CS 653 Mobile Computing *Spring 2014*

Problem Set 4 Solutions

Problem 1 [5 marks]

Consider a transport flow from a fixed host A, to a wireless client C, via an access point B. The transport protocol running at A is a TCP-like protocol that keeps a window of unacknowledged packets and waits for ACKs from the receiver C. However, unlike TCP, the protocol uses a fixed window value. The one-way delay between A to B and between B and A for all packets is 100 ms each. The wireless link between B and C is the slowest link on the path. The bottleneck link B-C can transmit data packets at the rate of 100 packets/second. (Assume that the data packet size is fixed, so that data can be measured in terms of packets rather than bytes for ease of calculations.) Assume that the reverse link between C and B can send ACKs at a very fast rate with negligible transmission time. Assume that node B has an infinite buffer to store any number of packets that come from A.

a. What is the minimum RTT of a packet between A and C, considering the delay between A-B and the transmission time on the B-C link, and the time taken for an ACK to get back to A?
b. What is the minimum number of unacknowledged packets that A must send in order to fully utilize the bottleneck link? What is the throughput of the transfer in packets/second when A maintains this minimum number of packets in its window?
c. Suppose A maintains a fixed window of 10 packets. What is the average RTT (i.e., the average time from a packet being sent to an ACK coming back) of the packets? And what is the average throughput of the transport flow in packets/second?
d. What is the answer to part (c) if A maintains a fixed window of 50 packets?
e. Generalize the answer to parts (c) and (d) above and come up with an expression for the average RTT and throughput of the data transfer when A maintains a fixed window of N packets. Your answer should handle all possible values of N (you may have different answers for different ranges of N). Plot your answers (i.e., the values of average RTT and throughput) as a function of N.

Solution

a. Minimum RTT = time on A-B for data (100 ms) + transmission time on B-C (10 ms) + time for ACK to get back (100 ms) = 210 ms.
b. Min no. of packets to utilize bottleneck link = bandwidth delay product = 100 packets/s * 210 ms = 21 packets. When there are 21 packets in the window, the bottleneck link will be just utilized, and the throughput is 100 packets/s.
c. If A maintains a window of 10 packets, then each packet will see an RTT of 210 ms. Initially, if A sends out the first 10 packets in a burst, these first few packets may see longer RTTs, because they may be queued behind each other. However, in the steady state, ACKs come back every 10

ms, so A releases one new packet every 10 ms. In this state, each packet will arrive to an empty queue at the bottleneck link, and hence will see zero queueing delay.The throughput in this case is 10 packets every 210 ms, or 47.6 packets/s.

d. If A maintains a window of 50 packets, in the steady state, there will be 21 packets in the pipeline and 29 packets in the bottleneck buffer at any point of time. So each packet will see an RTT of 200 ms (on A-B) + 10 ms (on B-C) + 29*10 ms (queueing delay) = 500 ms. The throughput will be the bottleneck rate of 100 packets/s, since the bottleneck link is fully utilized.

e. Generalizing the two cases above, the following are expressions for RTT and throughput when there are N packets in the window.
If N <= 21, RTT = 210 ms. Throughput = N/0.21 packets/s.
If N >= 21, RTT = 200 + (N-20)*10 ms. Throughput = 100 packets/s.