CS144
An Introduction to Computer Networks

Worked Example

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Alice is streaming a high definition video at 10Mb/s from a remote server in San Francisco. All packets are 250bytes long. She measures the ping time to the server and the minimum time she measures is 5ms. Once the AIMD window reaches steady state, for the rest of the video, the sawtooth oscillates between constant minimum and maximum values. The buffer is perfectly sized so that it is just big enough to never go empty.

1. What is the <u>smallest</u> value of the AIMD window (in bytes)?

The minimum ping time of 5ms is when the buffer is empty but the bottleneck link is full.
At 10Mb/s, there is therefore 50,000 bits in the "pipe".
This means the minimum or "trough" of the AIMD sawtooth is 50,000 bits, or 6250 bytes.

<u>Answer: 6,250 bytes.</u>

2. What is the <u>largest</u> value of the AIMD window (in bytes)?

When the buffer and bottleneck link are both full, the RTT is doubled from 5ms to 10ms.
At 10Mb/s, this corresponds to 100,000 bits.
50,000 bits are in flight, and 50,000 bits are in the buffer.
Therefore the maximum or "peak" of the AIMD sawtooth is 100,000 bits or 12,500 bytes.

<u>Answer: 12,500 bytes.</u>

3. How big is the packet buffer in the router (in bytes)?

We already decided in Q2 that when full, the buffer holds one minimum RTT, or 50,000 bits.

Answer: 6,250 bytes.

4. After a packet is dropped, how long does it take for the window to reach its maximum value again?

Packets are 2,000 bits long and so the window will increase by 2,000 bits every RTT. Therefore, it takes 25 RTTs to increase the RTT by 50,000 bits and fill the buffer. The average RTT is 7.5ms, therefore it will take 187.5ms.

Answer: 187.5ms.

5. If Alice now tries to watch the same video from a server in Australia (with RTT 250ms), how big should the router buffer be (in bytes) if the network still runs at 10Mb/s?

The minimum RTT is 250ms, so the buffer needs to be at least 250ms * 10Mb/s = 2.5 x 10^6 bits. Because we express storage in powers of 2, the answer is 2.4Mbits or 298 Kbytes.

Answer: 298 Kbytes.

6. When the server is in Australia, after a packet is dropped, how long does it take for the window to reach its maximum value again (in seconds)?

As before, the window increases by 2,000 bits every round.

To fill the buffer will take $2.5 \times 10^6 / 2 \times 10^3 = 1{,}250$ rounds.

The average RTT is 375ms.

So the time to reach the maximum again is 468.75 seconds, or almost 8 minutes!

Answer: 468.75 seconds.