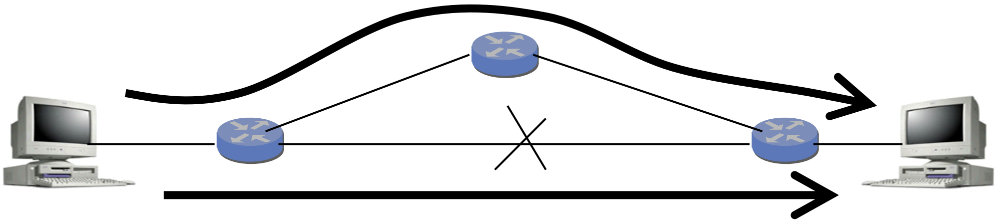
Assignment #5

1. Suppose two hosts have a long-lived TCP session over a path with a 100ms round-trip time (RTT). Then, a link fails, causing the traffic to flow over a longer path with a 500ms RTT.



(1) Suppose the router on the left recognizes the failure immediately and starts forwarding data packets over the new path, without losing any packets. (Assume also that the router on the right recognizes the failure immediately and starts directing ACKs over the new path, without losing any ACK packets.) Why might the TCP sender retransmit some of the data packets anyway?

答：虽然假设发送端和接收端迅速的切换到了新的路径，但由于实际上接收端RTO是根据之前每一次的数据传输的RTT动态计算的，而新的路径实际的RTT为500ms远高于原路径的RTT为100ms，所以会出现RTO与实际RTT不匹配，从而导致发送端超时重传数据包。

(2) Suppose instead that the routers do not switch to the new paths all that quickly, and the data packets (and ACK packets) in flight are all lost. What new congestion window size does the TCP sender use? Why?

答：因为ACK数据包同样也丢失了，所以在发送端对于上一个数据包会触发超时重传，此时拥塞窗口（congestion window）的大小一定会被置为1MSS

2. Consider the following behavior of a TCP connection (using the congestion control algorithm we learned in class).

At time 0, a TCP sender initiates a connection. As soon as the connection is established, the TCP sender will begin sending data. The MSS is 1KB and RTT is 100 ms.

1) Assuming the connection does not lose any data or experience any timeouts, at what time will the sender's congestion window be 16KB? (Assuming *threshold* is 32MSS)

答：发送端在 time 0 时发起链接，利用 1 个 RTT 完成连接的建立，此时的 cwnd 为 1MSS。之后进入慢启动阶段，因为 16KB<32MSS(32KB)，所以拥塞窗口大小会在每次数据包传输（1 个 RTT）后翻倍。

16KB = 1MSS$\times 2^4$**，故需要用时为 RTT+4**$\times$ RTT = 500ms

Right after the sender's congestion window has reached a size of 16KB, a timeout occurs. After the timeout is detected, the sender continues sending more data over the established connection.

2) Assuming no additional packets loss or timeouts, how long (since the observed timeout) will it take for the congestion window to build to size 14KB?

答：在一次超时重传发生后：

threshold = cwnd/2=16KB/2 = 8MSS

Cwnd = 1MSS

因为 threshold<14KB，所以在没有任何丢包或超时的情况下，congestion window 会以 2 倍的速度增长，直到 cwnd = threshold，易知这需要 3$\times$ RTT**的时间。之后，cwnd 会以每个 RTT 加 1 的速度增长。**

故 cwnd 增长到 14KB 所需要的时间为：3$\times$ RTT $+ (14-8) \times$ RTT $= 9 \times$ RTT $=$ 900ms

3) While its congestion window is at 14KB, the sender receives triple duplicate acknowledgements for the same sequence number. How long after receiving the third duplicate acknowledgement will it take for the sender's congestion window to be at least 9KB again?

答：如果采用 Reno 算法，在发送端收到三次重复的冗余 ACK 后，激活快速重传，此时：
threshold = cwnd/2=14KB/2=7MSS
cwnd = cwnd/2 = 7MSS
之后 cwnd 会以每个 RTT 加 1 的速度增长，故 cwnd 增长到 9KB 所需要的时间为：

$$(9-7)\times \mathrm{RTT} = 2\times \mathrm{RTT} = 200\mathrm{ms}$$

如果采用 Tahoe 算法，由于接收三个冗余 ACK，此时：
threshold = cwnd/2=14KB/2=7MSS
cwnd = 1MSS
之后先经历慢启动过程，共经历 3 个 RTT 使得 cwnd 增长至 7MSS，
随后进入拥塞避免阶段，经历 2 个 RTT 使得 cwnd 增长至 9MSS。
故 cwnd 增长到 9KB 所需要的时间为：

$$3\times \mathrm{RTT} + 2\times \mathrm{RTT} = 500\mathrm{ms}$$

3. Consider a scenario with two hosts, Alice and Bob. A web server running on Alice is trying to send data to a browser on Bob. For each TCP connection, Alice's TCP stack maintains a send buffer of 512 bytes and Bob's TCP stack maintains a receive buffer of 1024 bytes. For simplicity, assume TCP sequence numbers began at 0 in this problem.

1) Bob's stack received up to byte 560 in order from Alice, although its browser has only read up to the first 60 bytes. What will be the ***ACK#*** and ***rcvr window size*** in the TCP headers that Bob next sends to Alice?

答：ACK 为 561，rcvr window size 为：1024 – (560 - 60) = 524 (byte)

2) Later in the same connection, Alice's congestion window is set to 1 MSS = 536 bytes and the advertised flow-control window from Bob is 560 bytes. The last ***ACK#*** that Alice received from Bob is byte 700, and the last byte that Alice sends to Bob is byte 900.

A) What is the smallest byte number that Bob will not accept?

答：Bob 端目前已经收到了第 700 号（不包括），其目前接收窗口 rwnd 大小为 560bytes，故其不会接收的最小字节编号为：700+560= 1260
（注：由下一问可知，当前 Alice 没有接受到更多的 ACK 的情况下，是不能发出第 1212 号及以后的字节的）

B) Assuming that Alice doesn't receive any more ACKs and her window does not change, what is the greatest byte number that Alice can send?

答：对 Alice，send buffer 为 512 byte，又最后被确认收到的字节 number 为 700-1=699。
由于对 Bob 的 AdvertisedWindow 为 560byte>512byte。
故易知 Alice 能发送的最后一个字节的 number 为：699+512 = 1211

C) Again assuming that Alice doesn't receive any additional ACKs, how many more bytes can the web server running on Alice write to its network socket before blocking?

答：由上一问易知 Alice 还能向缓冲区里写的字符数为 1211-900 = 311 bytes