1) TCP Flow control functions in order to prevent the sender from overwhelming the receiver in the process of data transfer. In this case, since Host A is sending data at a rate of 120 Mbps (peak) to Host B, which can only read out of its receiver buffer at a max rate of 50 Mbps. The sender limits the amount of "in-flight" data that it transmits to the receiver's window size (rwnd), which is its available buffer space. Thus, when transmitting the sender can transmit at a rate no larger than the receiver's free buffer size.

   Taking all of this into account, the buffer will start by setting transmission rate initially to 50 Mbps. Then, as the buffer at host B fills up, the rwnd value sent with ACK will decrease, and the transmission rate from host A will further decrease. In the case that the buffer at host B is completely filled, it sends a rwnd size of 0 to host A; host A then completely stops sending data, and waits until Host B is ready to accept data into its buffer again.

2) s_port: 5670
   dest_port: 2008
   sequence_number: 3120
   ACK_no: 981

   1, 0, 1 (whole sequence is 0 1 0 0 0 1).

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#3 Total # of packets in 1 period:

a) $= \frac{W}{2} + \frac{W}{2}+1 + \dots + \frac{W}{2} + \frac{W}{2} = \sum_{n=0}^{n=\frac{W}{2}} \left[\frac{W}{2}+n\right]$

$= \sum_{n=0}^{W/2} \frac{W}{2} + \sum_{n=0}^{W/2} n = \sum_{n=0}^{W/2} \frac{W}{2} + \sum_{n=1}^{W/2} n$

$= \underbrace{\frac{W}{2}\left(\frac{W}{2}+1\right)}_{\#\text{ of terms in the summation}} + \frac{\frac{W}{2}\left(\frac{W}{2}+1\right)}{2} = \frac{W^2}{4} + \frac{W}{2} + \frac{W^2}{8} + \frac{W}{4}$

$= \frac{3W^2}{8} + \frac{3W}{4}$ total packets in 1 period

Only 1 packet lost in 1 period

Loss rate $= \frac{\#\text{ Packets lost}}{\text{total packets}} = \boxed{\frac{8}{\frac{3W^2}{8}+\frac{3W}{4}}}$ ✓

b) Solve for W from part a's answer: $L = \frac{8}{3W^2+6W}$ → linear term will be negligible as W gets large

$3W^2+6W+L-8=0$

$W = \frac{-6 \pm \sqrt{36-4(3)(L-8)}}{6} = \frac{-6 \pm \sqrt{36-12L+96}}{6}$

$= \frac{-6 \pm \sqrt{128-12L}}{6}$ ✗ ignore

$L \approx \frac{8}{3W^2}$

$LW^2 = \frac{8}{3}$

$W = \sqrt{\frac{8}{3L}} = \frac{2\sqrt{2}}{\sqrt{3L}}$

Avg Throughput (Avg rule) $= \frac{3}{4} W \cdot \frac{MSS}{RTT}$ Plug in W: $= \frac{3 \cdot 2\sqrt{2}}{4\sqrt{3L}} \cdot \frac{MSS}{RTT}$

$\boxed{\text{Average rate} \approx 1.22 \frac{MSS}{RTT}}$ ✓

#4

a) Receiver window $\geq$ (RTT) x (Bandwidth)

$\geq$ (400ms) x (800 Mbps)

$\geq 400\text{ms} \times \frac{1\text{s}}{1000\text{ms}} \times \frac{800\text{ Mb}}{1\text{ sec}} \times \frac{10^6\text{ bits}}{1\text{ Mb}}$ all bytes the sequence #s

Receiver Window $\geq 32 \times 10^7$ bits max value that can be stored $\frac{1}{8} = 4 \times 10^7$ bits

$\log_2(3.2 \times 10^8) = 28.2$ # of bits needed: $\log_2(4 \cdot 10^7) = 25.25$ bits; round up

Receiver window = 26 bits needed

Sequence Num $\geq$ (Max Lifetime) x (Bandwidth)

$\geq$ (25 s) x (800 Mbps)

$\geq 25\text{s} \times \frac{800\text{ Mb}}{1\text{s}} \times \frac{10^6\text{ bits}}{1\text{ Mb}} = 2 \times 10^{10} / 8 = 2.5 \times 10^9$ Bytes

round by 8 for sequence #s of bytes

$\log_2(2 \times 10^{10}) = 34.2$.

$\log_2(25 \times 10^9) = 34.2$; round up

Sequence Num = 32 bits needed

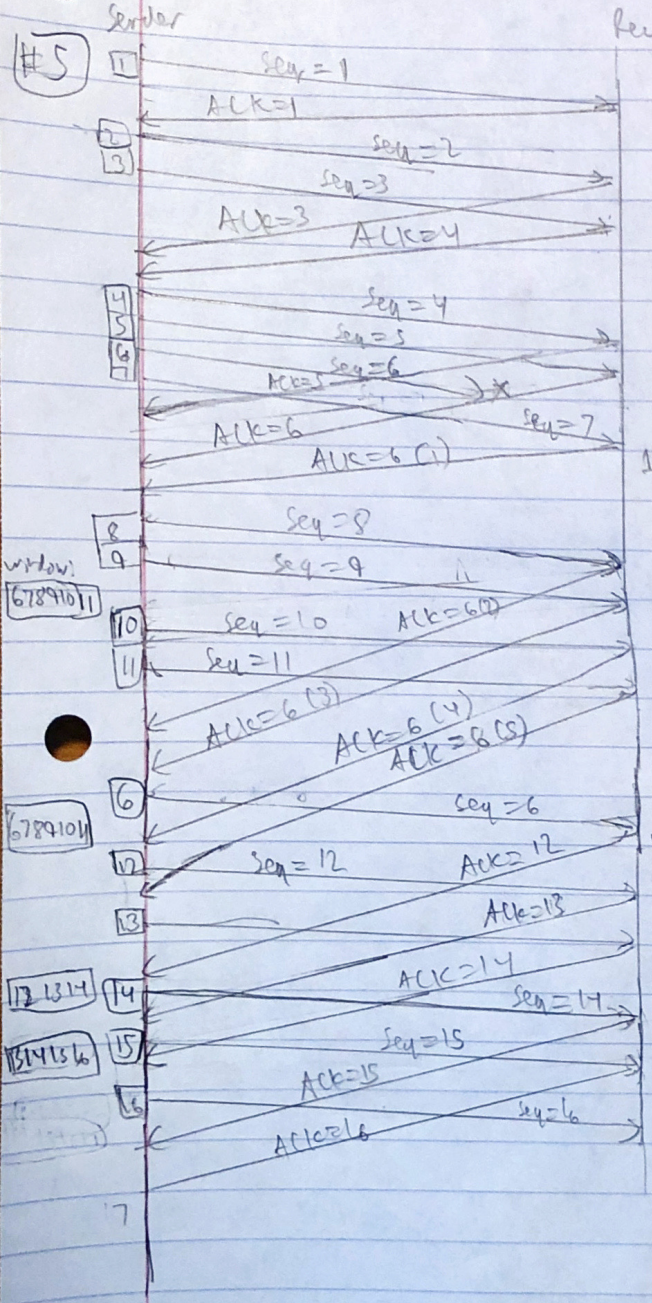
b) Receiver window $\geq$ (RTT) x (Bandwidth). 16 bits: $2^{16} = 65536$ Receiver window (byte-addressed)

Bandwidth $= \frac{\text{Receiver window}}{\text{RTT}}$

$= \frac{65536\text{ B}}{400\text{ms}} \times \frac{1000\text{ms}}{1\text{s}}$

$= 163.840$ Kbps

#5



	cwnd	ssthresh	
	1	5	
	2	5	
	3	5	
	4	5	
	5	5	* switch to slow start
	6	5	
1st Duplicate ACK	6	5	(do nothing)
	"	"	(nothing)
2nd Duplicate	6	5	(do nothing)
3rd Duplicate	6	3	* Switch to Fast Retransmit
4th Duplicate	7	3	* Switch to Fast Recovery
5th Duplicate	8	3	- still fast recovery
	3	3	→ end of fast recovery; * ssthresh = cwnd; slow start
	4	3	→ switch to additive increase
	[4+1/4]	3	
	[4+2/4] = 4	3	

When ACK 15 is received by the sender: cwnd = 4, ssthresh = 3