National University of Singapore
School of Computing
CS5229: Advanced Computer Networks
Semester I, 2021/2022

Lecture 2 Training
Window-Based End-to-End Congestion Control

Release date: 20th August 2021
Due: 26th August 2021, 23:59

In Lecture 2, we discussed how TCP does a slow start in the beginning of the transmission. In this lecture training, we will investigate how a sender's congestion window (`cwnd`) evolves during the slow start (on a per-RTT basis) and how it impacts network congestion. We will also examine the effect of the initial congestion window size on the slow start and how it impacts user experience, especially during web browsing. Consider the following network scenario:

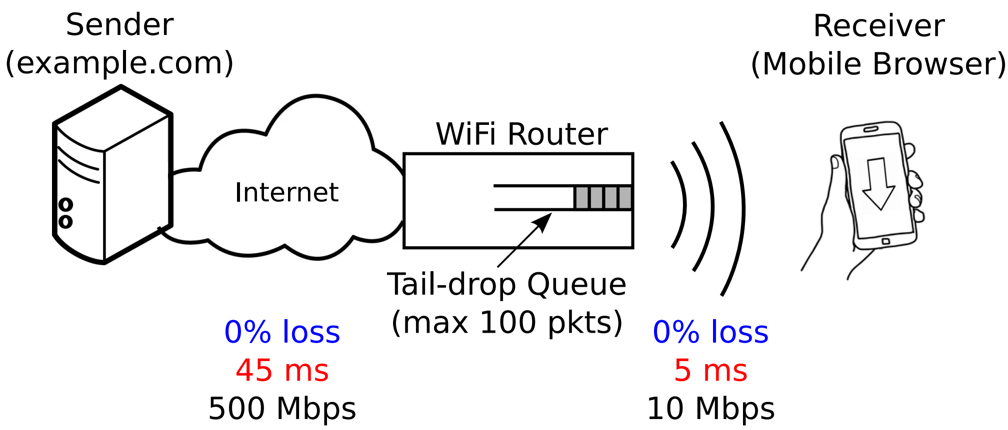

Figure 1: A simple network scenario

The mobile browser (TCP receiver) in Figure 1 wants to download a webpage from a server hosting `example.com` (TCP sender).

Unlike Lecture 1 training, assume that there are no transmission losses in the network for simplicity. Packet loss can only happen when the queue on the WiFi router overflows (> 100 packets). The link speeds are in Mega bits per second, where 1 Mbps = 1,000,000 bits per second. Also, assume that the WiFi router adds no hop delay or queueing delay (no matter the queue size). We consider the size of each data packet to be 1,500 bytes. Furthermore, assume[1] that each packet can carry 1,500 bytes of TCP payload. For example, the sender would need 2 packets to transmit a webpage of 3 KB (3,000 bytes) to the receiver.

The sender uses the following slow start mechanism which proceeds in time intervals of the RTT: (i) In the first RTT interval, the sender's initial `cwnd` is equal to 2 packets. The sender bursts these 2 packets and receives corresponding 2 ACKs from the receiver. (ii)

[1] In practice, a typical MTU-sized packet is 1,518 bytes long "on the wire" and can carry only 1,460 bytes of TCP payload: Ethernet header & checksum (14 + 4 = 18 bytes) + IP header (20 bytes) + TCP header (20 bytes) + TCP payload (1,460 bytes)

For each subsequent RTT interval, the sender increases the `cwnd` by 1 packet for every ACK it receives during the previous RTT interval. (iii) The receiver always sends 1 ACK for each packet received from the sender. This means that, the sender would effectively double its `cwnd` in each subsequent RTT interval. (iv) The sender would exit the slow start and switch to congestion avoidance if/when it detects the first packet loss.

Given this information, answer the following questions on Coursemology:

Q1 In which RTT[2] will the queue in the WiFi router start building up (queue size greater than 0)? Note that the RTT numbering starts with 1 i.e. in RTT #1, the sender sends 2 packets and receives 2 ACKs.

Q2 In which RTT will the first packet drop occur at the WiFi router?

Q3 Suppose the mobile browser needs to download a webpage of 90 KB (90,000 bytes) from `example.com`. How many RTTs would it take to complete the webpage download? A webpage download is considered to be "complete" when the sender receives the ACK for the last packet sent.

Next, suppose we upgrade our WiFi router and now our wireless link has a link speed of 100 Mbps.

Q4 In this new scenario, in which RTT will the queue in the WiFi router start building up?

Q5 In which RTT will the first packet drop occur at the WiFi router?

Q6 Suppose we want to download a webpage of 90 KB (90,000 bytes) from `example.com` again. How many RTTs would it take to complete the webpage download?

Instead of upgrading the WiFi router, suppose we increased the sender's initial `cwnd` to 10 packets and kept the wireless link's speed at 10 Mbps.

Q7 In this case, how many RTTs will it take to download the same 90 KB webpage as above?

[2] we refer to a RTT time interval simply by "RTT". Note that the time is divided into intervals of the RTT.