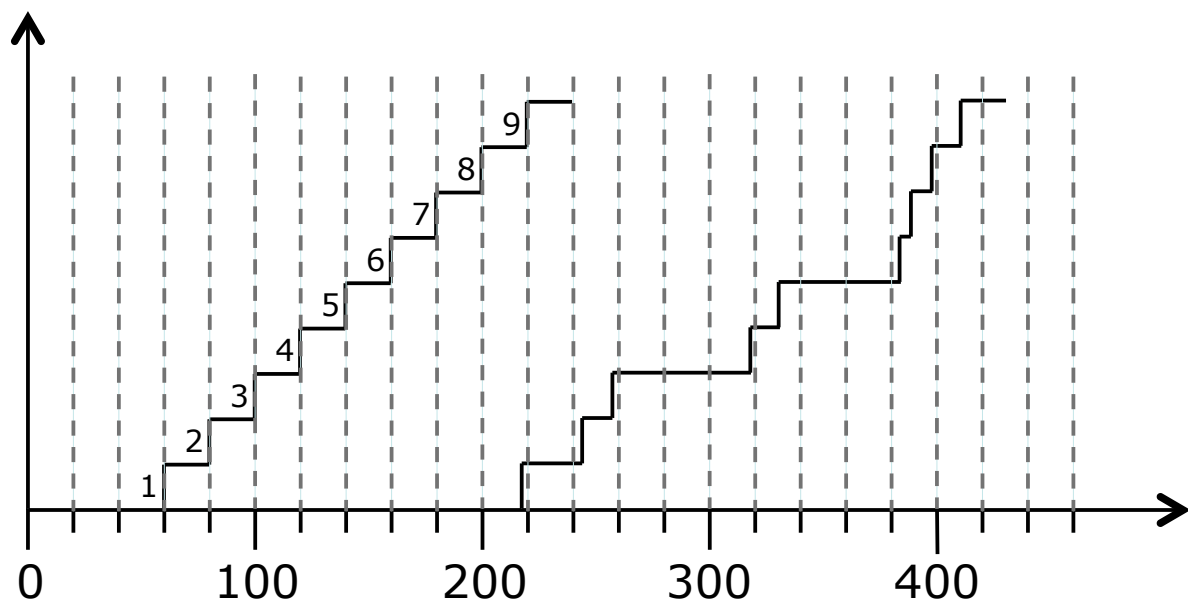(5 points) The chart below shows packets sent by an audio source and received at a sink. Assume that the time between packet transmissions is 20 ms and that packets are timestamped by the sender and that the receiver playout buffer uses a fixed playout delay of 200 ms. Also, assume that the sender's and receiver's clocks are exactly synchronized.


List the packet numbers for those packets that arrive too late to be played out.

packets 6 and 7 are late

What is the smallest playout delay required to ensure that packets never arrive too late for playout (for the example)? You may round up to a multiple of 20 ms.

The minimum playout delay is 240 ms

(5 points) The diagram below shows a video server and a web site that are simultaneously sending to a residential network with a 2 Mb/s download bandwidth. The one way propagation delay for both data streams is 50 ms. Assume that the video stream is 1 Mb/s and that web server is downloading a large file to the client as fast as it can using TCP.
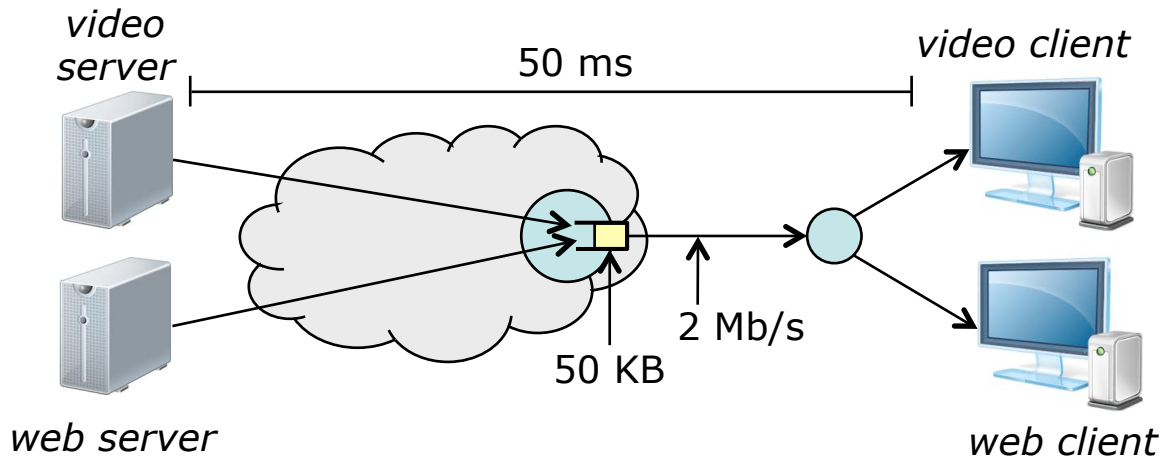
If the output queue at the access router is 50 KB long and the video is sent using UDP, what is the minimum size for the playout buffer to ensure that packets never reach the video application too late to be played out?

2 Mb/s is 250 KB/s, so a 50 KB buffer has a max delay of 200 ms.

Since the video rate is 125 KB/s, we need 25 KB of delay in the playout buffer.

How big should the playout buffer be if the video is sent using TCP, assuming no packet ever has to be sent more than three times (that is, a packet might get lost twice, but never three times). Assume the worst-case possible delay for a late packet.

The minimum delay in this case is 50 ms.

The maximum delay is 2.5×RTT + 3×(max queuing delay)=850 ms. That gives a delay variation of 800 ms, so the playout buffer must be large enough to handle that much delay. At a video rate of 1 Mb/s, the required buffer size is .8 Mb or 100 KB.