Data Communication Networks
Final

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NAME:————————————

- This final test is take home...
- There are 8 Problems (but each problem has multiple parts, possibly on separate pages).
- Make sure your answer is clear.
- Do not leave unanswered questions even if you think you do not have the complete answer. Partial credit **might** be given.
- Attach pages if needed
- No collaboration or even discussion is allowed for this test

Problem 1: Miscellaneous (40 points)

Problem 2: Stop-and-Wait ARQ (10 points)

Problem 3: Max-Min Fairness (10 points)

Problem 4: Fair Queueing (10 points)

Problem 5: Bridges (5 points)

Problem 6: Counting to infinity (5 points)

Problem 7: Shortest path (10 points)

Problem 8: Shortest path tree and minimum spanning tree (10 points)

Total: (100 points)

Problem 1: Miscellaneous questions (40 points)

Q1 (5 points): While TCP uses the same sliding window algorithm that is commonly found in the data link level, TCP differs from data link protocols in several important ways. For each of the following ways in which TCP differs from a data link protocol, give the TCP feature that addresses this difference. Be as precise as possible.

(a) Mismatch between sender's and receiver's processing speeds

(b) Multiple connections over time

(c) Variable RTT

(d) Potentially long delay on the Internet

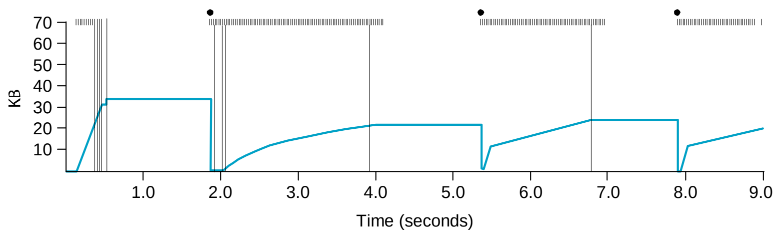
(e) Intermediate shared buffers

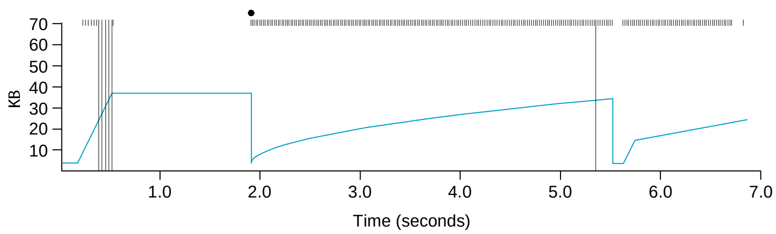
Q2 (5 points): Describe Nagle's algorithm in your own words, and explain what problem it solves.

Q3 (5 points): You are hired to design a reliable byte-stream protocol that uses a sliding window (like TCP). This protocol will run over a 622Mbps network. The RTT of the network is 100ms, and the maximum segment life is 50 seconds. How many bits would you include in the AdvertisedWindow and SequenceNum files of your protocol header? (Do not round to the nearest power of two).

Q4 (5 points): The RED router mechanism maintains two queue thresholds: MIN and MAX. Explain how a RED router processes an arriving packet in terms of these two thresholds. Explain why it is possible for the queue in a RED router to contain more than MAX packets.

Q5 (5 points): In the following TCP traces, the line represents the value of the congestion window over time, solid bullets at top represent timeouts, hash marks at top represent time when each packet is transmitted, and vertical bars represent time when a packet that was eventually retransmitted was first transmitted.





(a) Identify the feature that the version of TCP illustrated in the second trace has that the version of TCP illustrated in the first trace does not have. Explain why this feature results in the different behavior.

(b) Explain why both traces have heavy losses at approximately 0.5 sec.

(c) Explain why the congestion window is flat between 0.5s and 1.9s.

(d) For the first trace, explain what the TCP congestion control algorithm is doing between 2.0s and just after 3.5s.

(e) For the second trace, explain what triggers the change in the slope of the congestion window at just after 5.7s.

Q6 (5 points): Explain why the Ethernet has a minimum packet size of 64 bytes. Given an example illustrating how a smaller packet size could be a problem. What happens to the minimum packet size when the Ethernet rate rises to 100 Mbps? What are the drawbacks to so large a minimum packet size?

Q7 (5 points): Suppose a router has built up the routing table given below. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4. Describe what the router does with a packet addressed to each of the following destinations.

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	interface 0
128.96.39.128	255.255.255.128	interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
<default>		R4

(a) 128.96.39.10

(b) 128.96.40.12

(c) 128.96.40.151

(d) 192.4.153.17

(e) 192.4.153.90

Q8 (5 points): Give an example of an arrangement of routers grouped into autonomous systems so that the shortest path from a point A to another point B crosses the same AS twice. Explain what BGP would do with this situation.

Problem 2: Stop-and-Wait ARQ (10 points)

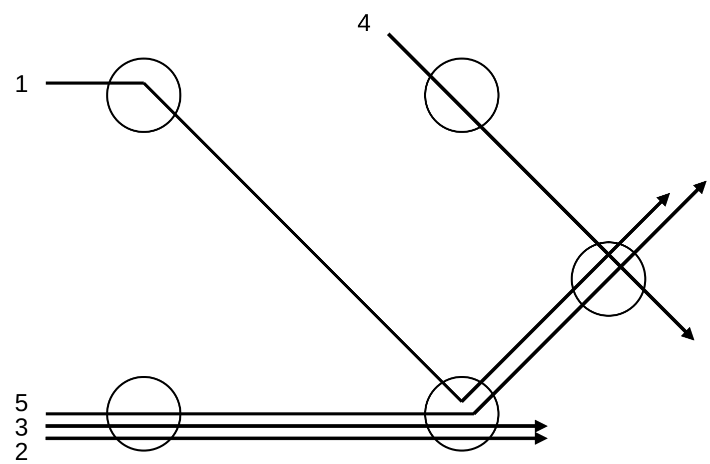
Consider a Stop-and-Wait ARQ strategy in which, rather than using a sequence number for successive packets, the sending DLC sends the number of times the given packet has been transmitted. Thus, the format of the transmitted frames is $\boxed{j \mid \text{packet} \mid \text{CRC}}$, where j is 0 the first time a packet is transmitted, 1 on the first retransmission, and so on.

The receiving DLC returns an Ack (received) or Nak (received with error), without any request number, for each frame it receives.

(a) (5 points) Assume frames might be lost and never arrive in both direction. Show an example where the receiving DLC cannot decide which packet it is really receiving.

(b) (5 points) Now assume that only Acks and Naks might be lost and never arrive. Show by example that it is possible for a packet to never be accepted by the receiving DLC, i.e. DLC never receives a correct version of the packet. *Hint*: A solution in which a frame always arrives in error is not acceptable; therefore, there is a non-zero probability that a frame will arrive with no error.

Problem 3: Max-Min fairness (10 points)
Consider the following 5 flows and assume all link capacities are 1.



(a) (5 points) Find the max-min fair rates for each flow.

(b) (5 points) Now assume that we change the definition of max-min fairness so that, in addition we include a constraint for each flow

$$r_f \leq b_f$$

where b_f is an upper bound on the rate of flow f. Modify the algorithm for solving max-min fairness we described in class to solve this problem. *Hint*: add a new link for each flow.
Repeat part (a) if $b_2 = b_4 = b_5 = 1$ and $b_1 = b_3 = 1/4$.

Problem 4: Fair queueing (10 points)
Consider the following arrival patterns at A, B, and C.

A: 1 2 4 6

B: 2 6

C: 1 2 6

Assume all packets have length 1 and the server capacity is one packet per time unit. Give the real time when each packet finished transmission in

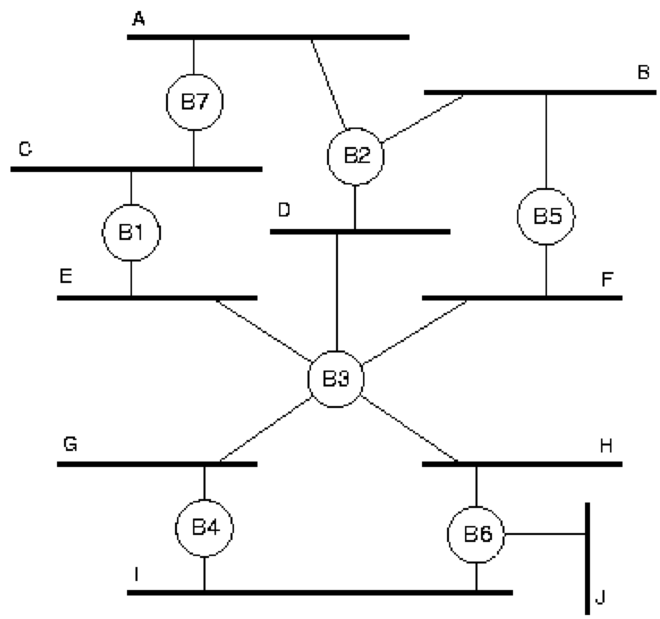
(a) Fair Queueing system

(b) Ideal system

Provide a table similar to the one in homework 6. Only partial credit is given for answers not showing the worked table.
As a final answer, you can fill this table:

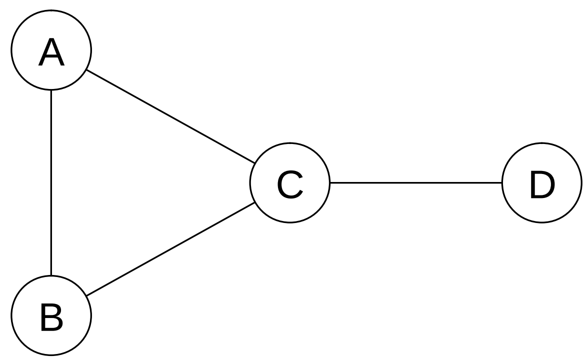
packet	real time in FQ	real time in ideal system
A1		
A2		
A3		
A4		
B1		
B2		
C1		
C2		
C3		

Problem 5: Bridges (5 points)
Given the extended LAN shown below, indicate which ports are not selected by the spanning tree algorithm for bridges.



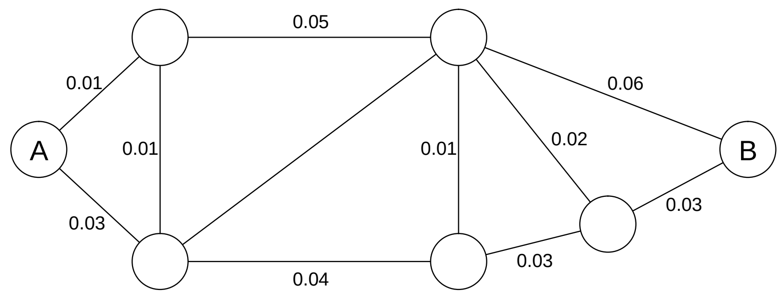
Problem 6 (5 points): Counting to infinity

Split horizon is the technique that when a node sends a routing update to its neighbors, it does not send those routes it learned from each neighbor back to that neighbor. We argued in class that this can solve the counting to infinity problem in distributed Bellman-Ford in the simple case of loops of length 2.



Show that split horizon cannot avoid the counting to infinity problem in the above network when link C-D fails (all links have weight 1). Clearly show the sequence of messages received by each node and how it updates its knowledge about the shortest path to node D.

Problem 7: Shortest path (10 points)
Consider the following network:



Assume that the weight on the link represent the probability of the link failing, and that links fail independently of each other.

(a) (2 points) Choose any path from A to B and indicate your choice on the figure above. What is the probability that this path will not fail, i.e. A and B can communicate on this path? In general, given a path with edges e_1, e_2, ..., e_n and weights w_1, w_2, ..., w_n what is the probability that the path will not fail?

(b) (2 points) We would like to find the path with the highest probability of not failing. Using the fact that $\log AB = \log A + \log B$, show that we want a path e_1, e_2, $\ldots$, e_n that minimizes

$$-\log(1 - w_1) - \log(1 - w_2) - \ldots - \log(1 - w_n)$$

(c) (2 points) Since w_i are all small, $1 - w_i$ is close to 1, and we can use the approximation $\log(1 - w_i) \approx -w_i$. Show how this approximation can transform our problem above into a shortest path problem on the graph.

(d) (4 points) Find the path with the highest probability of not failing. Show your work, e.g. Dijkstra's algorithm. What is that probability?

Problem 8: Shortest path tree and minimum spanning tree (10 points)
Consider two graphs $G = (V, E)$ and $G' = (V', E')$ which are identical except for the weights of the edges. If the weight of edge e in G is $w(e)$, then the weight of edge e in G' is $a.w(e) + b$ for some contants a and b.

(a) (3 points) Are the minimum spanning trees for G and G' identical? If your answer is positive, provide a proof. If your answer is negative, provide a counter example.

(b) (3 points) Are the shortest path between any two nodes in the two graphs identical? If your answer is positive, provide a proof. If your answer is negative, provide a counter example.

(c) (4 points) If your answer is negative for part (a) or part (b), can you think of conditions on the constants a and b that would make your answer positive?