TCP Congestion Control

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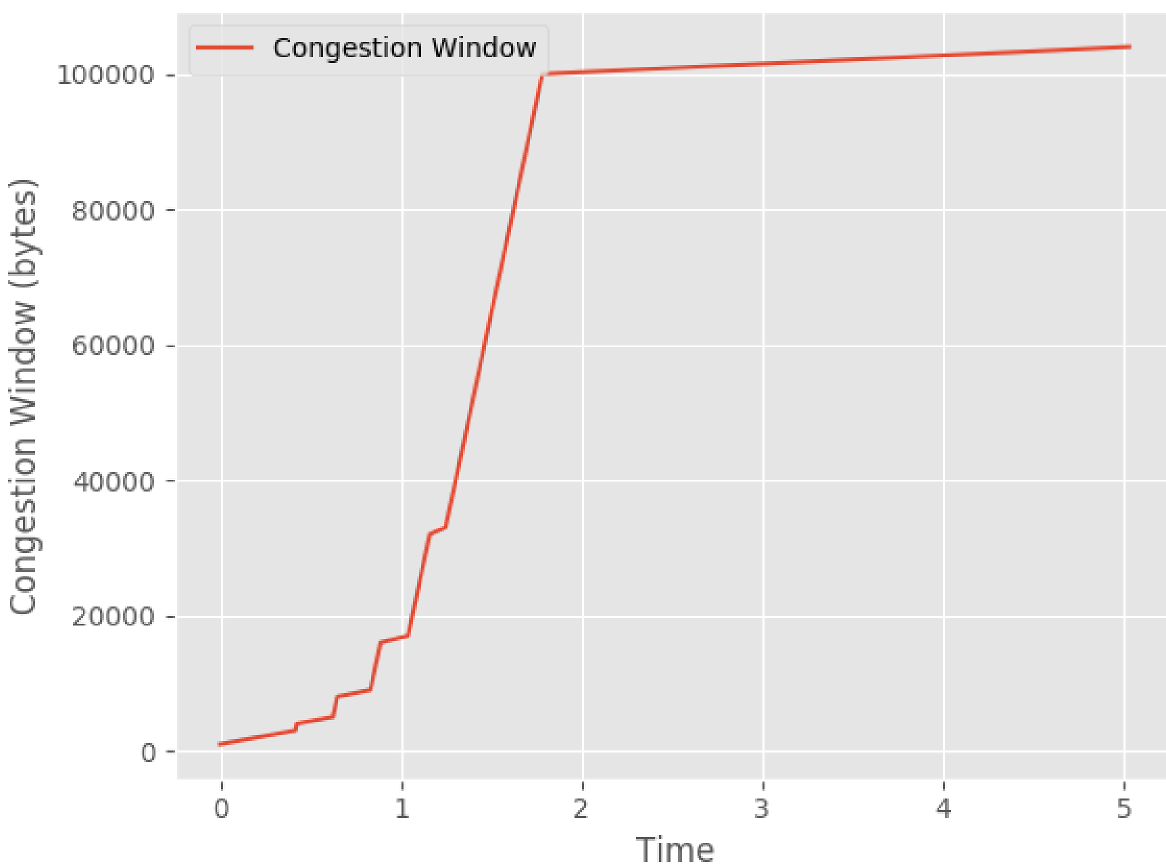
1 Test 1

The first test run was just a simple file transfer on a basic, one-hop network. After integrating TCP Tahoe congestion control into the TCP implementation, a large pdf file was transferred with no loss on a 10Mbps link with a 100ms propagation delay. During this test, every change in the size of the congestion window was logged with the simulation time and the size of the window. The maximum segment size was set to 1,000 bytes, and the initial slow start threshold was set to 100,000 bytes.

1.1 Results



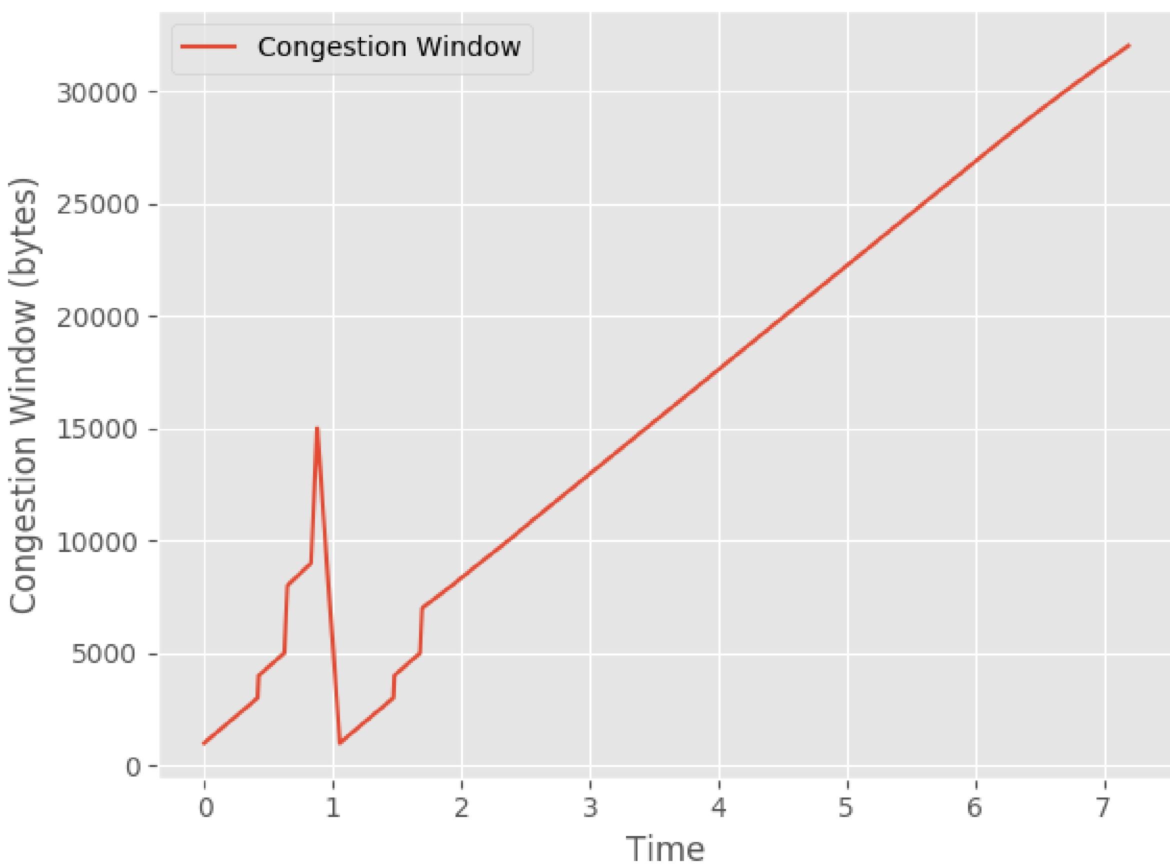
1.2 Analysis

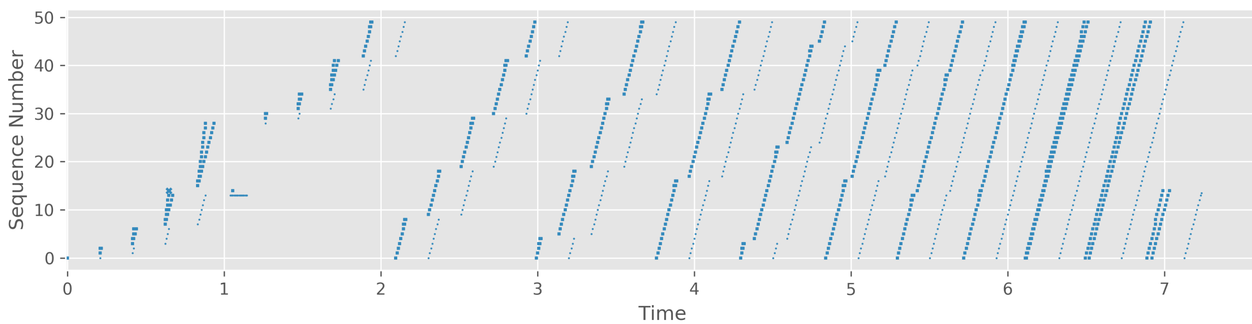
This test and the data produced show the effect slow start has on the growth rate of the congestion window size. The distinction between exponential and additive increase noticeable. Just before 1.5 seconds into the simulation, the congestion window size reaches the threshold, and additive increase begins. Before 1.5 seconds, the growth was clearly exponential. Once the threshold is reached, additive increase causes a more gradual linear growth. The steps in the graph are due to the latency on the link. With a 100ms propagation delay, the round trip time is 200ms. This means the first packet sent out from the window will be acknowledged 200ms later, while the rest of the ACKs for packets in that same window are received in quick succession after the first. The jumps indicate each packet from one window being acknowledged rapidly, and the size of the window is shown to double each "cycle" until the threshold is reached.

2 Test 2

After a simple test with no loss, the file transfer was repeated, however, this time, sequence number 14,000 was dropped. After this loss, no other loss event occurred. This test serves to illustrate the effect of packet loss on this implementation of TCP.

2.1 Results





2.2 Analysis

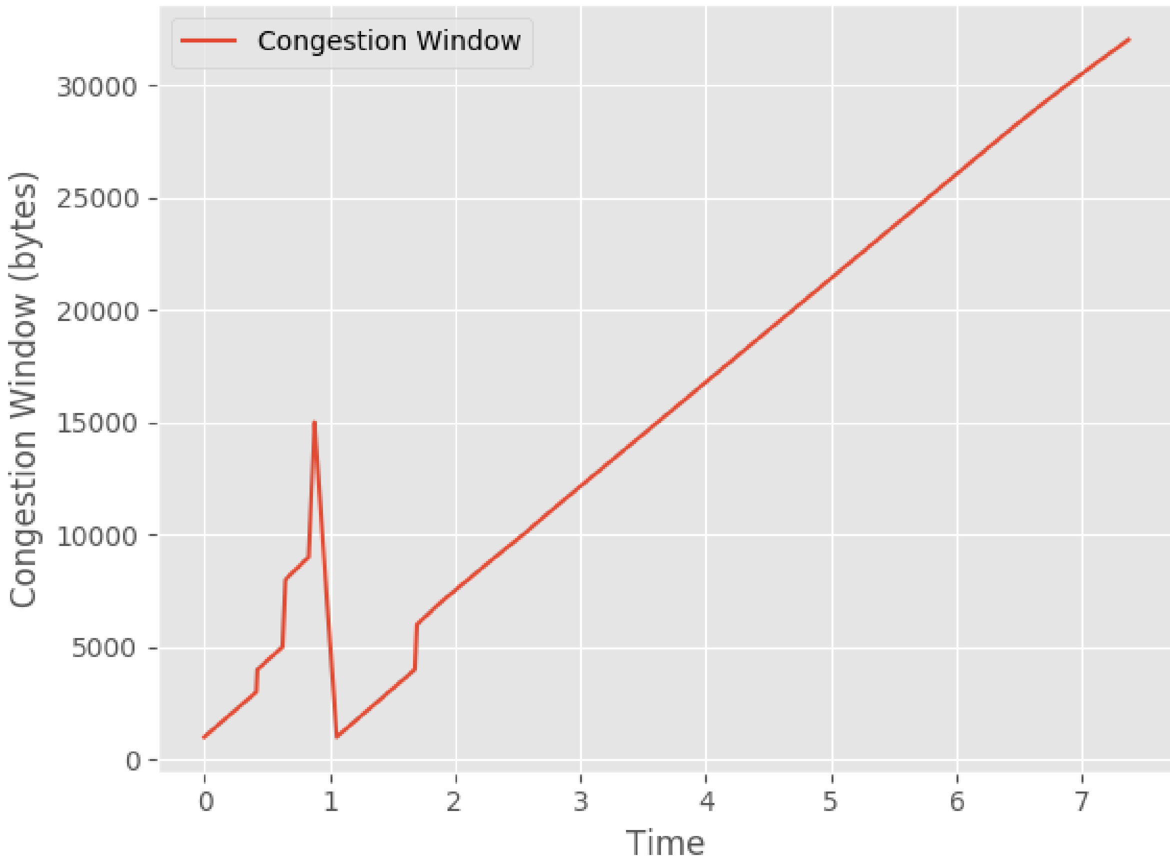
Just from the congestion window plot, it is evident that the loss of a single packet affects congestion window growth a great deal. Because this loss occurred during slow start, not only is the congestion window size reset, but the slow start threshold is set very low. During the second slow start period, this threshold is reached very quickly, and additive increase is started when the congestion window size is only 7,000 bytes. All of this has the effect of the congestion window never coming close to reaching the size it reached in the first test. Instead, the size of the congestion window at the end of the second test is about one third the size it was in the first test.

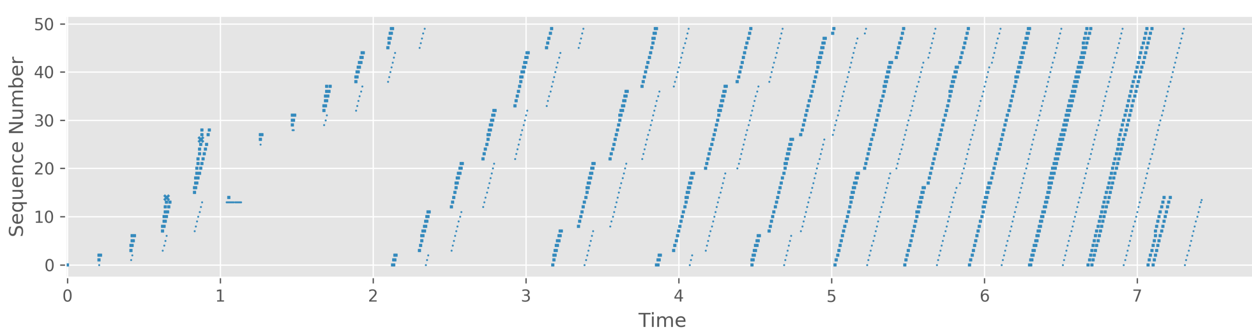
The sequence plot appears as expected - the points grouped in lines reflecting the packets sent in one window. At the end of the third group, the packet is dropped. As the ACKs are received for that window, the next window begins transferring as well, until the third duplicate ACK is received. This triggers slow start again, and since only one packet was dropped, the ACK that is received while the window is still just 1,000 bytes acknowledges the next window as well, not just the dropped packet. So slow start continues from the next window, until additive increase takes over just before 2 seconds into the simulation. From this point on, the window only grows by one MSS each time an entire window is acknowledged. This also matches the graph from Kevin Fall and Sally Floyd's graph on the same topic from their paper about SACK TCP.

3 Test 3

The same configuration was used for the third test instead of a single loss, two packets were dropped. In addition to sequence 14,000, sequence 26,000 was also dropped in this test.

3.1 Results





3.2 Analysis

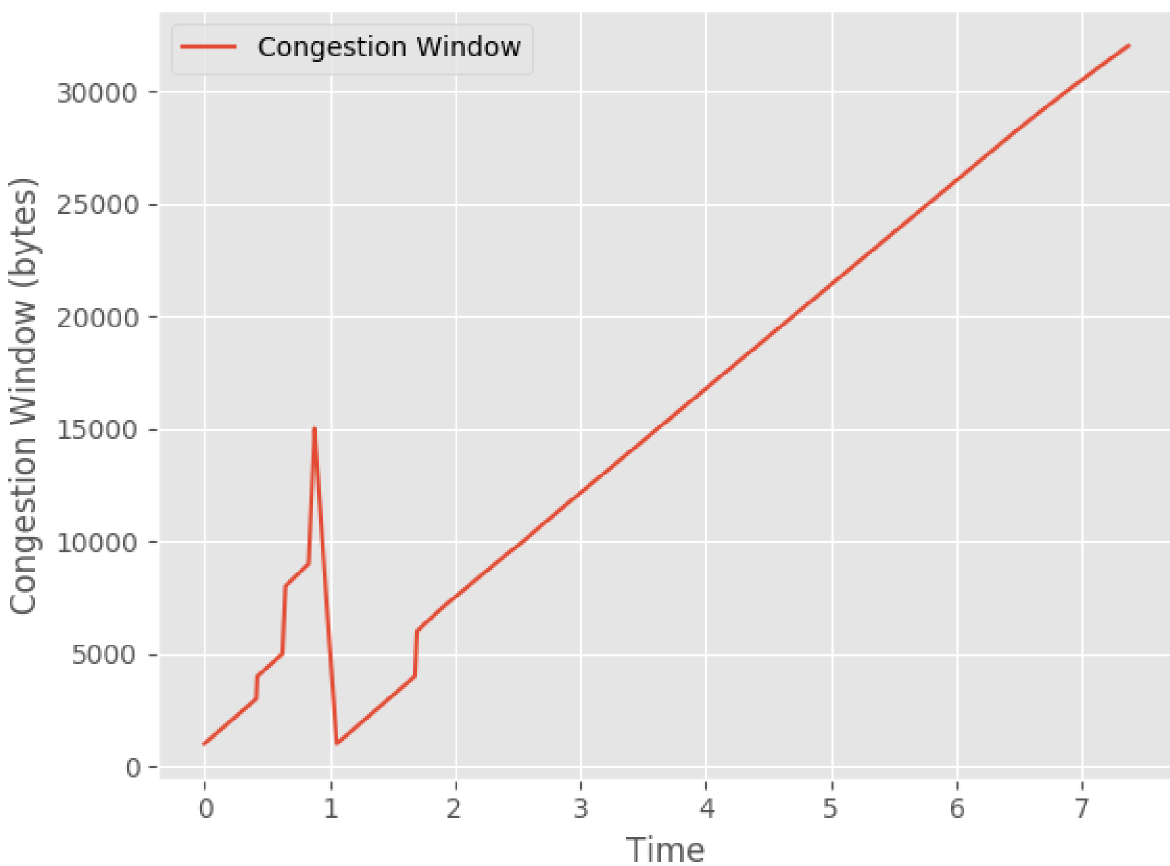
The results of the third test were very similar to the results from the previous test. Both the congestion window and sequence number plots resemble the plots generated from the second set of results. The reason for this is that the sender never "realized" that the second packet was dropped. Before retransmitting the 15th packet, the sender had already transmitted the next window. This window was larger than the window that the 15th packet was sent in. Sequence 14,000 was sent as part of the fourth window, which was 8,000 bytes. The next window would have reached 16,000 bytes, and it contained the 27th packet, which was also dropped. This means that the next loss occurred while the sender was waiting for the first dropped packet to be acknowledged. When the sender retransmitted, it did not keep track of the rest of the outstanding packets, and they would have been retransmitted as well. The receiver, however, acknowledged all outstanding packets up to the 27th packet, so the sender resumed slow start by sending the 27th packet as the first packet of the second window in the second round of slow start. The only difference between the second test and this test was that in the second test, after slow start was restarted, the second window began with sequence 29,000 as opposed to sequence 26,000.

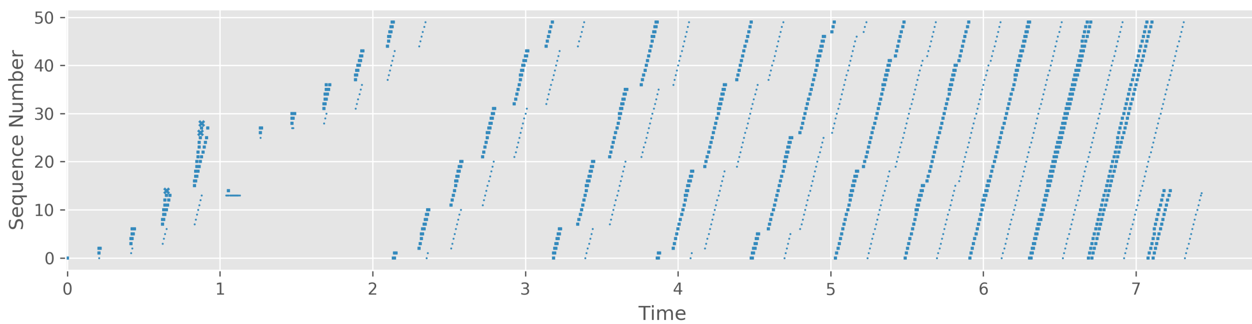
Overall, this change had little effect on the file transfer. Where the last packet was sent in the second test at around 7 seconds, the last packet of test 3 was sent at around 7.2 seconds. In the second test, additive increase began at about 1.9 seconds. In the third test, it began at roughly 2.1 seconds. Besides a slight variation in both plots, the impact of the second dropped packet was much less than the impact of the first. It should be noted that this is largely due to the timing of the second loss. If the second packet was dropped later in the transfer, the window size would be reset again, and there would be a more noticeable delay from the second loss. Like test 2, the sequence plot matches the SACK TCP paper plot of the same scenario.

4 Test 4

The last test consisted of the same process, only dropping an additional packet during the file transfer. The same two packets as test 3 were dropped, as well as sequence number 28,000.

4.1 Results





4.2 Analysis

The congestion window plots of the third and fourth tests are identical. The sequence number plots are also nearly the same. The main difference between the sequence plots is that sequence 28,000 had to be resent. During test 3, sequence 28,000 was acknowledged when sequence 26,000 was retransmitted. In test 4, sequence 28,000 was lost, so it did have to be sent again. All this means is that the file transfer during test 4 was 1,000 bytes behind test 3. Other than that, the sequences are identical. As in the previous two tests, the graph used in the TCP SACK paper of TCP Tahoe with three packets dropped matches the graph generated from the fourth test.