This homework contains 8 questions. The deadline is on Jan. 3 (Thu.) 23:59.
Total of points is 100. Please submit your answers to the TA (office: EC-635).

1. (10 points) **RTT estimation:** Recall that TCP uses *exponential weighted moving average* (EWMA) to estimate RTT between an end-to-end path using the equation

$$\text{RTT} = (1 - \alpha) * \text{RTT} + \alpha * \text{sampleRTT}$$

   (a) (5 points) Assume that α is set to 0.4, and the initial RTT is set to the first sample RTT. What will be the final estimated RTT when the sender collects the following 4 samples (in milliseconds)?

   <div align="center">20   30   30   20</div>

   (b) (5 points) The following equation can be used to consider the safety margin in timeout estimation:

   $$\text{timeout} = \text{RTT} + \beta * \text{DevRTT}$$

   Consider the following two cases. Which one corresponds to a larger timeout? Why?

   <div align="center">a) 20   30   30   20</div>

   <div align="center">b)10   30   40   20</div>

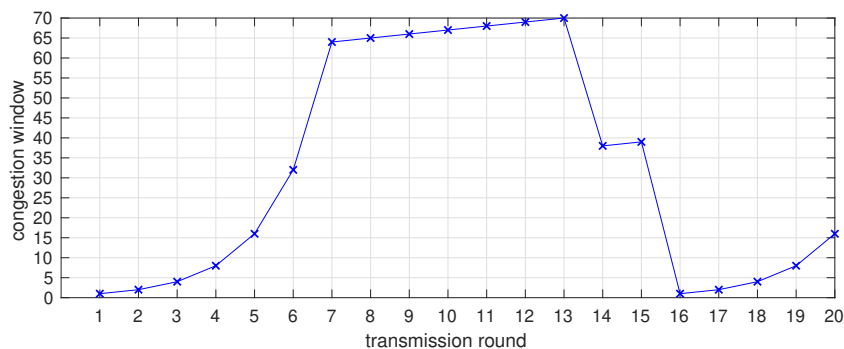2. (15 points) **TCP congestion control:** Consider the following figure. Assuming TCP Reno is the protocol.

Figure 1: TCP window size as a function of time

   (a) (5 points) Identify the intervals of time when TCP slow start is operating.

(b) (5 points) Identify the intervals of time when TCP congestion avoidance is operating.

(c) (5 points) What is the initial value of `ssthresh` at the 5th and 15th transmission round, respectively?

3. (10 points) **Control and data plane.**

    (a) (4 points) Briefly explain what is the control plane and the data plane in a router. Describe what are their major tasks.

    (b) (4 points) Briefly explain what is the difference between the per-router control plane and the centralized control plane.

    (c) (2 points) Does an SDN use a per-router control plane or a centralized control plane?

4. (15 points) **Prefix matching.** Consider the following routing table at a router.

| prefix	output port
11000110 10111111 1100**** ********	1
11000110 10111111 1111010* ********	2
11000110 10111111 1111**** ********	3
otherwise	4

    (a) (5 points) What is the output port is the destination address is
        11000110 10111001 11000010 00001001?

    (b) (5 points) What is the output port is the destination address is
        11000110 10111111 11110111 11101001?

    (c) (5 points) What is the output port is the destination address is
        11000110 10111111 11110101 11101001?

5. (10 points) **Queueing.** Consider a router that help forward packets classified into two classes. Say that ten packets arrive the router with the following class and arrival time:

sequence	1	2	3	4	5	6	7	8	9	10
class	2	2	1	2	2	1	1	2	2	1
time (second)	1.5	2.3	2.4	4.1	4.5	5.8	6.5	6.6	7.1	7.5

Assume that the transmission time of each packet is *one second*.

    (a) (4 points) Assume that class 1 has a high priority, while class 2 has a low priority. When will each packet be sent if the router forwards packets using priority queueing? (Note that there is no preemptive.)

    (b) (4 points) Explain what does *non-preemptive* mean.

    (c) (4 points) When will each packet be sent if the router forwards packets using round robin queueing?

6. (10 points) **Subnet.**

   (a) (5 points) What is the maximum number of hosts in the subnet 140.113.87.0/23?

   (b) (5 points) What is the subnet mask of subnet 140.113.87.0/23 in decimal?

7. (10 points) **DHCP.**

   (a) (5 points) Assume there is no packet error and no packet loss. How many messages are required to obtain an IP address from a DHCP server?

   (b) (5 points) What is the destination address of the first DHCP request message? What does it mean? Why we use this as the first destination IP address?

8. (20 points) **Link-state routing.** Consider the following network topology with 6 nodes. Let the number associated with each link be the cost of the link. Try to find the shortest path from node w to the remaining nodes using the link-state algorithm.
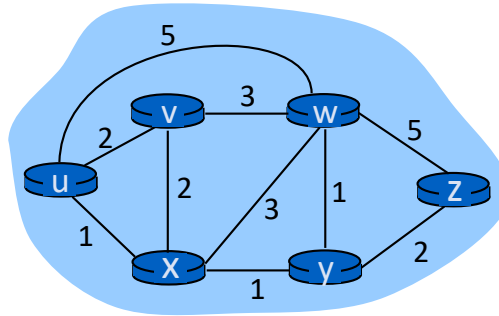
   (a) (10 points) Write down the step-by-step procedure of the link-state algorithm as building the distance/predecessor table from node w to all the remaining nodes.

   (b) (5 points) What is the routing path from w to u?

   (c) (5 points) What is the forwarding table at node y?