Name:____________________________

Student ID #:________________________________

Campus/SITN-Local/SITN-Remote?_____________

MC	MC Long	18	19	**TOTAL**
		/20	/20	

CS244a: An Introduction to Computer Networks

Final Exam: Thursday February 16th, 2000

You are allowed 2 hours to complete this exam.

(i) This exam is closed book and closed notes. However, you may refer to a sheet of 8.5"x11" paper (double-sided) of your own design.

(ii) Show your reasoning clearly. If your reasoning is correct, but your final answer is wrong, you will receive most of the credit. If you just show the answer without reasoning, and your answer is wrong, you may receive no points at all.

Important: Make sure you securely attach any additional pages to your exam!

The Stanford Honor Code

In accordance with both the letter and spirit of the Honor Code, I didn't cheat on this exam.

Signature:____

Multiple Choice Questions.

Instructions: *in the following questions, check all listed assertions that appear to be correct. There is at least one correct assertion per question, but there may be more. Each correct assertion checked will earn you one point.* ***For each incorrect assertion you check, you will lose one point.*** *If you don't know an answer, checking no assertion will neither earn you nor lose you any points.*

Here's an example question:

1. **Example multiple choice question**. I think the instructor for this class is really mean because:

(a.) He gives us really long, mean assignments.

(b.) He makes us show up for class on time.

☑ (c.) He asks mean multiple choice questions.

(d.) He is mean.

☑ (e.) None of the above. He is, in fact, sweet and charming.

The correct answer is of course (e). But in a moment of craziness, you answer (c) <u>and</u> (e). You gain one point for (e), but lose one point for (c). So your total is zero.

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1. **Layering.** "Layering" is commonly used in computer networks because:

(a.) It forces all network software to be written in ANSI 'C'.

(b.) Encapsulation is the lowest overhead method to transmit data.

(c.) It allows widespread code and implementation re-use.

(d.) It keeps networks warm enabling them to run faster.

2. **CRC.** Which are true statements about messages of length 6-bits (including the CRC) that are protected by the generator $G = x^3 + x + 1$?

(a.) All single bit errors are detected.

(b.) No errors longer than 3 bits are detected.

(c.) All single bit errors can be corrected.

(d.) All errors in which every other bit of the message is inverted are detected.

(e.) Errors in which all bits of the message are inverted are detected.

3. **Elasticity Buffer.** An elasticity buffer is used to store bits arriving at a network interface. If the receiving station uses a 200-bit elasticity buffer and the clocks of the transmitter and receiver have a minimum frequency of 99.999MHz and a maximum frequency of 100.001MHz, which of the following statements are true:

(a.) All packets have to be less than or equal to 12,500 bytes long.

(b.) All packets have to be less than or equal to 4500 bytes long.

(c.) The two clocks have a tolerance of $\pm 100\text{ppm}$.

(d.) The two clocks have a tolerance of $\pm 10\text{ppm}$.

(e.) The transmitter's clock is always faster than the receiver's clock.

4. **TCP**. Which of the following are true statements about TCP:

(a.) The Slow-Start algorithm increases a source's rate of transmission faster than "additive increase".

(b.) A source's retransmission timeout value (RTO) is always set equal to the measured RTT.

(c.) Setting RTO < the measured RTT may lead to unnecessary retransmissions.

(d.) A source's retransmission timeout value is set to a value that increases with the variance in measured RTT values.

5. **TCP:** Which of the following are true statements about TCP:

(a.) TCP is a Layer 3 protocol used by routers to exchange routing table information.

(b.) TCP segments can only be lost when router queues overflow.

(c.) If the window size of a TCP connection is smaller than the round-trip "bandwidth-delay" product, the link will operate very efficiently.

(d.) There is no performance benefit to having a window size larger than the RTT.

(e.) A receiver reduces the advertised window size in response to congestion.

6.**Random Early Detection (RED).** Which of the following are true?

(a.) RED is tolerant of bursts because when the average queue occupancy if close to the maximum threshold, there is still room in the queue to accept new bursts of packets.

(b.) RED drops packets with probability 1 when the router's queue length is greater than the maximum threshold value.

(c.) The probability of RED dropping a packet belonging to a flow is directly proportional to the number of the flow's packets queued at the router.

(d.) If two flows, one TCP and one UDP, share a "RED" router, the RED algorithm will ensure that both flows receive an identical share of the outgoing link.

7. **ATM**. Which of the following are true statements about ATM:

(a.) It uses fixed length packets, called cells.

(b.) Most of its cells are fixed length. However, some packets used for detecting congestion, are shorter.

(c.) It delivers only $20 bills.

(d.) ATM cells may become misordered during transit.

8. **TCP**. Which of the following are true:

(a.) TCP minimizes throughput by minimizing packet delay.

(b.) TCP minimizes delay by maximizing throughput.

(c.) TCP achieves high throughput by causing large buffer occupancy in the routers.

(d.) TCP connections always start with a 4-way handshake.

9. **Link Layer Protocols**. Which of the following are true:

(a.) Ethernet uses Manchester encoding to provide enough transitions for the receiver to recover the clock that was used to transmit the data.

(b.) FDDI uses 4B/5B encoding to provide enough transitions for the receiver to recover the clock that was used to transmit the data.

(c.) Manchester encoding leads to more efficient use of the link capacity than 4B/5B encoding.

(d.) We know that Token Ring could not use Manchester encoding because there would be no way to detect a collision.

10.**TCP.** The TCP protocol uses a sliding window protocol. The window size varies because:

(a.) Routers along the route advertise a varying window size to prevent congestion.

(b.) The destination advertises a reduced window size when its buffers are congested.

(c.) The destination advertises a reduced window size when packets take a long time to reach it.

(d.) The source reduces its window size when it detects that congestion is occurring.

11. **The Internet Protocol (IP)**:

(a.) Always delivers packet to their destination in the same order that they were transmitted,

(b.) Never delivers packets to their destination in the same order that they were transmitted,

(c.) Requests the sender to retransmit packets that are received out of order,

(d.) Always passes received datagrams to the next layer in the order that they are received; even if they were fragmented along the way.

12. **Fair Queueing.** Which of the following are true:

(a.) A fair queueing scheduler used in a router transmits one packet at a time.

(b.) A fair queueing scheduler used in a router transmits just one bit from each packet at a time before moving onto the next packet.

(c.) If traffic arriving at each router in a network is leaky-bucket constrained, and if each router uses weighted fair queueing schedulers, then bounds can be placed on the end-to-end delay of each packet.

(d.) If a fair queueing scheduler calculates the finishing time of two packets, *A* and *B*, such that *A* is scheduled to depart before *B*, then at a later time as new packets arrive, the scheduler may change its mind and schedule *B* ahead of *A*.

(e.) Weighted fair queueing allows a router to provide each flow with a weighted share of the link capacity.

13. Multicast. Which of the following statements are true:

(a.) Computers use IGMP (the Internet Group Management Protocol) to request that corrupted packets be retransmitted to all members of the group.

(b.) RSVP was designed to allow resource reservations to be "receiver-initiated". This is because different receivers in a multicast group may wish to receive different qualities of service.

(c.) When an IP router receives an IP multicast datagram, it must perform two lookups into its forwarding table. Once using the IP source address, and once using the IP multicast group address.

(d.) An IP multicast datagram cannot visit a router twice, because the topology of the Internet has been carefully designed to be a loop-free spanning tree.

Longer Multiple Choice Questions

Instructions: *in each of the following questions* **exactly one** *assertion is correct per question. Each question is worth three points. If you check the correct answer, you will gain* **three** *points. If you check the wrong answer, or if you check more than one answer you will lose* **one** *point. To discourage guessing, if you check no answers you will neither gain nor lose any points.*

1. **Example multiple choice question with multiple points**.

(a.) This is part (a).

(b.) This is part (a).

(c.) This is part (b).

(d.) This is not part (d).

The correct answer is of course (a), but you answer (b). You lose one point for (b), so your total is minus one.

14. A link of rate R is used to transmit packets of average length P. To each packet, C CRC bits are added so that errors may be detected by the receiver. For the purposes of this question, we'll assume that the CRC detects *all* errors even though we learned in class that this is not always the case.

If the bit-error rate (BER), B, is very small (i.e. so that $PB \ll 1$), what is the expected number of times that a packet must be sent before it is successively received? (You may wish to use the identity: $\sum_{i=0}^{\infty} ix^i = \frac{x}{(1-x)^2}$, if $x < 1$).

(a.) $\frac{1}{(P+C)B}$

(b.) $\frac{1}{1-(P+C)B}$

(c.) $\frac{P}{1-RB}$

(d.) $\frac{P+C}{P+C-B}$

(e.) $\frac{R}{1-PB}$

15. For the link in Question 14, we will define E to represent the fraction of all the transmitted bits that are data bits belonging to packets correctly received by the receiver. Which of the following is true:

(a.) $E = \frac{(P+C)(1-PB)}{P}$

(b.) $E = PR(1-(P+C)B)$

(c.) $E = \frac{P(1-(P+C)B)}{P+C}$

(d.) $E = \frac{PR}{(P+C)(1-PB)}$

16. An experiment is performed using the link in Question 14. The experiment finds the value of P (which we will call $\hat{P}$) that maximizes E. It turns out that when E is maximized, 1/100th of the received packets are found to arrive at the receiver with a CRC mismatch. What is the ratio $\frac{\hat{P}}{C}$?

(a.) $\frac{\hat{P}}{C} = 99$

(b.) $\frac{\hat{P}}{C} = 100$

(c.) $\frac{\hat{P}}{C} = \frac{1}{100}$

(d.) $\frac{\hat{P}}{C} = 1000$

(e.) $\frac{\hat{P}}{C} = 990$

17. Using the generator polynomial $x^3 + x + 1$, calculate the CRC for the message $M = 101101$. Which of the following values equals the CRC:

(a.) 0011

(b.) 101

(c.) 110

(d.) 011

Longer Questions

18. **(20 points) Flow control, fluid models and leaky-buckets.**

The operators of San Francisco Airport (SFO) wish to upgrade their large storage tank ("buffer") that holds fuel used to refuel aircraft. They hear that you are an expert in networking, so they employ you as a consultant to help them figure out how big their storage tank should be.

You are to assume that airplane land at SFO with their fuel tanks empty. Just before they leave, each airplane is refuelled with 10,000 gallons from the storage tank.

(a.) If a plane departs from the airport on average once every 100 seconds, at what minimum average rate must the storage tank be filled?

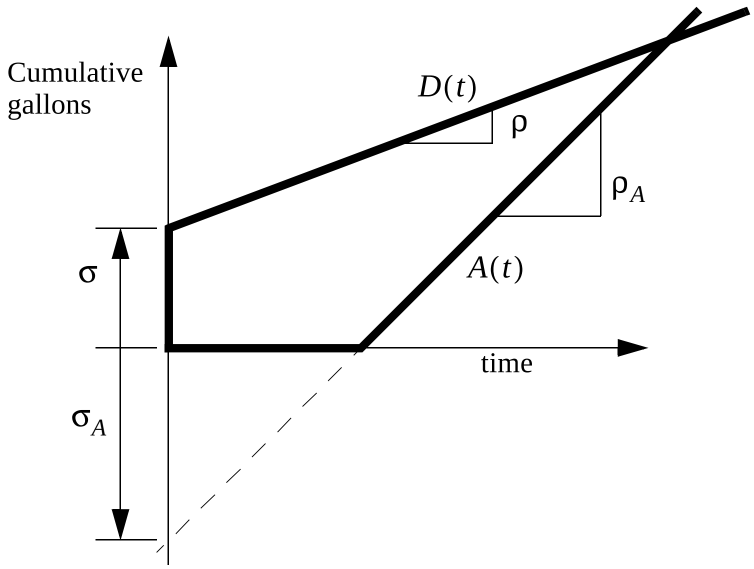
(b.) (Flow control to prevent the tank from overflowing). A pipeline is used to refill the storage tank from a remote pumping station. The pipeline can be controlled to fill the tank at a rate of either 200 gallons per second, or 0 gallons per second (assume that the rate changes instantaneously). In order to prevent the storage tank from overflowing, a threshold or level detector is placed in the tank. Whenever the fuel level exceeds the threshold, a signal is sent to the remote pumping station to switch off the flow. The threshold detector is set to send a signal whenever there is only just enough room to put another T gallons into the tank. It takes 100 seconds from when the threshold is crossed until fuel stops flowing into the storage tank. How large should T be so that the tank does not overflow?

(c.) (Preventing the tank from going empty). Having made sure that the tank never overflows, we'll now try to ensure that it never underflows (if it did, the airport would grind to a halt!). For this part of the question, we're going to assume a "fluid flow" model. As before, fuel flows into the storage tank at a rate of either 200 gallons per second or 0 gallons per second. When a plane is ready to depart it is "instantaneously" (i.e. in zero time) filled with 10,000 gallons of fuel from the storage tank.

(i) Based on the information you know so far, is it possible to determine if the tank will ever underflow (i.e. go empty)? If not, what information is missing?

(ii) You learn that air traffic control regulates the departure of planes from SFO using a (σ, ρ) leaky-bucket regulator (recall that in a (σ, ρ) regulator, the rate of a burst, "*C*", is assumed to be infinite). You decide to measure the departure of planes to determine what values of σ and ρ the air-traffic controllers use in their regulator. You find that, on average, a plane departs every 100 seconds. Also, you note that when planes leave in "bursts", the burst is never longer than 10 planes long. What values can we deduce that the air-traffic controllers are using for their (σ, ρ) regulator? Express your solution in both units of "airplanes" and "gallons".

(iii) You decide to use a leaky-bucket-like mechanism to control the *minimum* rate at which fuel is pumped from the pumping station into the fuel storage tank. We'll still call your mechanism a "leaky-bucket regulator", even though it bounds the minimum rate of the service rather than the maximum. The regulator has parameters (σ_A, ρ_A). The axes below show a sketch of the regulator used by air traffic control (which leads to an upper bound on the fuel departure process $D(t)$). The sketch also shows your regulator that controls the minimum rate at which the tank is refilled by placing a lower bound on the arrival process, $A(t)$. Indicate on the graph below the point at

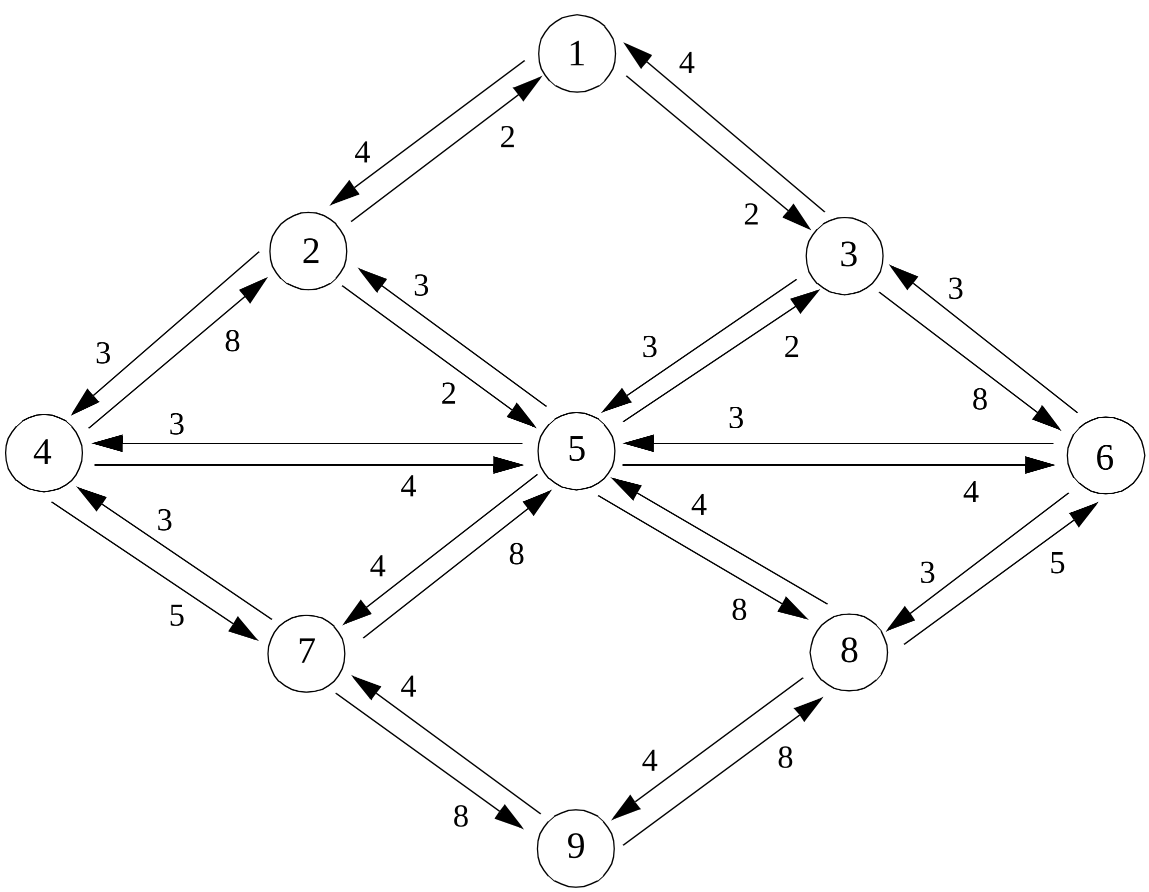


which the occupancy of the tank is minimized. Write down an inequality for the lower bound of the tank's occupancy in terms of $\sigma, \rho, \sigma_A, \rho_A$.

(iv) If you decide to install a tank of size 200,000 gallons, use your answer in part (iii) above to determine values you should use for σ_A and ρ_A so that the tank never goes empty.

(d.) (Preventing overflow when arrivals are made up of discrete "packets"). Now let's assume that we replace the pipeline with a fleet of fuel trucks each able to carry 10,000 gallons of fuel. Airport regulations dictate that when a truck arrives at the airport its contents must be emptied into the storage tank immediately. i.e. the trucks are not allowed to queue waiting their turn to unload. Trucks are sent from the pumping station every 50 seconds (or not at all when the storage tank is full). If it takes at *most* 1000 seconds for a truck to drive from the pumping station to the fuel storage tank at the airport, how large should T be now?

19. **(20 Points) Routing.** In this question, we'll use both the Bellman-Ford and Dijkstra's algorithms to determine the lowest cost path to router 1 from all other routers in the graph below.



(i) The Bellman-Ford algorithm.

Assume that each router starts with a cost of ∞ to reach any other router. Use a sequence of tables (one table for each time the routers exchange their routing tables), to show how each router learns the *next-hop* and *cost* to reach router 1.

(ii) Dijkstra's algorithm.

Assuming that the link-state information has been correctly received by all routers, show how the candidate set and shortest path set evolve as each router finds the shortest path spanning tree rooted at router 1.