Name: **V#:**

Sample Final Exam

CMSC 440

Data Communications and Networking

Virginia Commonwealth University

Directions:

Question	Points	Score
I (2Px20Q)	40	
II.1	10	
II.2	6	
II.3	6	
II.4	8	
II.5	6	
II.6	4	
II.7	6	
II.8	8	
II.9	6	
II.10	9	
II.11	10	
II.12	9	
II.13	12	
III.14	5	
III.15	5	
III.16	20	
III.17	20	
III.18	10	
Total	**200**	

1. Do not open this exam until we instruct you to do so.
2. This is a closed book, closed notes, closed Internet, closed neighbor, pencil and paper exam.
3. This exam represents ***30% of total CS 440 grade.***
4. This exam is designed to be completed in **150 min**. Turn immediately the exam when we call for it.
5. The exam has three classes of questions with ***total of 200 points.***
6. Read each question carefully, paying attention to detail, including the units given in the problem statement and the units asked for in the question.
7. Write answers in the spaces provided. Indicate your final answer clearly. Cleanly erase or cross out any work you do not want graded.
8. Show your work and explain your reasoning where appropriate; this will help to earn partial credit.
9. If you need additional space, use the back of the page.
10. Electronic devices except calculators must be completely turned off and stowed in your backpack.
11. Write your name and V# on each sheet of paper

Time: 150 minutes
Good Luck!

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Part I: Terms [40 points] – Fill in the blank with the appropriate term. [2 points each]

Multiplexing, Border Gateway Protocol (BGP), pipelined protocol, CSMA/CD, IP Fragmentation, 3-packet handshake, MAC address, Flow Control, Additive Increase Multiplicative Decrease (AIMD), Slow Start, Link-State, ARP protocol, Autonomous System, Forwarding, Routing, Tunneling, Cyclic Redundancy Check (CRC), multiple access protocol, ALOHA, infrastructure mode.

1) At the source host, the job of gathering data chunks from different sockets, adding header information (for demultiplexing at the receiver), and passing the resulting segments to the network layer is called ___multiplexing________________.

2) In ___pipelined protocol___, the sender is allowed to send multiple packets without waiting for an acknowledgment.

3) After the _________3-packet handshake __________ is complete, a TCP connection is said to be established and the two processes can send application data to each other.

4) The main objective of _____flow control_____ is to have the receiver tell the sender how much spare room it has in its receive buffer; and to have the sender restrict the amount of data that it puts in the pipeline to be less than the spare room.

5) TCP's congestion control consists of linear increase in cwnd of 1 MSS per RTT and then a halving of cwnd on a triple duplicate-ACK event. For this reason, TCP congestion control is often referred to as an _additive-increase multiplicative decrease (AIMD)_ form of congestion control.

6) In the _____slow-start_____ state of TCP, the value of cwnd begins at 1 MSS and increases by 1 MSS every time a transmitted segment is first acknowledged.

7) ___Link-State____ routing algorithms are centralized in nature—each node needs to have a complete network topology and all link costs information.

8) An _____autonomous system______ is a network that is under the control of a single organization.

9) _____Routing____ refers to the process of determining the end-to-end path that a packet will take through the network.

10) ____Forwarding_____ refers to the per-router action of moving a packet arriving at an input port to the appropriate output port.

11) ____Border Gateway Protocol (BGP)_____ is the protocol used to route datagrams among autonomous systems, and thus it is the “glue” that binds the Internet together.

12) ____Tunneling____ can be used to connect two routers logically over a path that contains multiple routers. For example, it allows two IPv6 routers to exchange IPv6 datagrams with each other, via routers that only “speak” IPv4.

13) ___IP Fragmentation/ Network Layer Fragmentation____ is the process of splitting the data payload in the IP datagram into two or more smaller IP datagrams, encapsulate each of these smaller IP datagrams in a separate link-layer frame; and send these frames over the outgoing link.

14) ______Cyclic Redundancy Check (CRC)______ is one of the error detection schemes that is used in many link-layer protocols, including Ethernet and Wi-Fi.

15) The purpose of a _____multiple access protocol_____ is to coordinate the transmissions of the senders to reduce the probability of-or even entirely eliminate-the collisions at the receivers.

16) One of the simplest and well-known random access protocols is _____ALOHA_______

17) The ____MAC address_____ is the 48 bits host’s link-layer address and is typically written in hexadecimal notation.

18) The ____ARP protocol____ is the process a sending host uses to determine the destination MAC address

19) The _____CSMA/CD_____ protocol, utilized by Ethernet, is a random access protocol along the lines of unslotted ALOHA.

20) The ___infrastructure mode___ is one of the two types of wireless networks that we encounter in our daily lives.

Part II: Short Answer [100 points]

1. [10 points] Consider the following:

a. [5 points] Suppose a process in host C has a UDP socket with port number 787. Suppose host A and host B each send a UDP segment to host C with destination port number 787. Will both of these segments be directed to the same socket at host C? If so, how will the process at host C know that these segments originated from two different hosts?

Yes, both segments will be directed to the same socket. For each received segment, at the socket interface, the operating system will provide the process with the IP address of the host that sent the segment. The process can use the supplied IP addresses to determine the origins of the individual segments.

b. [5 points] Suppose that a Web server runs in host C on port 80. Suppose this Web server uses persistent connections, and is currently receiving requests from two different hosts: A and B. Are all of the requests being sent through the same socket at host C? If they are being passed through different sockets, do both of the sockets have port 80?

For each persistent connection, the Web server creates a separate “connection socket.” Each connection socket is identified with a four-tuple: (source IP address, source port number, destination IP address, destination port number). When Host C receives an IP datagram, it examines these four fields in the datagram/segment to determine to which socket it should pass the payload of the TCP segment. Thus, the requests from A and B pass through different sockets. The identifier for both of these sockets has 80 for the destination port; however, the identifiers for these sockets have different values for the source IP addresses.

2. [6 points] List three different mechanisms used to support reliable data transfer:

1. Checksum
2. ACKs
3. Timers
4. sequence numbering.

3. [6 points] In Go-back-N (GBN) protocol:

a. [3 points] Does this protocol have a timer for each unacknowledged packet?

- No, GBN has only one timer, for the oldest unacknowledged packet

b. [3 points] When a timer expires, what happens?

- When the timer expires, the sender resends all packets that have been sent but have not yet been acknowledged.

4. **[8 points]** Consider sending a large file from one host to another over a TCP connection that has no loss.

a. [4 points] Suppose TCP uses AIMD for its congestion control without slow start. Assuming CongWin increases by 1 MSS every time an ACK is received and assuming approximately constant round-trip times, how long does it take for Congestion Window (CogWin) to increase from 1 MSS to 5 MSS (assuming no loss events and constant RTT)?

- It takes 1 RTT to increase CongWin to 2 MSS; 2 RTTs to increase to 3 MSS; 3 RTTs to increase to 4 MSS; and 4 RTTs to increase to 5 MSS.

b. [4 points] What is the average throughput (in terms of MSS and RTT) for this connection up through time = 4 RTT?

- In the first RTT 1 MSS was sent; in the second RTT 2 MSS were sent; in the third RTT 3 MSS were sent; in the fourth RTT 4 MSS were sent. Thus, up to time 4 RTT, 10 MSS were sent (and acknowledged). Thus, one can say that the average throughput up to time 4 RTT was (10 MSSS)/(4 RTT) = 2.5 MSS/RTT

5. [6 points] Identify three important differences between a virtual circuit network (for example, ATM) and a datagram network (for example, Internet).

a. A virtual circuit requires call setup.
b. A virtual circuit has call teardown.
c. In a VC network, a packet carries a VC ID rather than a destination address.
d. Resources can be allocated to a call/connection in a VC network (typically during call setup).

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6. [4 points] Consider an IP subnet with prefix 129.17.129.96/27. Provide the range of IP addresses (of form xxx.xxx.xxx.xxx to yyy.yyy.yyy.yyy) that can be assigned to this subnet.

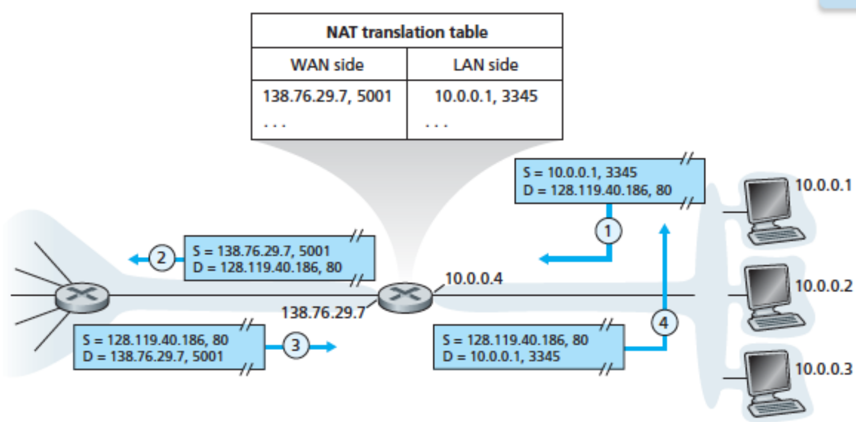
- Given this prefix, the available range of space is: 129.17.129.96 to 129.17.129.127 However, the eligible IP range to be assigned to individual hosts is 129.17.129.97 to 129.17.129.126 (since no host could have all its host address bits as either 0's or 1's)

7. [6 points] Suppose an organization owns the block of addresses of the form 129.17.129.96/27. Suppose it wants to create four IP subnets from this block, with each block having the same number of IP addresses. What are the prefixes (of form xxx.xxx.xxx/y) for the four IP subnets?

- There are 32 addresses in the range; we give 8 addresses to each block; thus the prefix of each of these subnets will be:

a) 129.17.129.96/29 --> 129.17.129.96 to 129.17.129.103
b) 129.17.129.104/29 --> 129.17.129.104 to 129.17.129.111
c) 129.17.129.112/29 --> 129.17.129.112 to 129.17.129.119
d) 129.17.129.120/29 --> 129.17.129.120 to 129.17.129.127

8. [8 points] Consider the scenario shown in the following figure that shows the traffic of a connection between host 10.0.0.1 using port 3345 and a Web server listening at port 80 at 128.119.40.186.



a. [4 points] Suppose that host 10.0.0.2 initiates a connection, using source port 5500 to a Web server listening at port 80 at 128.119.40.186. Complete the NAT translation table with the corresponding entry for this new connection.

NAT translation table	
WAN side	LAN side
138.76.29.7, 5002	10.0.0.2, 5500

Note that the use of 5002 on the WAN side is arbitrary. The NAT box will simply use an unused port number.

b. [4 points] What are the source and destination IP addresses and port numbers of the IP datagram arriving to the WAN side of the router from the interface address 138.76.29.7?

- For the datagram returning from the Web sever: source IP: 128.119.40.186, source port: 80, dest. IP: 138.76.29.7, dest. Port: 5002.

9. [6 points] Suppose the information content of a packet is the bit pattern 1110101010101111 and an even parity scheme is being used. What would the value of the checksum field be for the case of a two-dimensional parity scheme? Your answer should be such that a minimum length checksum field is used.

11101
10100
10100
11110
00011

10. [9 points] In CSMA/CD,

a. [4 points] after the fourth collision, what is the probability that the node chooses K=3?
- The node chooses K from the elements in the set {0, 1, 2, … ,15} with equal probability. The probability that it chooses K = 3 is thus 1/16.

b. [5 points] The result K =3 corresponds to a delay of how many microseconds on a 10 Mbps Ethernet?
With K = 3, the node waits 3 * 512 = 1536 bit times. The corresponding delay over a 10 Mbps Ethernet link is (1536 bits / 10^7 bit/sec) = 153.6 microseconds.

11. **[10 points]** Consider two nodes A and B on the same Ethernet segment, and suppose the propagation delay between the two nodes is 225 bit times.

a. **[4 points]** Suppose at time t = 0 both nodes A and B begin to transmit a frame. At what time do they detect the collision?
Both nodes A and B detect the collision at time t = 225 bit times

b. **[6 points]** Assuming both nodes transmit a 48-bit jam signal after detecting a collision, at what time (in bit times) do nodes A and B sense an idle channel?
At time t = 225 + 48 = 273 both nodes stop transmitting their jam signals. The last bit of the jam signal from B arrives at A at time t = 273 + 225 = 498 bit times. Similarly, the last bit of the jam signal from A arrives at B at time t = 273 + 225 = 498 bit times.

12. **[9 points]** Given the list of different services that a link layer can potentially provide to the network layer includes: a) framing, b) medium access, c) reliable delivery, d) flow control, e) error detection, f) error correction, g) full-duplex and half-duplex. For each of these services, discuss whether Ethernet supports it or not.

a) framing? Yes

b) medium access? Yes

c) reliable delivery? No

d) flow control? No

e) error detection? Yes

f) error correction? No

13. **[12 points]** We studied a number of multiple access protocols, including TDMA, CSMA, slotted Aloha, and token passing.

a. [**6 points]** Suppose you were charged with putting together a large LAN to support IP telephony (only) and that multiple users may want to carry on a phone call at the same time. Recall that IP telephony digitizes and packetizes voice at a constant bit rate when a user is making an IP phone call. How well suited are these four protocols for this scenario? Provide a brief (one sentence) explanation of each answer.

- TDMA works well here since it provides a constant bit rate service of 1 slot per frame.
- CSMA will not work as work well here (unless the channel utilization is low) due to collisions and variable amount of time needed to access the channel (for example, channel access delays can be unbounded) and the need for voice packets to be played out synchronously and with low delay at the receiver.
- Slotted Aloha has the same answer as CSMA.
- Token passing works well here since each station gets a turn to transmit once per token round, yielding an essentially constant bit rate service.

b. **[6 points]** Now suppose you were charged with putting together a LAN to support the occasional exchange of data between nodes (in this part of this question, there is no voice traffic). That is, any individual node does not have data to send very often. How well suited are these four protocols for this scenario? Provide a brief (one sentence) explanation of each answer.

- TDMA would not work well here as if there is only one station with something to send, it can only send once per frame. Hence, the access delays are long (one half frame time on average), and the throughput over a long period of time is only 1/N of the channel capacity.
- CSMA would work well since at low utilization, a node will get to use the channel as soon as it need to.
- Slotted Aloha has the same answer as CSMA
- Token passing would work better than TDMAbut slightly less well than CSMA and Slotted Aloha, since it must wait for the token to be passed to the other stations (who likely wouldn't use it) before sending again.

14. [5 points] Consider sending a 2,000-byte datagram into a link with a MTU of 980 bytes. Suppose the original datagram has the identification number 227. How many fragments are generated? For each fragment, what is its size, what is the value of its identification, fragment offset, and fragment flag?

- The maximum size of data field in each fragment 960 bytes (note the 20 bytes IP header). Thus, the number of required fragments = **Ceiling ((**2000 - 20) / 960**)** = 3

- Each fragment will have identification number 227. Each fragment except the last one will be of size 980 bytes (including IP header). The last datagram will be of size 80 bytes (including IP header). The offsets of the three fragments will be 0,120, 240. The first two fragments will have the last fragment will have flag = 1; the last fragment will have flag = 0.

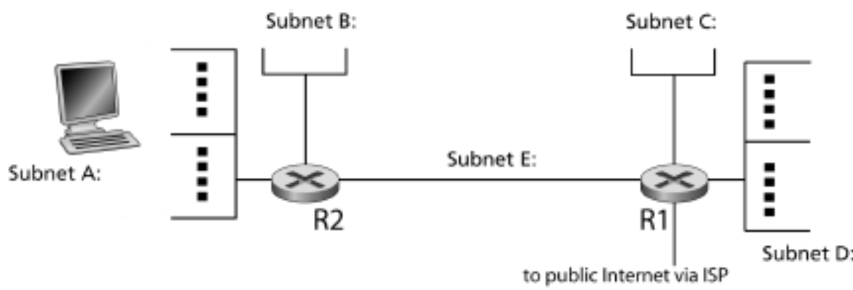
15. [5 points] Consider a datagram network using 32-bit host addresses. Suppose that a router has three interfaces, numbered 0 through 2, and that packets are to be forwarded to these link interfaces as follows. Any address not within the ranges in the table below should not be forwarded to an outgoing link interface. Create a forwarding table using longest prefix matching.

Destination address range	Outgoing link interface
00000000 00000000 00000000 00000000 through 00000001 11111111 11111111 11111111	0
00000000 00000000 10000000 00000000 through 00000000 00000000 11111111 11111111	2
01010101 00000000 00000000 00000000 through 01010101 11111111 11111111 11111111	1
01010110 00000000 00000000 00000000 through 01010111 11111111 11111111 11111111	2

Because of the longest prefix matching rule, all addresses beginning with 0000000 00000000 1 are now forwarded to interface 2, while all other addresses beginning with 00000000 are forwarded to interface 0. The forwarding for prefixes 01010101 and 0101011 are the same as before.

Prefix	Outgoing link interface
0000000	0
00000000 00000000 1	2
01010101	1
0101011	2

16. [20 points] Consider the network shown below. Each of the subnets A-D contains at most 30 hosts; subnet E connects routers R1 and R2.



a. [5 points] Assign network addresses to the five subnets shown above (that is, write the addresses you have assigned).

- Each subnet needs to address up to 30 hosts, using the rightmost 5 bits of the address. The five subnet addresses are thus x.y.z.000/27, x.y.z.001/27, x.y.z.010/27, x.y.z.011/27, and x.y.z.100/27 where the first three binary digits of the last byte of the addresses are shown explicitly. More properly, these addresses are x.y.z.0/27, x.y.z.32/27, x.y.z.64/27, x.y.z.96/27, and x.y.z.128/27 in dotted decimal notation.

Other answers with different bit values in bits 25, 26, and 27 are also possible, as long as the five three-bit patterns used are unique.

b. [3 points] Suppose that there are 17 hosts in A–D. Does your answer to Question 3.a change? If so why or why not?

- The answer stays unchanged. In order to address 17 hosts, 5 bits are still needed, and so the network part of the address will be 27 bits long again.

c. [3 points] What is the network prefix advertised by router R1 to the public Internet?

- x.y.z./24

d. **[3 points]** Does the host in A ever need to know the MAC address of the R1's interface in subnet E in order to send an IP packet to the host in D? Explain your answer in one or two sentences.

- No. The host in subnet A needs to address a link-layer frame (containing the IP packet addresses to the host in D) to the R2 interface in subnet A only.

e. **[3 points]** Now suppose that router R2 above is replaced by an Ethernet switch , S2 (Router R1 remains a router). Are the interfaces that previously were in subnets A, B, and E still in the same separate three IP subnets now that R2 is replaced by S2? Explain your answer in a few sentences.

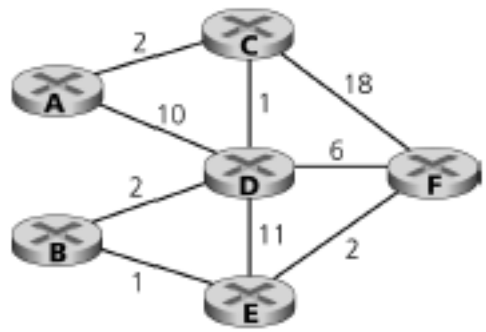
- No. They are now all in the same subnet from an IP addressing point of view, since there is no longer any intervening router

f. **[3 points]** In order to send an IP packet to the host in D, does the host in A ever need to know the MAC address of the R1's left interface now that R2 is replaced by S2? If so, how does it get the MAC address of R1's left interface? Explain your answer in one or two sentences.

Yes. Now the host in A now needs to address its link-layer frame to the left interface of R1. The host in A gets the MAC address of the left interface of R1 using ARP. The host in A knows that in order to route its packet to the host in D, it must first send that packet (over Ethernet) to router R1, whose IP address is in the hosts routing table. Thus, it uses ARP to get the MAC address associated with the IP address of R1's left interface.

17. [10 points] Consider the shown network.

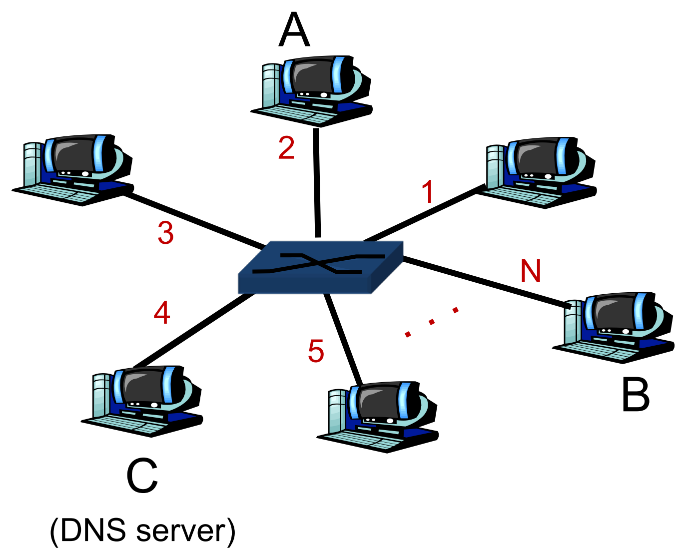
a. [8 points] Show the operation of Dijkstra's (link-state) algorithm for computing the least cost path from E to all destinations.



N	D(A), P(A)	D(B), P(B)	D(C), P(C)	D(D), P(D)	D(F), P(F)
E	Infinity	1, E	Infinity	11, E	2, E
EB	Infinity		Infinity	3, B	2, E
EBF	Infinity		20, F	3, B	
EBFD	13, D		4, D		
EBFDC	6, C				
EBFDCA					

b. [2 points] What is the shortest path from E to A, and what is the cost of this path?
- The shortest path from E to A is: E - B - D - C - A. The cost of this path is 6.

18. [10 points] Consider an Ethernet LAN consisting of N nodes interconnected with a switch. Suppose the switch's forwarding table is initially empty. Suppose node A wants to TCP three-way handshake with node B, where both nodes are on the LAN. Assuming this is the only traffic on the network, and there are no packet errors or loss.



a. **[5 points]** How many frames will be transmitted in the process of establishing the TCP connection? Assume node A knows the IP address of node B, and ARP tables have all the necessary mappings.

- Node A creates a TCP SYN packet, which (after encapsulation in an IP datagram) gets encapsulated into an Ethernet frame. This Ethernet frame will have B's MAC address for its destination address.
- Node A transmits the frame.
- When the frame arrives at the switch, the switch will take note of A's location and then transmit the frame onto the other N-1 links, giving a total of N transmissions so far.
- When B receives the frame, it will send a SYNACK, encapsulated in an Ethernet frame with A's MAC address for the destination address. Thus, there are N+1 frames so far.
- When the switch receives the frame, it will take note of B's location; it will already have an entry in its table for A and thus will only transmit the frame onto one link. Thus, there are N+2 frames so far.
- When A receives the SYNACK it will send an ACK. Two more transmissions are required for this ACK

→ Giving a total of N+4 transmitted frames.

b. **[5 points]** Now, host A only knows the hostname of Host B (and not its IP address). Assume the DNS server is Host C in the LAN, and Host A knows the IP address of the DNS server, how many frames will be transmitted in the process of establishing the TCP connection?

- First, Host A needs to do an ARP exchange with node C to get node C's MAC address. This generates N+2 Ethernet frames. This also generates entries for A and C in the switch table.
- Then node A must do a DNS exchange with C. This will generate 4 Ethernet frames, giving N+6 frames thus far.
- Node A will now have B's IP address, but not B's MAC address. So A will have to do an ARP exchange with B. Since B is not yet in the switch table, the ARP exchange will generate another N+2 Ethernet frames, giving a total of 2N+8 frames thus far.
- The TCP exchange will then generate another 6 frames.

→ Giving a total of 2N+14 frames.