Name: ______________________ **Student ID: ____________________**

National Taiwan Normal University
Department of Computer Science and Information Engineering

CSC0056 - Data Communication
Final Exam (Jan. 6, 2020)

(Six group questions; exam time: 2 hours 50 minutes (9:20am-12:10pm))

1. (15 points) **Multi-access communication.** The analysis of the slotted Aloha protocol is a good example of performance analysis in data communication. In the following questions, consider there are *m* senders sending data to one receiver. Each question is a statement, and if you think the statement is true, simply answer 'T'; otherwise, answer 'F' and provide your reason:
   1a. (5 points) In analyzing the slotted Aloha, the no-buffering assumption provides a way to analyze the lower bound to the delay for systems with buffering; the $m=\infty$ assumption provides a way to analyze the upper bound to the delay that can be achieved with a finite number of nodes.
   1b. (5 points) In the slotted Aloha, data re-transmissions due to collision will lead to an increase in the attempted transmission rate.
   1c. (5 points) In the slotted Aloha, as the system started having more data arrivals, initially there will be an increase in departure rate, thanks to a better utilization of time slots; as the system kept having more and more data arrivals, eventually there will be a decrease in the departure rate, because the system will be overwhelmed by data re-transmissions.

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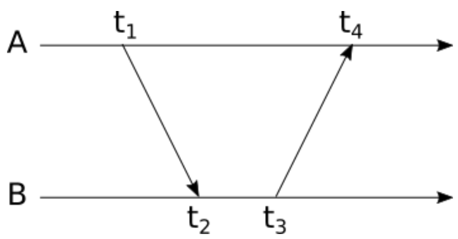
2. (20 points) **Time synchronization and deadline estimation.** Answer the following three questions:



2a. (8 points) Consider the above figure, with two hosts A and B and their message exchanges. Let t_1=100, t_2=160, t_3=200, t_4=240. By only considering these timing information, what is the mean time offset between the two hosts? Just provide the absolute value of the offset.

2b. (7 points) Briefly explain why the PTP use of transparent clocks (either end-to-end or peer-to-peer) may improve the accuracy of synchronization.

2c. (5 points) In Homework 6, we studied that for a networked application with an end-to-end deadline requirement, a way to estimate an upper bound of deadline in the intermediary is to subtract the end-to-end deadline by both the lower bound of delay between a sender and the intermediary and that between the intermediary and a receiver. Now, suppose we instead estimate an upper bound of deadline in the intermediary by subtracting the end-to-end deadline by both the maximum of the measured delay between a sender and the intermediary and that between the intermediary and a receiver. Does that give us a *tighter* upper bound of deadline in the intermediary? Why or why not? You may draw timelines to help your analysis and explanation.

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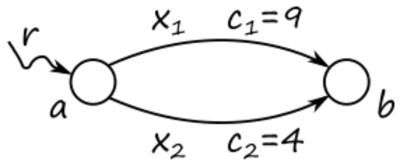
3. (15 points) **Network flow and optimal routing.** Consider the following OD pair with input flow r, two paths x_1 and x_2, each having capacity c_1 and c_2, and the cost function $D(x)$:

$$D(x) = D_1(x_1) + D_2(x_2)$$
$$D_1(x_1) = (c_1 - x_1)^{-1}$$
$$D_2(x_2) = (c_2 - x_2)^{-1}$$



Suppose $r = 4$. Is $(x_1, x_2) = (4, 0)$ an optimal routing? If you think the answer is yes, explain your reasoning; if you think the answer is no, compute the optimal routing (x_1, x_2).

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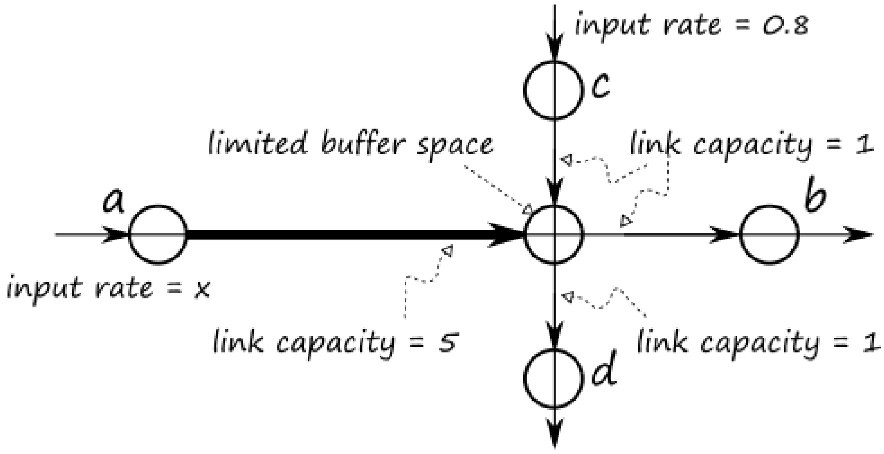
4. (10 points) **Flow control.** Consider the following five-node network. There are two sessions, one from top to bottom with a Poisson input rate = 0.8, and the other from left to right with a Poisson input rate = x. Assume that the central node has a large but finite buffer pool that is shared on a first-come first-serve basis by the two sessions. If the buffer pool is full, an incoming packet is rejected and then re-transmitted by the sending node.



4a. (5 points) We see that if $x = 0$, the total throughput is 0.8 (that is, 0.8 for the c-to-d session and 0 for the a-to-b session). Explain why as the value of x increases, the total throughput will first increase and then will decrease toward 1.2.

4b. (5 points) Suppose we try to use a window flow control strategy at node a to limit some amount of data flow entering into the network. Let W denote the window size. Using this strategy, node a will count the number n of packets it has already transmitted but for which it has not yet received back a permit, and will transmit new packets only if $n < W$. Suppose that the transmission time of a single packet is 0.1 millisecond, and the round-trip delay is 0.5 millisecond. If we set W=10, will this method really help limit data flow? Why?

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5. (20 points) **Automotive data communication.** In class, we learned how ECUs (electronic control units) may exchange data via the CAN protocol. Now, suppose that the 'dominant' level is represented by a logical '1' and the 'recessive' level by a logical '0'. If, at a certain point of time, three ECUs have some data to send over the same CAN bus, with the following message IDENTIFIERs:

	MSB LSB
Data D_1's message IDENTIFIER:	00101101111
Data D_2's message IDENTIFIER:	00111001101
Data D_3's message IDENTIFIER:	00101000111

5a. (15 points) List the relative priority of these three messages according to CAN's arbitration.

5b. (5 point) Following 5a, suppose that a fourth ECU has data to send just right after the highest-priority message has completed transmission. The message IDENTIFIER is as follows:

	MSB LSB
Data D_4's message IDENTIFIER:	00101011100

List the new relative priority of these three remaining messages according to CAN's arbitration.

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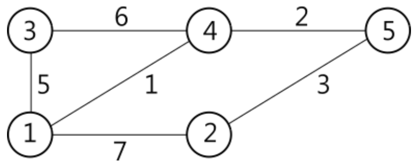
6. (20 points, plus 10 extra points) **Trees and paths used in data communication**. Consider the following graphs. Each node represents a wireless embedded device, and each arc between two nodes indicates that the two nodes may have a direct data communication with each other. The arc weight represents the one-way propagation delay for communication in either direction.



6a. (10 points) To have a device receive data from all other devices in a timely manner, we may construct a minimum weight spanning tree structure and have devices deliver data along the paths of the tree. Now, use Kruskal's algorithm to construct the minimum weight spanning tree. Draw your answer for each iteration.

6b. (10 points) Following 6a, if we already know the receiving device, then we may consider construct the shortest paths from all devices to that device. Use Dijkstra's algorithm to construct the shortest paths from all nodes to node 1. Draw your answer for each iteration.

6c. (extra 5 points) Suppose that at each time point, each of nodes 4 and 5 with a high probability may want to deliver its own data to node 1 along its shortest path, and other data will be queued for later delivery. In this case, is it still a good idea to have node 2 deliver its own data along the shortest path constructed in 6b? Why?

6d. (extra 5 points) Suppose that except for the source node and the destination node, one node in a graph may be disconnected from all others (the device's battery is dead, for example). To ensure data delivery in presence of such a one-node failure, what might be a design requirement to construct data delivery paths between source and destination?