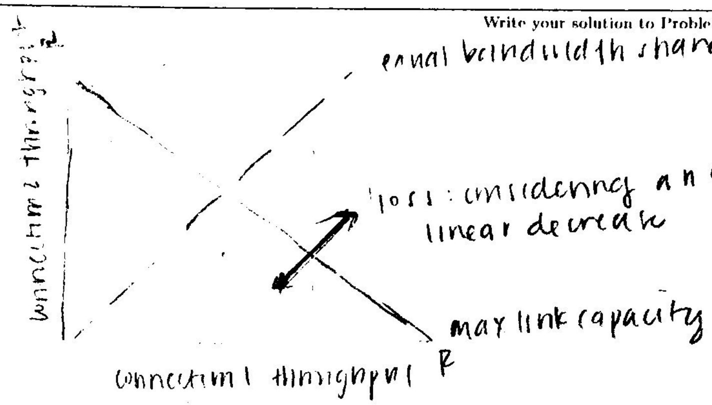
Problem 1

Suppose that instead of a multiplicative decrease, TCP decreased the window size by a constant amount. Would the resulting AIAD algorithm converge to an equal share algorithm? Justify your answer using a graphical diagram similar to Slide 100 of the lecture.

Write your solution to Problem 1 in this box



AIAD does not converge to an equal share algorithm since the window does not oscillate around the ideal point of intersection of the equal bandwidth and max link capacity lines. As the AIAD algorithm experiences loss, it will not be fair depending on the amount that the window size is decreased by. If the amount that each connection decreases by is similar, the throughput remains static. If one connection were to decrease more than the other, the first connection would be starved.

Problem 2

TCP is a very symmetric protocol, but the client/server model is not. Consider an asymmetric TCP-like protocol in which only the server side is assigned a port number visible to the application layers. Client-side sockets would simply be abstractions that can be connected to server ports. Can you propose header data and connection semantics to support this. What will you use to replace the client port number?

Write your solution to Problem 2 in this box

In order to support this, there will need to be some kind of identifier assigned to the client side, perhaps a process ID or some sort. This would be used when demultiplexing data coming from the server. The headers would need to include this number. Now, the server must bind itself to a client and the client & server would be two completely different and asymmetric sockets.

Problem 3

On the TCP throughput, in the period of time from when the connections rate varies from W/(2 RTT) to W/RTT, only one packet is lost (at the very end of the period).

(a) Show that the loss rate (fraction of packets lost) is equal to L lossrate $= 1/(3/8W^2 + 3/4W)$

(b) Use the result above to show that if a connection has loss rate L, then its average rate is approximately given by $\simeq 1.22 \times MSS/(RTT \times \sqrt{L})$

Write your solution to Problem 3 in this box

(a) The loss rate L is the ratio of the number of packets lost over the number of packets sent. The number of packets sent is:

$$\frac{W}{2} + \left(\frac{W}{2}+1\right) + \dots + W = \sum_{n=0}^{W/2}\left(\frac{W}{2}+n\right)$$

$$= \frac{W}{2}\left(\frac{W}{2}+1\right) + \sum_{n=0}^{W/2} n$$

$$= \frac{W^2}{4} + \frac{W}{2} + \frac{\frac{W}{2}\left(\frac{W}{2}+1\right)}{2}$$

$$= \frac{W^2}{4} + \frac{W}{2} + \frac{W^2}{8} + \frac{W}{4}$$

$$= \frac{3W^2}{8} + \frac{3W}{4}$$

The total loss rate is $\dfrac{1}{\frac{3}{8}W^2 + \frac{3}{4}W}$. ✓

(b) For large W, $\frac{3}{8}W^2 >> \frac{3}{4}W \Rightarrow L \approx \frac{8}{3}W^2$ or $W \approx \sqrt{\frac{8}{3L}}$

So the avg. is $\dfrac{W + \frac{W}{2}}{2} = \frac{3}{4}W = \frac{3}{4}\sqrt{\frac{8}{3L}}\,\frac{MSS}{RTT} \approx \boxed{\dfrac{1.22\,MSS}{RTT\sqrt{L}}}$ ✓

Problem 4

You are designing a reliable, sliding window, byte-stream protocol similar to TCP. It will be used for communication with a geosynchronous satellite network, for which the bandwidth is 1 Gbps and the RTT is 300 ms. Assume the maximum segment lifetime is 30 seconds.

(a) How many bits wide should you make the ReceiveWindow and SequenceNum fields? (ReceiveWindow is also called "Advertised Window" in some other textbooks.)

(b) If ReceiveWindow is 16 bits, what upper bound would that impose on the effective bandwidth?

Write your solution to Problem 4 in this box

(A) $\frac{1 \text{ Gb}}{s} = \frac{1\times10^9 \text{ b}}{s} = \frac{1\times10^9 \text{ b}}{1\times10^3 \text{ ms}} = 1\times10^6 \text{ b/ms}$

To ensure the network is fully used, the receive window must be larger than (Delay × Bandwidth)

$\text{ReceiveWindow} \geq (1\times10^6 \text{ b/ms})(300 \text{ ms})$

$= 3.\times10^8 \text{ b}$

$\log_2 (3\times10^8) \text{ bits} \Rightarrow \boxed{29 \text{ bits}}$

The number of sequence numbers must be larger than the max possible # of packets in the network, or (bandwidth) × (lifetime)

$\text{seq. \#} \geq \left(30 s \times \frac{10^9 \text{ b}}{s}\right) = 3\times10^{10} \text{ b}$

$\log_2 (3\times10^{10}) \Rightarrow \boxed{35 \text{ bits}}$

(b) Since 16 b < 3×10^8 b, the limiting factor for the bandwidth is now 16 b. Thus, the effective

$\text{bandwidth} = \frac{2^{16} \text{ b}}{300 \text{ ms}} = \boxed{218.453 \frac{\text{b}}{\text{ms}}}$

Problem 5

Consider the evolution of a TCP connection with the following characteristics. Assume that all the following algorithms are implemented in TCP congestion control: slow start, congestions avoidance, fast retransmit and fast recovery, and retransmission upon timeout. If ssthresh equals to cwnd, use the slow start algorithm in your calculation.

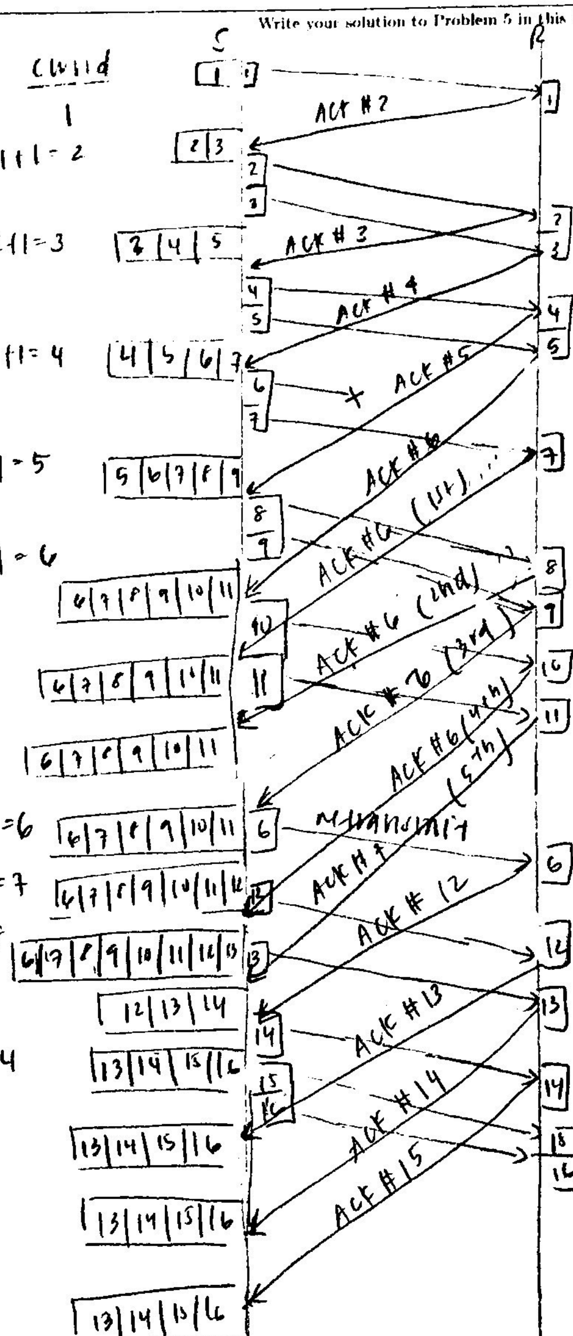
- The TCP receiver acknowledges every segment, and the sender always has data segments available for transmission.
- The network latency in sending a segment (header and payload) from the sender to the receiver is 30ms and the network latency in sending an acknowledgment (header only) from the receiver to the sender is 20ms. Ignore packet-processing delays at the sender and the receiver.
- Initially ssthresh at the sender is set to 5. Assume cwnd and ssthresh are measured in segments, and the transmission time for each segment is negligible.
- Retransmission timeout (RTO) is initially set to 500ms at the sender and is unchanged during the connection lifetime. The RTT is 100ms for all transmissions.
- The connection starts to transmit data at time t = 0, and the initial sequence number starts from 1. TCP segment with sequence number 6 is lost once (i.e., it sees segment loss during its first transmission). No other segments are lost during transmissions.

What are the values for cwnd and ssthreshold when the sender receives the TCP ACK with number 15? Show your intermediate steps or your diagram in your solution.

Problem 5 continued on next page. . .

Write your solution to Problem 5 in this box

time	algorithm	ssthresh	cwnd
t=0	SS	5	1
t=50	SS	5	1+1=2
t=100	SS	5	2+1=3
t=120	SS	5	3+1=4
t=170	SS	5	4+1=5
t=190	SS	5	5+1=6
t=240	no action	5	6
t=290	no action	5	6
t=310	FR/FR	$\frac{6}{2}=3$	3+3=6
t=360	FR/FR	3	6+1=7
t=380	FR/FR	3	7+1=8
t=430	FR/FR	3	3
t=480	SS	3	3+1=4
t=530	CA	3	$4+\frac{1}{4}$
t=580	CA	3	$4+\frac{1}{2}$
t=630	CA	3	$4+\frac{3}{4}$



$\boxed{cwnd = 4+\frac{3}{4} \quad ssthresh = 3}$