time intervals when Congestion Avoidance is operating.

   c) After the 16th transmission round, is segment loss detected by triple duplicate ACK or timeout?

   d) After the 22nd transmission round, is segment loss detected by triple duplicate ACK or timeout?

   e) What is the initial value of ssthresh at the first transmission round?

   f) What is the value of ssthresh at the 19th transmission round?

   g) What is the value of ssthresh at the 25th transmission round?

   h) During which transmission round is the 80th segment sent?

   i) Suppose that a packet loss is detected after the 26th round by the receipt of triple duplicate ACKs. What will be the values of the congestion window size and ssthresh?

8. The analysis for dynamic congestion windows that we presented in lecture implicitly assumed that there was only a single network link between the sender and the receiver. Redo the latency analysis for sending an object of O bytes assuming that there are T links between sender and receiver. To simplify the analysis, assume all links have the same transmission speed and that there is no congestion in the network (*i.e.*, that there are no queuing delays at any network interconnection point).

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Recall that the RTT is simply the total propagation latency on the round-trip path. You may also ignore the processing overhead at each network interconnection point.

9. Consider a web browsing session on a network where a user requests a page with 10 embedded, 5 Kbyte images (assume that the base page is also 5 Kbytes long). Assume a TCP implementation with an *MSS* of 536 bytes (a common *MSS* in many TCP implementations). For each of the questions below, consider networks with bandwidths of 54 Kbps, 100 Kbps, 1 Mbps, and 10 Mbps.

   a) Assuming a round-trip-time of 100 *ms*, construct a chart that compares the response time for retrieving the web page and its embedded object under a persistent and a non-persistent HTTP connection.

   b) Construct a second response time chart assuming an *RTT* of 1 second.

   c) Consider now a browser using parallel non-persistent HTTP connections (recall that this is the most common use of HTTP). Let x denote the maximum number of parallel connections the browser is permitted to open to a given server. A browser will first open an HTTP connection to retrieve the base page and then upon receiving and parsing this file, the browser will initiates x parallel connections to retrieve the embedded objects. Show that the response time for the download of the web page and its contents is of the form

   $$(M+1)O/R + 2(M/x + 1)RTT + SSL$$

   where M is the number of embedded objects, O is the size of an embedded objects (assumed to be a constant for all embedded objects), R is the capacity of the link connecting the browser to the server, and SSL is the latency of TCP slow-start due to server stalling.

10. Suppose that TCP increased its window size by three segments rather than one for each ACK received during slow-start. In this scenario the first window would consist of 1 segment, the second window would consist of 4 segments, the third window would consist of 16 segments, *etc*. For the variables K, P, and Q, used in the analysis of TCP latency:

    a) Express K in terms of O and S.

    b) Express Q in terms of RTT, S, and R.

    c) Express the latency of a TCP connection in terms of P, O, R, and RTT.

11. Consider a modification to TCP's additive-increase, multiplicative-decrease congestion control algorithm wherein a connection reduces the threshold by a constant amount upon detecting packet loss rather than by reducing the threshold to one-half of the current congestion window. Would the resulting additive-increase additive-decrease algorithm retain the property that a set of two connections sharing a link would receive roughly equal shares of the link's capacity? Does your answer depend on the initial rates (starting point) of the two connections? Explain.

A Reminder on the Honor Code

Students are *encouraged* to work together on this homework assignment. *Acceptable collaboration* includes:

- Discussing the assigned problems to understand their meaning,
- Discussing possible approaches to assigned problems,

In *all* cases you must *explicitly* acknowledge *any and all substantive help received from other individuals* during the course of the preparation of your homework solution. That is, if you collaborate with other individuals then you *must* include an explicit acknowledgment in your homework solution of the persons from whom you received aid. You should include the acknowledgement with your Honor Code pledge. Acknowledging others, if done properly, will not adversely affect your grade.

Unacceptable collaboration on written homework includes:

- Copying (verbatim use) of physical papers or computer files,[1] and
- Submission of solutions that are jointly authored, or authored either wholly or in part by other individuals.

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[1] This includes computer files that are copied and then edited and/or reformatted.

The general rule to be followed is that the strategy and approach of solutions may be developed jointly but *all* actual solutions (*i.e.*, the final solution) must be *constructed* and *written up* individually. Work done jointly should not be done in sufficient detail as to make it a final solution. For example, solutions may *sketched* out jointly, however each student must construct the final form of their solution individually and write-up their own solution. Should questions arise the course of working on a problem please feel free to immediately contact the instructor either by telephone, electronic mail, or by an office visit. In principle, if you work with others in good faith and are honest and generous with your attributions of credit you will have no problems.