Solution attached

CSC0056 Final Exam

- Exam time: 9:20am-12:10pm, Jan. 11th, 2021.
- 100 points total.

1. **(15 points)** Consider the slotted Aloha system. Explain why (1) with the no-buffering assumption, there could be two stable points where the departure rate equals the arrival rate, and (2) with the infinite-set-of-nodes assumption, there is only one stable point where the departure rate equals the arrival rate.

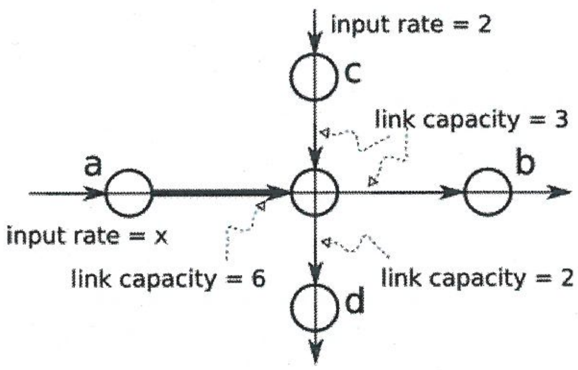
2. **(10 points)** Consider the CAN bus, with a *wired-AND* implementation, and with five MCUs attached to it. Suppose that the only traffic on the bus is the following: MCUs M_1, M_2, M_3, and M_4 periodically send messages to MCU M_5 with no need for acknowledgement. Let $\frac{1}{3}$ be the message creation rate of M_1 (i.e., if it created a message at the 1st time slot, it will create another message at the 4th time slot), and let $\frac{1}{7}$ be the message creation rate of M_2, M_3, and M_4. To ensure that M_1 will never have more than one message waiting to be sent, which of the following identifiers should we assign to the messages of M_1?

	MSB $\longrightarrow$ LSB
IDENTIFIER 1:	0 1 0 1 0 1 0 1 1 1 1
IDENTIFIER 2:	1 1 1 0 0 1 0 1 1 0 0
IDENTIFIER 3:	1 0 0 1 1 0 0 0 0 1 1
IDENTIFIER 4:	1 1 0 1 1 0 1 1 0 1 1
IDENTIFIER 5:	1 0 1 1 0 0 0 1 0 0 1

3. **(20 points)** Consider a typical wireless data communication graph, where each node represents a wireless host, and each link between two nodes indicates that the wireless hosts are within the transmission range of each other. Consider using TDMA to transmit data from node N_A to node N_B that is at least five links away from each other. Each TDMA time slot accounts for 1 millisecond and the capacity for each link is 50K bits per second. At least how long it would take to send 500 bits from N_A to N_B, considering the primary and secondary interference?

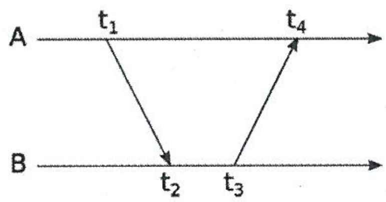
4. **(15 points)** Consider real-time, fault-tolerant, broker-based data communication. In class we've studied a strategy that combines (1) data retransmission from the data-sender host and (2) data replication to the backup broker, to avoid excessive data losses. Now, suppose we can have a buffer of infinite size at each data-sender host, so that all previous data has a copy stored at their data-sender host. Give at least two reasons that we will still want to replicate data to a backup broker.

5. **(20 points)** Consider the following network topology with Poisson input rates as shown. Answer three questions:



1. **(5 points)** Suppose that the central node has unlimited buffer space. What is the maximum total throughput of the network as x increases?
2. **(5 points)** Suppose that the central node has limited buffer space. With data retransmissions for dropped packets, what is maximum total throughput of the network as x increases?
3. **(10 points)** Following Question 5.2, now we use a leaky bucket scheme at node a to control the data flow. Assume that permits are generated on a *per packet basis*. Suppose bucket size W=1, packets arrive at rate λ=2, and permits arrive at rate r=3. What is the average waiting time for a packet at node a to obtain a permit?

6. **(20 points)** Consider NTP and answer the following two questions:
   1. **(5 points)** Consider the following time-lines, with t_1=90, t_2=100, t_3=105, and t_4=145, and compute the mean time offset between hosts A and B using the NTP protocol:



   2. **(15 points)** When doing real-time data communication experiments over a network, it is important to measure the one-way delay from one host to another host. Without time synchronization, why could we observe a *negative* one-way delay? With NTP enabled, where both data-sender host and data-receiver host keep synchronizing to a NTP server host while the experiment is running, why could we *still* observe a negative one-way delay? For each question, use a numerical example to explain.

Name: Solution **Student ID:** CSC0056 final

(1) Review textbook Section 4.2.1~4.2.2.

With no buffering assumption, the arrival rate will decrease as the congestion develop. Now, since the departure rate follows the Poisson distribution, we see that

(1) if the departure rate is higher than the arrival rate, the level of congestion will decay and thus the arrival rates will increase;

(2) if the departure rate is lower than the arrival rate, the level of congestion will grow and thus the arrival rates will decrease.

With the infinite-set-of-nodes assumption, the arrival rate does not change along with the departure rate. Therefore, as the congestion develops to cause a decrease in the departure rate, the departure rate will never rise after it becomes lower than the arrival rate. #

(2) In the wired-AND implementation, 0 is dominant. Thus the priority levels of those identifiers follow the order $1 > 3 > 5 > 4 > 2$. Since M_1 will never create another message until the third slot after its previous creation, it suffices to assign M_1 with an identifier having the priority level among the top three.

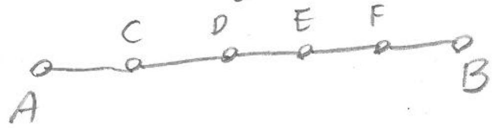
Ans: 1, 3, or 5.

#

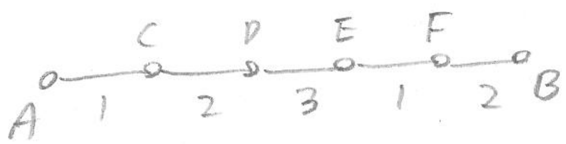
Name: ______________________ **Student ID:** ____________________ Page

(3) 50 kbits / second = 50 bits / millisecond

With no interference it would take 500/50 + 4 = 14 milliseconds to send 500 bits along a single path:



Now, because of secondary interferences, concurrent transmissions can take place only if the links are at least two-link away from each other. Therefore, at best we can use a TDMA schedule with three time slots in a cycle:



So, it would take (500/50) × 3 + 4 = 34 milliseconds to complete. ※

Multi-path transmissions will not improve the delay, because both A and B will impose scheduling constraints due to primary and secondary interference...

(4) Reason 1. It may increase the delay a lot if the sender is far away from the broker.

Reason 2. It may lead to a burst of arrivals at the backup broker.

Reason 3. It will consume addition network bandwidth.

ne: ____________ **Student ID:** ____________

(5.1) Review textbook Section 6.1.2.

Ans: $3+2=5$, constrained by the link capacities to b and d.

(5.2) Ans: $3+3\times\left(\frac{3}{6}\right)=4.5$, constrained by the link capacities to b and from a and c.

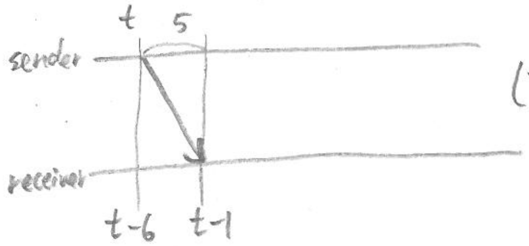
(5.3) Review textbook Section 6.3.

A key observation is that when $W=1$, the system works like a time-division multiplexing with time slot equal to $\frac{1}{r}$ units. Therefore we may think of it as a queueing system with average arrival rate λ and constant service rate r, which is essentially a M/D/1. The average waiting time is one half of the average waiting time of a M/M/1 : $\frac{\rho}{2\mu(1-\rho)} = \frac{2/3}{2\times3\times(1/3)} = \frac{1}{3}$ #

We did not cover M/D/1 this semester so I'll give 10 points to all.

(6.1) $\frac{1}{2}(100-90+105-145)=-15$ #

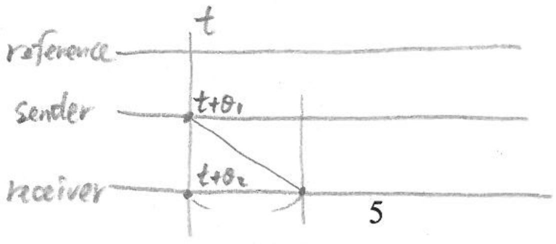
(6.2) A. Suppose $\theta=-6$ and $\delta=5$



$(t-1)-t=-1<0$

B. Suppose $\delta \ll 1$ let $\theta_1=1$, $\theta_2=0.7$, $\delta=0.2$

$(t+0.7+0.2)-(t+1)=-0.1<0$



Recall that NTP provides accuracy around 1 ms and local network one-way delay could be less than 0.2 ms. Thus the above situation could happen. #