13. (4%) (a) How does a TCP sender detect congestion?
    (b) How does a TCP sender adjust send rate?
14. (4%) Describe the additive-increase and multiplicative-decrease algorithm in the TCP congestion control mechanism.
15. (10%) In this problem we consider the delay introduced by the TCP slow-start phase. Consider a client and a Web server directly connected by one link of rate R. Suppose the client wants to retrieve an object whose size is exactly equal to 15 S, where S is the maximum segment size (MSS). Denote the round-trip time between the client and server as RTT (assumed to be constant). Ignoring protocol header, determine the time to retrieve the object (including TCP connection establishment) when $S/R \geq$ RTT. $RTT + RTT + \frac{S}{R} + RTT + (2+4+8)\frac{S}{R}$
16. (10%) Consider the following plot of window size as a function of transmission round. Assuming TCP Reno is the protocol experiencing the behavior shown below.

Transmission round
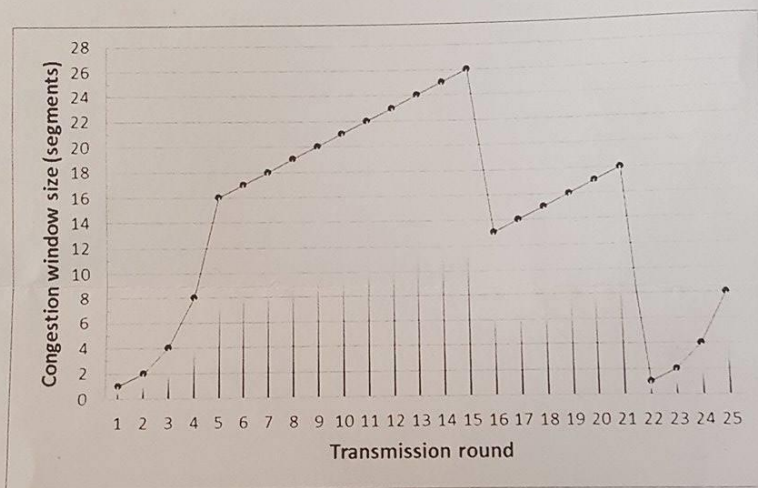
a) Identify the intervals of time when TCP slow start is operating. $[1,5]$ $[22,25]$
b) Identify the intervals of time when TCP congestion avoidance is operating. $[5,15]$ $[16,21]$
c) After the 15th transmission round, is segment loss detected by a triple duplicate ACK or by a time out?   3 duplicate ACK
d) After the 21st transmission round, is segment loss detected by a triple duplicate ACK or by a time out?   time out
e) During what transmission round is the 25th segment sent?

5th transmission round

1. (8%) What are the components of the cookie technology?
2. (6%) What are the major components of the Internet mail system?
3. (5%) (a) When a host wishes to find the IP address of a Web server, where does the host send the DNS query?
   (b) Suppose that a new company wishes to have a domain name. What type of name server is required to be installed?
4. (5%) Explain the problems with a centralized design of a DNS system?
5. (4%) What mechanisms can be used to handle packet losses in a reliable transfer protocol?
6. (5%) What is the purpose for using timers in reliable data transfer protocols? Explain.
7. (5%) What is the purpose for using sequence numbers in reliable data transfer protocols? Explain.
8. (8%) (a) What are the drawbacks of the Go-Back-N protocol?
   (b) What mechanisms are used in the Selective-Repeat protocol to remedy the drawbacks?
9. (5%) Consider the go-back-n protocol with a sender window size of 8 and a sequence number range of 512. Suppose that at time t, the next in-order packet that the receiver is expecting has a sequence of 86. Assume that the medium does not reorder messages. What are the possible sets of sequence numbers inside the sender's window at time t? Justify your answer.
10. (9%) Draw a diagram to describe the steps of the three-way handshake procedure for establishing a TCP connection. Please provide the values of related fields in the TCP header of each message.
11. (6%) What are the causes for wasted network capacity?
12. (8%)
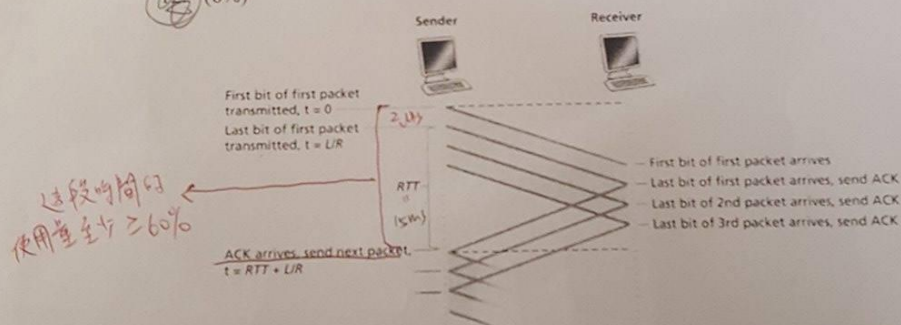
A sender is allowed to send multiple packets without waiting for acknowledgments, as illustrated in the above figure. The maximum number of packets the sender is allowed to send is without waiting for acknowledgments called the window size. Suppose that the round-trip delay between the sender and receiver is 15 ms and the transmission time of a packet is 2 microseconds. All packets are of the same size. How big would the window size have to be for the channel utilization to be greater than 60 percent?