CS 168 Spring 2026 — Congestion Control, Discussion 7

1 True/False

1.1 UDP uses congestion control.

False, TCP uses congestion control.

1.2 Flow control slows down the sender when the network is congested.

False, flow control ensures the sender doesn't overflow the receiver's buffer.

1.3 For TCP timer implementations, every time the sender receives an ACK for a previously unACKed packet, it will recalculate ETO.

False, only clean samples are used. For example, ACKs on a packet that have been retransmitted are not used since the sender cannot be sure which version the ACK is from.

1.4 CWND (congestion window) is usually smaller than RWND (receiver window).

True.

1.5 AIMD is the only "fair" option among MIMD, AIAD, MIAD, and AIMD.

True.

2 Impact of Fast Recovery

Consider a TCP connection, which is currently in Congestion Avoidance (AIMD):

- The last ACK sequence number was 101.
- The CWND size is 10 (in packets).
- The packets 101–110 were sent at t = 0, 0.1, …, 0.9 (sec), respectively.
- The packet 102 is lost only for its first transmission.
- RTT is 1 second.

2.1 Without fast recovery:

- On new ACK, CWND += $\frac{1}{\lfloor \text{CWND} \rfloor}$
- On triple dupACKs, SSTHRESH = $\lfloor \frac{\text{CWND}}{2} \rfloor$, then CWND = SSTHRESH.

Time (sec)	**Receive ACK (due to)**	**CWND**	**Transmit Seq # (mark retransmits)**
1.0	102 (101)	$10 + \frac{1}{10} = 10.1$	111
1.2	102 (103)	10.1	/
1.3	102 (104)	10.1	/

Time (sec)	Receive ACK (due to)	CWND	Transmit Seq # (mark retransmits)
1.4	102 (105)	$\lfloor \frac{10.1}{2} \rfloor = 5$	102 (Rx)
1.5	102 (106)	5	/
1.6	102 (107)	5	/
1.7	102 (108)	5	/
1.8	102 (109)	5	/
1.9	102 (110)	5	/
2.0	102 (111)	5	/
2.4	112 (102)	$5 + \frac{1}{5} = 5.2$	112 - 116

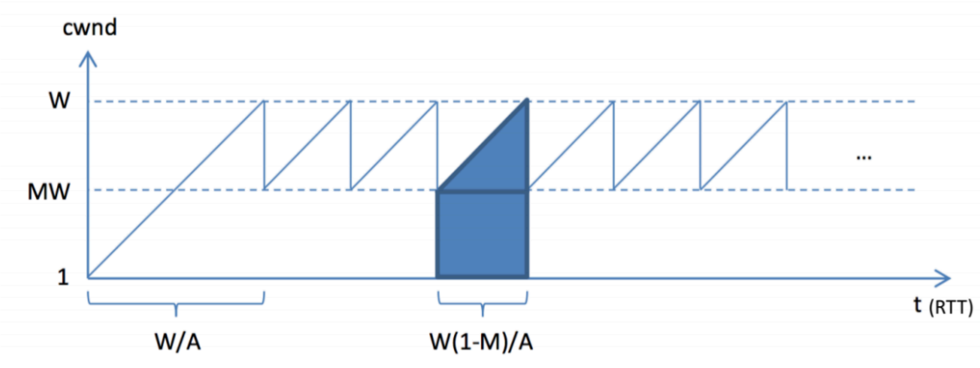
2.2 With fast recovery:

- On triple dupACKs, SSTHRESH = $\lfloor \frac{\text{CWND}}{2} \rfloor$, then CWND = SSTHRESH + 3, enter fast recovery.
- In fast recovery, CWND += 1 on every dupACK.
- On new ACK, exit fast recovery, CWND = SSTHRESH.

Time (sec)	Receive ACK (due to)	CWND	Transmit Seq # (mark retransmits)
1.0	102 (101)	$10 + \frac{1}{10} = 10.1$	111
1.2	102 (103)	10.1	/
1.3	102 (104)	10.1	/
1.4	102 (105)	$\lfloor \frac{10.1}{2} \rfloor + 3 = 8$	102 (Rx)
1.5	102 (106)	9	/
1.6	102 (107)	10	/
1.7	102 (108)	11	112
1.8	102 (109)	12	113
1.9	102 (110)	13	114
2.0	102 (111)	14	115
2.4	112 (102)	SSTHRESH = 5	116

Note: *Three dupACKs = 1 regular ACK + 3 ACKs of a sequence number that have been ACKed before already, so we retransmit on the 4th ACK of seq 102.*

3 AIMD Throughput



Consider a generalized version of AIMD, where:

- For every window of data ACK_ed, the window size increases by a constant A.
- When the window size reaches W, a loss occurs, and the window size is multiplied by a constant $M < 1$.

For simplicity, *assume that $W(1-M)$ is divisible by A*. Thus, the window sizes will cycle through the following: WM, WM + A, WM + 2A, ... W. Let the RTT denote the packet round trip time. A graph of window size versus time is referenced in the figure above.

3.1 What is the average throughput? *Express your answers in the number of packets, so we do not need to consider MSS.*

Throughput = $\frac{\text{Average number of packets in flight}}{\text{RTT}} = \frac{(\text{MW}+W)}{2\times \text{ RTT}} = \frac{W(M+1)}{2\times \text{ RTT}}$

3.2 Calculate the loss probability p, using W and M.

We have one drop out of every $\frac{W(1-M)}{A} \times \frac{\text{MW}+W}{2}$ packets sent (the area of the shaded trapezoid in the plot). Thus, the loss probability is:

$p = \frac{1}{\frac{W(1-M)}{A} \times \frac{\text{MW}+W}{2}} = \frac{2A}{W^2(1-M^2)}$

3.3 Derive the formula for throughput in part (a) when $M = 0.5$ and $A = 1$, using only p and RTT.

Throughput = $\frac{W(M+1)}{2\times \text{ RTT}} = \frac{3W}{4\times \text{ RTT}}$

p = $\frac{2A}{W^2(1-M^2)} = \frac{2}{0.75W^2} = \frac{8}{3W^2}$

We get $W = \sqrt{\frac{8}{3p}}$ from the loss probability p, and plug this into the throughput equation:

Throughput = $\frac{3W}{4\times \text{ RTT}} = \frac{3\times\sqrt{\frac{8}{3p}}}{4\times \text{ RTT}} = \sqrt{\frac{9\times 8}{16\times 3\times p}}\frac{1}{\text{RTT}} = \frac{1}{\text{RTT}}\sqrt{\frac{3}{2p}}$