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EECE 2460 Midterm Exam

(March 3, 2023)

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Total Points Received:

Part I (36 points): MC Questions + T/F Questions

Score: 28.5

Part II (64 Points): 6 Quantitative Questions

Score: 27

Part III (20 Points): 2 Bonus Questions

Score: 14

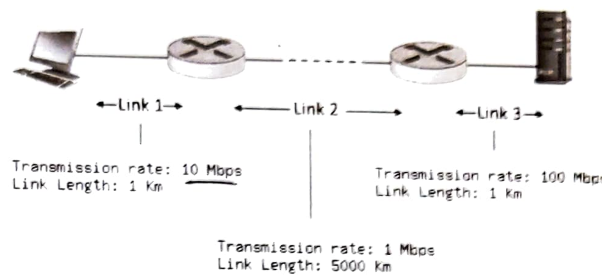
Maximum Points: 100 + 20

Total Score: 69.5

EECE 2460 Midterm Exam –Quantitative + Bonus Questions (March 3, 2023)

Note: Please show detailed procedures for full credits.

Problem 1 (8 points). Consider the figure on the right, with three links, each with the specified transmission rate and link length. Assume the length of a packet is 10Kbits. The propagation speed on each link is 2×10^8 m/sec. Assume queuing and processing delay is ignored. Note: $1K=10^3$, $1M=10^6$



(a) (6 points) What is the total delay of link 1, link 2, and link 3 respectively? (Dimensional analysis)

~~10K~~ ~~$\frac{10Mbps}{10Kbits}$~~ = $\frac{10Kbits}{10Mbps} = 0.001 s$

~~$\frac{2\times10^8 m}{s} \cdot \frac{1}{1Km} \cdot \frac{1Km}{1\times10^3 m}$~~ $\frac{1Km}{2\times10^8 m/s} = 5\times10^{-6} s$

$\boxed{\text{Link 1 delay} = 0.001005 s}$

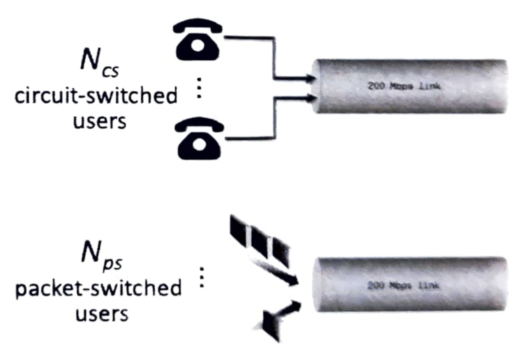
Link 2: $\frac{10Kbits}{1Mbps} + \frac{500Km}{2\times10^8} = 0.0125 s$

Link 3: $\frac{10Kbits}{100Mbps} + \frac{1Km}{2\times10^8} = 1.05\times10^{-4} s$ ~~0.0125 s~~

(b) (**2 points**) What is the total end-to-end delay?

Link1 + Link 2 + Link 3 = 0.00121 s $= \boxed{1.24 mS}$

Problem 2 (14 points). Consider an application scenario where a number of users need to share a communication link of capacity 200 Mbps. Each user requires 20 Mbps when transmitting, but only needs to transmit with the probability **p** =20 % of the time.



(a) (**5 points**) Determine N_{cs}, the maximum number of users that can be supported simultaneously if **circuit switching** is used. What is the data rate allocated to each user if Time Division Multiplexing (TDM) is used for circuit switching? What is the data rate allocated to each user if Frequency Division Multiplexing (FDM) is used?

a.1) $\frac{200Mbps ~~(0.2)~~}{20Mbps(0.2)}$ = 50 people when 20% chance of transmitting

a.2)

a.3)

(b) (**5 points**) Now suppose **packet switching** is used by N_{ps} = 30 users in this system. What is the probability that a given (specific) user is transmitting, and the remaining users are NOT transmitting? What is the probability that one user (any one among the 30 users) is transmitting, and the remaining users are not transmitting? Please provide detailed procedures for full credits, yet numerical value is not required.

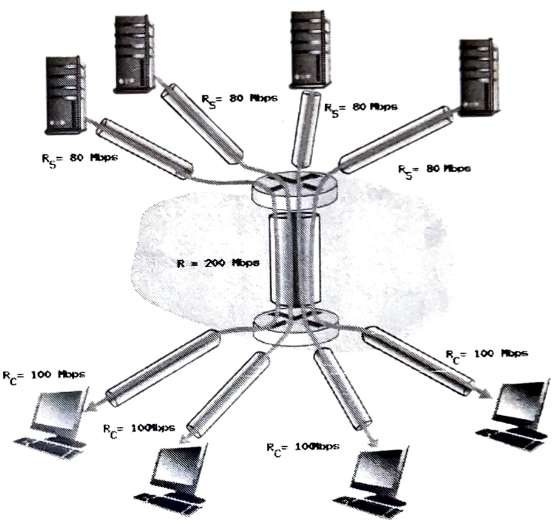
~~(1-P)~~ ~~I cannot memorize formulas... these types of~~

I cannot memorize these types of formulas... V0.025

(c) **(4 points)** For **packet switching**, again, assume $N_{ps} = 30$ users share this packet switching system, give the formula (in terms of p, N_{ps}) to determine the probability that at any given time, 10 or more users are transmitting simultaneously. No numerical result is required.

$(1-p)^n$ 7(0.025

Problem 3 (6 points). Consider the scenario where 4 TCP hosts are connected to 4 servers. The servers transmit to the receiving hosts at the fastest rate possible (i.e., at the rate at which the bottleneck link between a server and its destination is operating at 100% utilization). Assume the middle link is fairly shared (divides its transmission rate equally). Suppose that R = 200 Mbps and R_c is 100 Mbps and R_s is 80 Mbps. Assume that the servers are sending at their maximum rate possible.



(a) Determine the end-to-end throughput of each host and server pair. 80Mbps

(b) Determine the link utilizations for the server links, which is defined as the ratio of the end-to-end throughput to the server link capacity R_s.

80 : 100 [Mbps]

Problem 4 (6 points). Internet Check Sum:

(a) Suppose you have the following 2 bytes: 10101011 and 01000111. What is the 1's complement of the sum of these 2 bytes?

(b) Suppose you have the following 2 bytes: 11101100 and 11010101. What is the 1's complement of the sum of these 2 bytes?

a) 10101011
+01000111
11110010

1's comp = 00001101

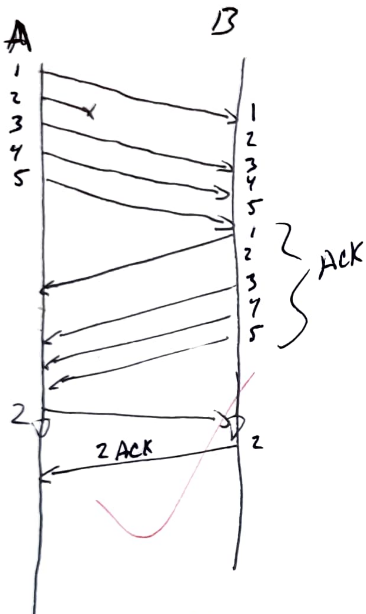
b) 11101100
11010101
(1)11000001

1's comp : 00011110

5

Problem 5 (15 points). Compare **Go-Back-N**, **Selective Repeat**, and **TCP**. Assume that the timeout values for all three protocols are sufficiently long, such that **five** consecutive data segments and their corresponding ACKs can be received (if not lost in the channel) by the receiving host (Host B) and the sending host (Host A) respectively. Suppose Host A sends **five** data segments to Host B, and the **second segment is lost**. In the end, all **five** data segments have been correctly received by Host B. (a) Draw the timeline diagram for each protocol and answer question (b). Use pkt1, pkt2, …, pkt5 and ACK1, ACK2, …, ACK5 to label the corresponding packet sequence number and ACK number, also mark timeout on the timeline diagram.

(a) (**9 points**) Draw the timeline diagram with all three protocols.



TCP, Selective repeat

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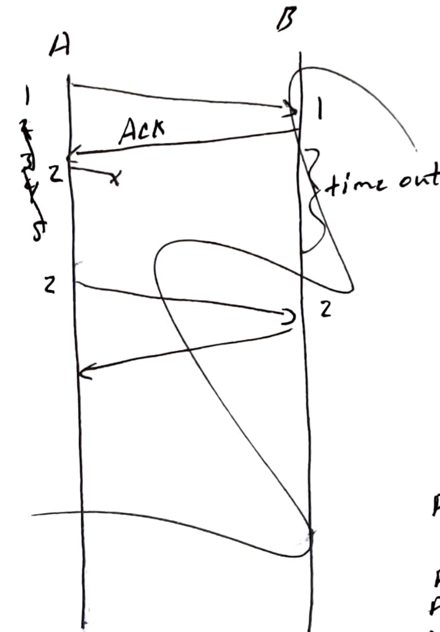

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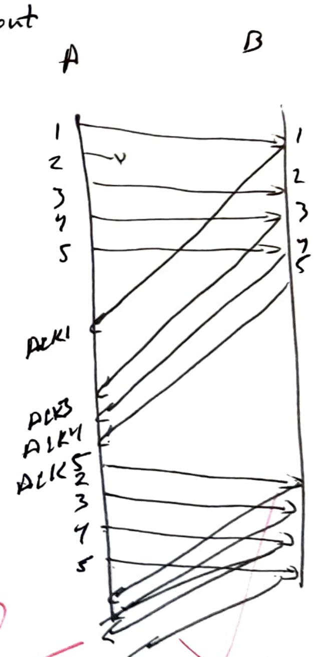


Go-Back-N

(b) (**6 points**) How many segments has Host A sent in total and how many ACKs has Host B sent in total? What are their sequence numbers? Answer this question for all three protocols.

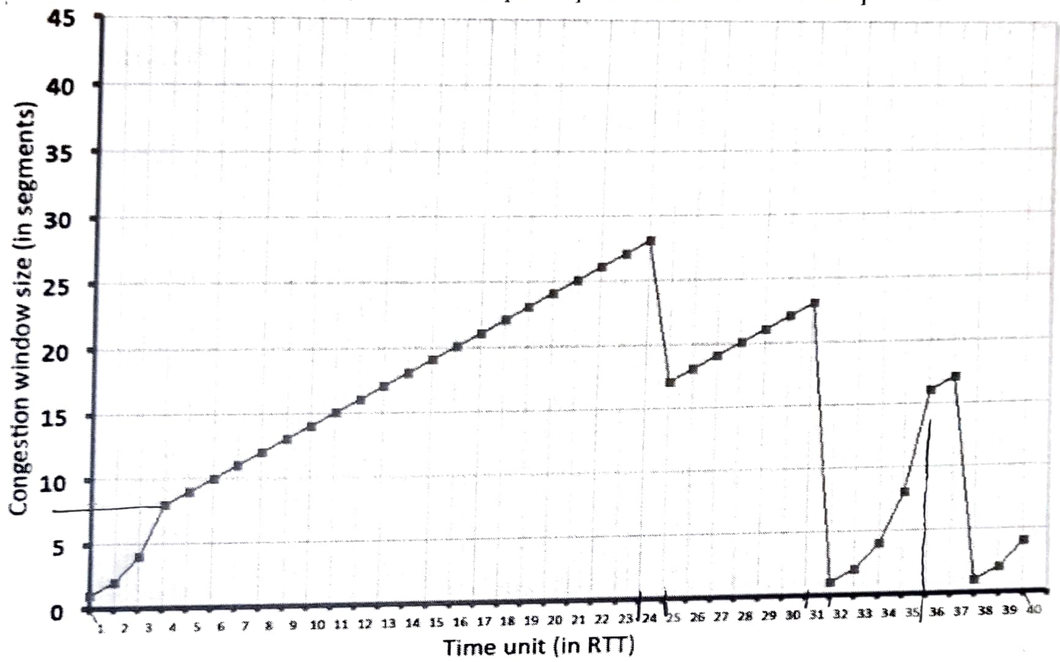
A) 6+6+8 = 20 sent

B) 5+5+8 = 18 sent

2.5

	TCP	SR	GBR
A	6 sent	6	8
B	5 Acks	5	8

Problem 6 (15 points). Consider the figure below, which plots the evolution of TCP's congestion window at the beginning of each time unit (where the unit of time is equal to the RTT); In the abstract model for this problem, TCP sends a "flight" of packets of size cwnd at the beginning of each time unit. The result of sending that flight of packets is that either (i) all packets are ACKed at the end of the time unit, (ii) there is a timeout for the first packet, or (iii) there is a triple duplicate ACK for the first packet.



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(a) Identify the times at which TCP is in **slow start**. Format your answer like: 1,3,5,9.

~~[9, 9.5]~~

0, 1, 2, 3, 3.5, 31.5, 32.5, 33.5, 34.5, 35.5

0

(b) Identify the intervals of time when TCP **congestion avoidance** is operating. Format your answer like: [6, 13]

[23.5, 24.5]

0.5

(c) Give the times at which TCP starts **fast recovery**. Format your answer like: 1,3,5,9.

24.5, ~~25.5, 26.5, 27.5, 28.5, 29.5, 30.5~~

2

(d) Give the times at which TCP has a packet loss by **timeout**. Format your answer like: 1,3,5,9.

30.5, 37.5

0.5

(e) Give the times at which TCP has a packet loss by **triple ACK**. Format your answer like: 1,3,5,9.

23.5, 24.5

1

(f) Give the times at which the value of **ssthresh** changes.

[23.5, ~~25.5~~] , [30.5, ~~31.5~~]

25 32

Bonus Questions (20 points): You may work on maximumly 2 out of 4 following bonus questions.

B1 (10 points). Suppose that TCP's current estimated values for the round trip time (estimatedRTT) and deviation in the RTT (DevRTT) are 100 msec and 10 msec. Suppose that the next two measured values of the RTT are 90 msec and 100 msec respectively. Compute TCP's new value of DevRTT and estimatedRTT, and the TCP timeout value after each of these two measured RTT values is obtained. Use the values of α = 0.1, and β = 0.1. Note: The formulas for exponential weighted moving average (EWMA) based **RTT** estimation and **timeout** estimation are as following:

*EstimatedRTT = (1- α) * EstimatedRTT + α * SampleRTT*
*DevRTT = (1- β) * DevRTT + β * | SampleRTT - EstimatedRTT |*
*TimeoutInterval = EstimatedRTT + 4 * DevRTT*

$EstRTT = 100ms$ $\qquad \alpha = 0.1$
$DevRTT = 10ms$ $\qquad \beta = 0.1$

8

$RTT_1 = 90ms$

$RTT_2 = 100ms$

$EstRTT_1 = (1-0.1)(100ms) + (0.1)(90ms) = 99ms$

$DevRTT_1 = (1-0.1)(10ms) + (0.1)|90ms - 99ms| = 9.9ms$

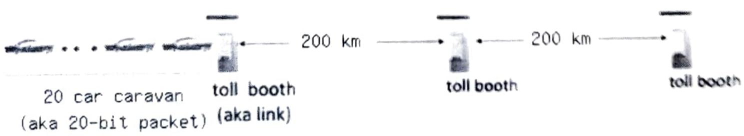
$EstRTT_2 = (1-0.1)(100ms) + (0.1)(100ms) = 100ms$

$DevRTT_2 = (1-0.1)(10ms) + (0.1)|100ms - 100ms| = 90ms$

B2 (10 points). Consider the figure below, which draws the analogy between store-and-forward link transmission and propagation of bits in packet along a link, and cars in a caravan being serviced at a toll booth and then driving along a road to the next tollbooth.

6

Suppose the caravan has 20 cars, and that the tollbooth services (that is, transmits) a car at a rate of one car per 2 seconds. Once receiving service a car proceeds to the next tool both, which is 200 kilometers away at a rate of 10 kilometers per second. Also assume that whenever the first car of the caravan arrives at a tollbooth, it must wait at the entrance to the tollbooth until all of the other cars in its caravan have arrived, and lined up behind it before being serviced at the toll booth. (That is, the entire caravan must be stored at the tollbooth before the first car in the caravan can pay its toll and begin driving towards the next tollbooth).



(a) How long does it take for the entire caravan to receive service at the tollbooth (that is the time from when the first car enters service until the last car leaves the tollbooth)?

$0.5 Cps + \frac{200 Km}{1 K/s} =$ $\qquad 20 cars \cdot \frac{0.5 cars}{s} = 40$ seconds

(b) Once the first car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

20 s

(c) Once the last car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

~~20s~~ 60 sec

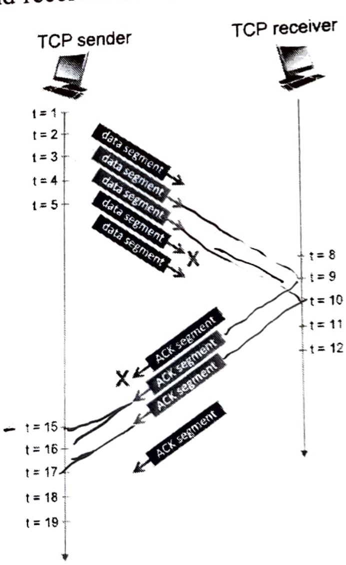
(d) Once the first car leaves the tollbooth, how long does it take until it enters service at the next tollbooth?

60 sec

(e) Are there ever two cars in service at the same time, one at the first toll booth and one at the second toll booth? Answer Yes or No.

No, they all must be lined up before service

B3. (10 points) Consider the figure on the right in which a TCP sender and receiver communicate over a connection in which the segments can be lost. The TCP sender wants to send a total of $\boxed{10 \text{ segments}}$ to the receiver and sends an initial window of 5 segments at t = 1, 2, 3, 4, and 5, respectively. Suppose the initial value of the sequence number is 50 and every segment sent to the receiver each contains ~~200~~ bytes. The delay between the sender and receiver is 7 time units, and so the first segment arrives at the receiver at t = 8, and an ACK for this segment arrives at t = 15. As shown in the figure, 1 of the 5 segments is lost between the sender and the receiver, but one of the ACKs is lost. *Assume there are no timeouts and any out of order segments received are thrown out.*



(a) What is the sequence number of the segment sent at t=1, 2, 3, 4, and 5?
(b) What is the value of the ACK sent at t=8, 9, 10, 11, and 12? (If segment lost, write 'x')
(c) What is the sequence number of the segment sent at t = 15, 16, 17, 18, and 19? (If ACK never arrives, write 'x')

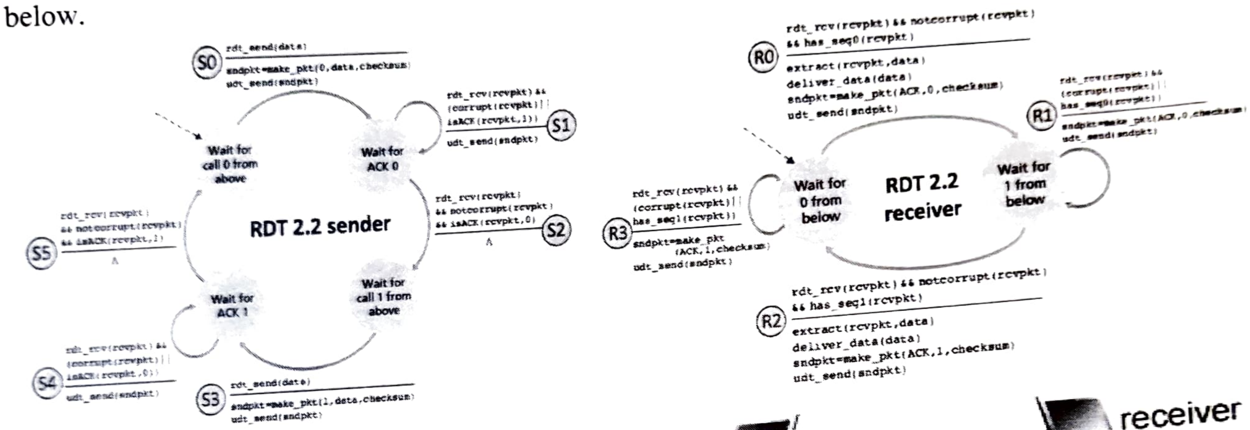
a) t=1 Seq = 250 | t=2 Seq = 450 | t = 3, Seq = 650 | t = 4 Seq = 1050 | t = 5 Seq = 1250

b) 250

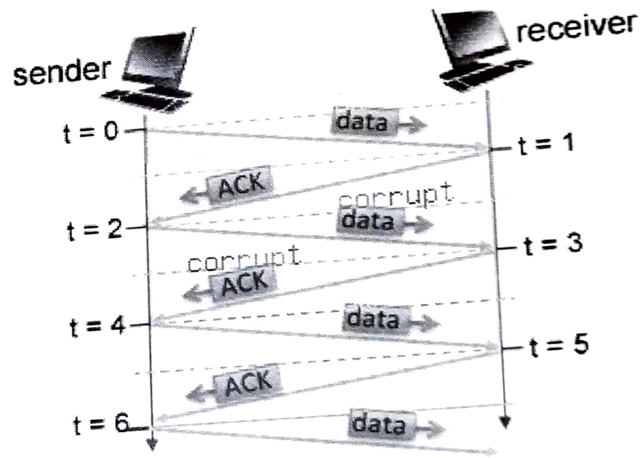
c) t=15 ACK = X | t = 16 ACK = 450 | t = 17 ACK = 650 | t = 18 ACK = 1050 | t = 19 Ack = 1250

lost

B4 (10 points). Consider the stop-and-wait based reliable data transfer protocol (**rdt 2.2**) sender and receiver below, with FSM transitions labeled in red. Also consider the sender and receiver timeline diagram following the FSMs, where a green OK label indicates a message that is not corrupted, and a red corrupt label indicates a message that is corrupted. We are interested in the sequence number (0 or 1) of a data message, and the ACK number (0 or 1) of an ACK message for the packets sent at t= 0, 1, 2, 3 in the figure below.



(a) **(6 points)** What is the **sender state** and the **receiver state** at time t=0, t=1, t=2, and t=3 respectively?



(b) **(4 points)** What is the **data message sequence number** (0 or 1) or **ACK number** (0 or 1) of the packet sent at time t=0, t=1, t=2, and t=3 respectively?