CS 168 Introduction to the Internet
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Discussion 11: Congestion Control

1 True False

1. UDP uses congestion control. **Solution:** False, TCP uses congestion control

2. Flow control slows down the sender when the network is congested. **Solution:** False, flow control ensures the sender doesn't overflow the receiver's buffer

3. For TCP timer implementations, every time the sender receives an ACK for a previously unACKed packet, it will recalculate ETO. **Solution:** False, only clean sample are used

4. CWND (congestion window) is usually smaller than RWND (receiver window). **Solution:** True

5. AIMD is the only "fair" option among MIMD, AIAD, MIAD, and AIMD. **Solution:** 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.

Fill in the tables below, until the sender transmits the packet #116.

1. Without fast recovery:

   - On new ACK, $CWND += \frac{1}{\lfloor CWND \rfloor}$
   - On triple dupACKs, $SSTHRESH = \left\lfloor \frac{CWND}{2} \right\rfloor$, 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	/
1.4	102 (105)	$\left\lfloor\frac{10.1}{2}\right\rfloor=5$	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. With fast recovery:

   - On triple dupACKs, $SSTHRESH=\left\lfloor\frac{CWND}{2}\right\rfloor$, 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)	$\left\lfloor\frac{10.1}{2}\right\rfloor+3=8$	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

3 AIMD Generalization and Derivation

Consider a generalized version of AIMD, where:

- For every window of data ACKed, 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 to denote the packet round trip time. A graph of window size versus time is referenced in Figure 3.

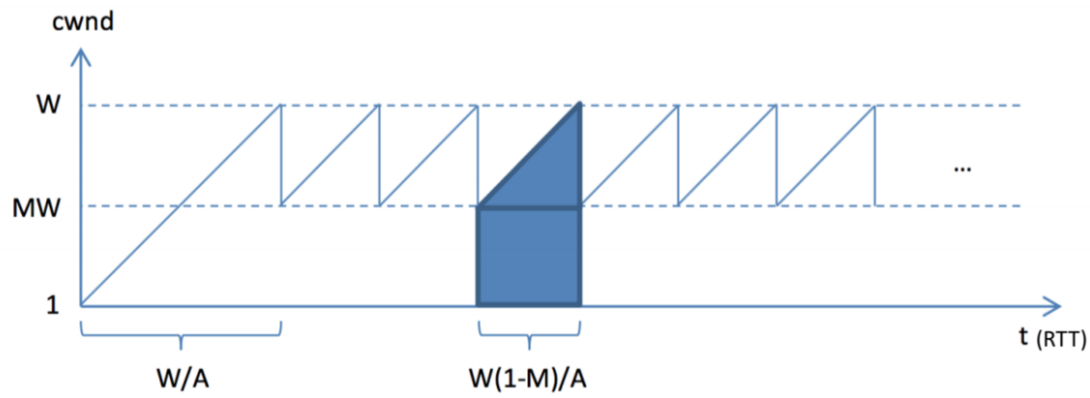

Figure 1: Graph of *Window size vs. time* referenced in AIMD Generalization and Derivation

We present the following questions.

1.) What is the average throughput? As we did in the lecture slides, express in your answers in the number of packets, so we do not need to consider MSS.

Solution:

$$\begin{aligned} Throughput &= \frac{Average\ number\ of\ packets\ in\ flight}{RTT} \\ &= \frac{\left(\frac{MW+W}{2}\right)}{RTT} \\ &= \frac{W(M+1)}{2 \cdot RTT} \end{aligned}$$

2.) Calculate the loss probability p, using W and M.

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

$$\begin{aligned} p &= \frac{1}{\frac{W(1-M)}{A} \cdot \frac{MW+W}{2}} \\ &= \frac{2A}{W^2(1-M^2)} \end{aligned}$$

3.) Derive the formula for throughput in part 1 when $M = 0.5$ and $A = 1$ and try using only p and RTT.

Solution:

$$Throughput = \frac{W(M+1)}{2 \cdot RTT} = \frac{3W}{4 \cdot RTT}$$
$$p = \frac{2A}{W^2(1-M^2)} = \frac{2}{0.75W^2} = \frac{8}{3W^2}$$

We get $W = \sqrt{\frac{8}{3p}}$ from loss probability p, and plug this into throughput, and voila, we arrive at the following.

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