Example 1

Assume a TCP sender without fast retransmit, but with slow start and congestion avoidance. Also assume:

- Segments n, n+1, n+2, …, n+10 are transmitted at times 0,1,2,…,10 ms
- Transmission time / segment = 1 ms
- RTT (2 x propagation + transmission + ACK processing + ACK transmission) = 10 ms
- Segment n is lost, no other losses of segments or ACKs
- No misordering of segments or ACKs by the network
- Retransmission timer for segment n is 60 ms, starting at the end of transmission
- cwnd = ssthresh = 64 at time 0
- Don’t consider a window limitation by the receiver

Example 1

1. At what time does the source detect the loss of segment n and how?
The loss is detected by a timeout at 61 ms. We assumed no fast retransmits and so loss is recognized by timeouts.

2. When does the ACK for segment n+3 arrive?
At 61 ms the loss of segment n is detected and sender retransmits it. The receiver will ACK not only segment n, but all the segments up to n+10 (cummulative ACKs) and the ACK reaches the sender at 71 ms (61 ms + RTT value of 10 ms).

3. After retransmitting segment n the source has 3 more packets available to send (n+11 to n+13). At what time is the ACK for segment n+13 received?
Due to the loss, cwnd is set to 1 and ssthresh to 32. When the ACK for segment n arrives (71ms), cwnd is set to 2. Segment n+11 and n+12 are sent at 71 and 72 ms respectively. At 81 ms the ACK for n+11 arrives. Cwnd increases and segment n+13 is sent out. The ACK arrives at 91 ms.

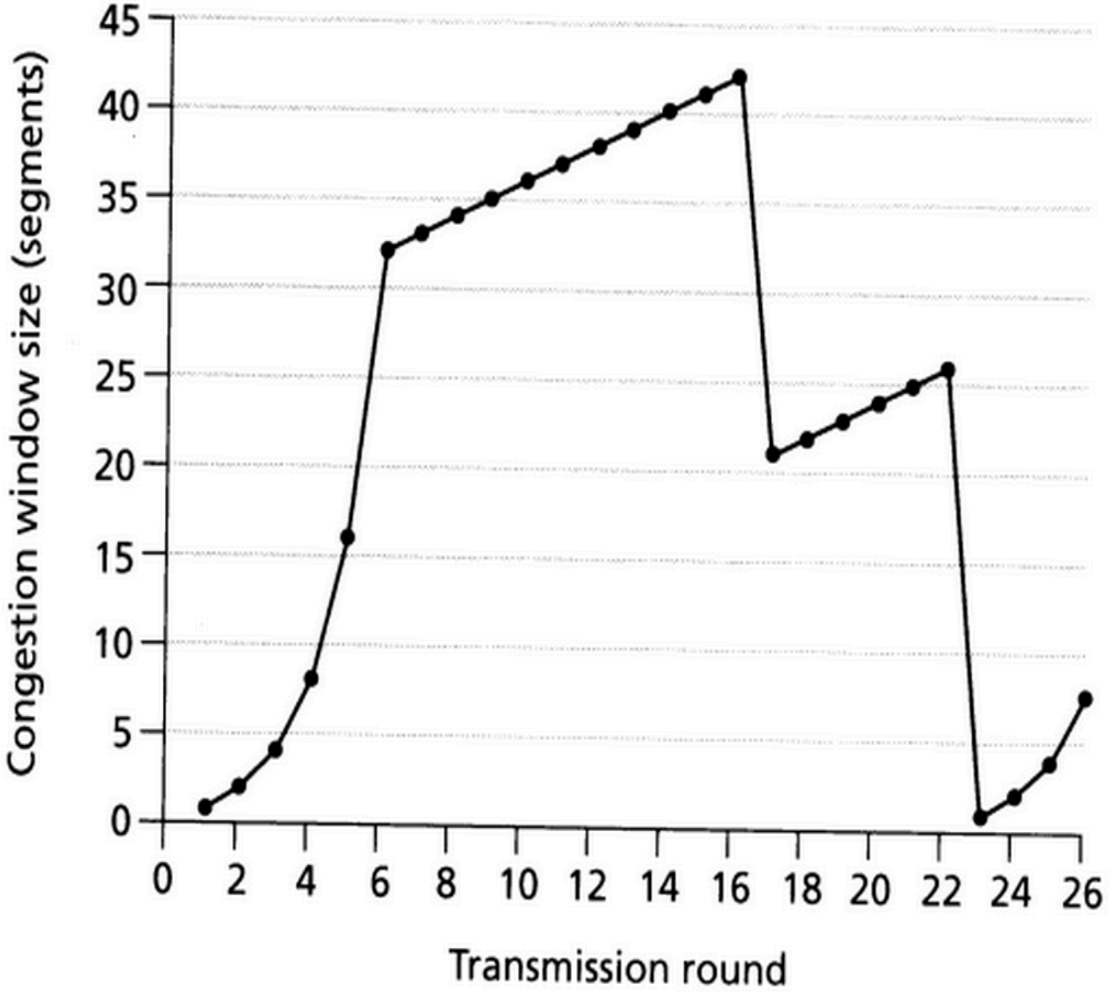
Example 1

4. Assume fast retransmit and fast recovery are implemented. When is the ACK for segment n+3 received? Also assume that segments n+11 to n+13 are available at time 60. When is the ACK for segment n+13 received?

Segment n is sent at 0 ms, but not ACK'ed. Segment n+1 is sent at 1 ms and ACK'ed at 11 ms. Segment n+2 is sent at 2 ms and ACK'ed at 12 ms. Segment n+3 is sent at 3 ms and ACK'ed at 13 ms. Due to loss of segment n, all the ACKs mentioned, refer to segment n. The three duplicate ACKs indicate a packet loss, thus segment n is retransmitted at 13ms and all segments up to n+10 are ACKed at 23ms.

Due to fast recovery cwnd is halved. Segments n+11 to n+13 can be sent in a row at 60, 61, and 62 ms respectively. The ACK for segment n+13 will arrive at 72 ms.

Example 2


Congestion window size (segments)
45
40
35
30
25
20
15
10
5
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26
Transmission round

Example 2

1. Identify the intervals where TCP slow-start is operating
[1,6] and [23,26]

2. Where is congestion avoidance operating?
[6,16] and [17,22]

3. After the 16th transmission round, is loss detected by triple duplicate ACKs or by timeout?
Triple duplicate ACK, otherwise congestion window would drop to 1

4. After the 22nd round is loss detected by triple duplicate ACKs or timeout?
Timeout, that's why congestion window goes back to 1

Example 2

5. What is the sstreshold value at the first transmission round?
32, then slow start stops and we have AI

6. What is the ssthreshold at the 18th transmission round?
The ssthresh is set to half the congestion window which is 42, so sstrhresh is 21

7. What is the ssthreshold at the 24th transmission round?
The congestion window before loss is 26, so ssthresh is 13

8. What will the values for congestion window and ssthresh be if packet loss is detected after the 26th round by triple duplicate ACKs?
Half the value of the congestion window, so we will get 4.