University of Southern California
EE450: Introduction to Computer Networks
Final Exam, $2^{\underline{10}}$ hours
May 6, 2022

Last Name: ________________________ First Name: ____________________

Part 1 (T/F)	30%	
Part 2 (Fill-in-the-Blank)	30%	
Part 3 (Routing Algorithms)	15%	
Part 4: Subnetting	10%	
Part 5: TCP Congestion Control	15%	
Total	100%	

<u>Notes</u>:

- All your answers should be on the exam paper.
- You can work the problems in any order you wish (the goal is to try to accumulate as many points as you can).
- Try your best to be clean, and to show all the steps of your work

<u>Rules</u>:

- This is a closed book, closed notes exam. One 8"x11" containing formulas <u>only</u> is allowed along with a calculator. Any other electronic gadget including a smart phone or an IPad is strictly prohibited.

- Adherence to the University's **Code of Ethics** will be strictly monitored and enforced. Academic Integrity violations, such as cheating, will result in a series of actions and penalties including the student failing the class.

Part 1: True/False/Multiple Choice

1. A subnet mask is used to identify the boundary between network bits and host bits in an IP address
2. Unlike Routers, L2 switches built their tables based on destination MAC address.
3. An IPv.4 packet can be fragmented and reassembled multiple times in transit.
4. A NAT/PAT maintains end-to-end addressing and improves network performance
5. The following masks (in slash notation for simplicity) are only used as default masks: /8, /16 and /24 for classes A, B and C respectively.
6. Link-state routing protocols compute the least-cost path between source and destination using complete, global knowledge of the network
7. SSID is a technical term for a Wi-Fi network address
8. In DV protocol, shortest path computations and updates are asynchronous
9. The entire Class C address space can be expressed as a single CIDR notation of 192/3
10. In 802.11 CSMA/CA, the sender can detect a collision without feedback from receiver
11. In 802.11, when two stations transmit RTS frames simultaneously, a collision will occur, and no CTS frame is received. Each station will wait a random period and try again.
12. A host sends a segment with a sequence number 100 and payload size of 100 Bytes. The ACK sequence number in that segment is 200.
13. IP Tunneling is most related to the concept of encapsulation
14. If an IP fragment does not arrive at the destination, the source host retransmits that fragment only, not the entire packet.
15. Every port of a router constitute a broadcast domain while every port of a L2 switch constitute a collision domain..

16. A 1000 Byte packet is fragmented when sent over a link with an MTU of 600. The resulting fragments are then sent over a link with 500. The minimum number of fragments received at destination is four.

17. At the network layer, a spanning tree is used to ensure that no redundant packets are received by any node

18. In 802.3 standard, if the coverage (distance) is increased, the minimum frame size would decrease.

19. In 802.3 standard, if the bandwidth is increased, the minimum frame size would increase as well

20. In 802.3, if an ACK is not received within a specified time (timeout) the sender will retransmit the frame

21. The results of connecting multiple L2 switches together is increasing the size of the broadcast domains.

22. In Wi-Fi, a wireless host needs only the MAC address of the AP. It does not need the MAC address of the default router.

23. If a TCP and a UDP flows share the same "bottleneck", the UDP flow is more likely to get a greater percentage of the available bandwidth

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24. Suppose a Certificate Authority (CA) has Bob's certificate registered with it, binding Bob's public key to Bob. This certificate is signed with:

    a. Bob's public key.
    b. The CA's public key.
    c. Bob's private key.
    d. The CA's private key

25. A sender sends an unencrypted message and its encrypted digest over a network. Which of the following types of information assurance is provided in this scenario?

    a. Data Confidentiality
    b. Authentication
    c. Data Integrity
    d. None of the above

26. A sender sends a message encrypted by a public key of the recipient. Which of the following is NOT provided in this scenario?

    a. Data Integrity
    b. Data Confidentiality
    c. Authentication
    d. All the above

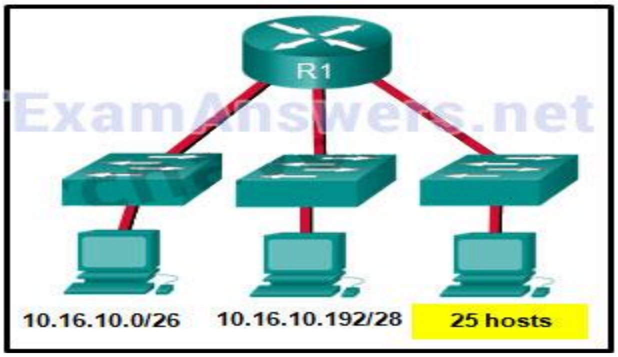
27. A sender sends a message encrypted by his own private key. Which of the following is NOT provided in this scenario?

    a. Data Confidentiality
    b. Authentication
    c. Data Integrity
    d. All the above

28. A switch will never learn a broadcast address because

    a. Broadcast frames are never sent to the switch
    b. A broadcast address will never be the source address of a frame
    c. Broadcasts only use network layer addresses.
    d. A switch never forwards a broadcast frame.
    e. None of the above

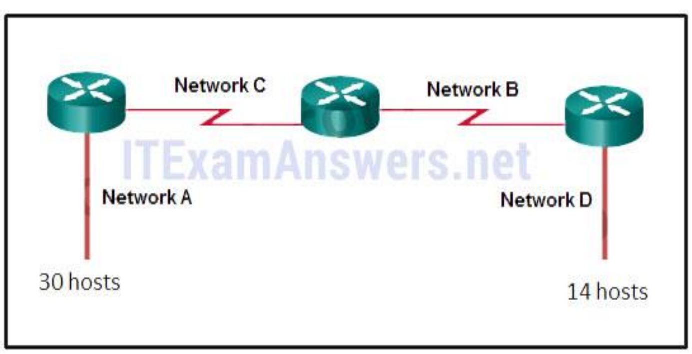
29. Considering the addresses already used and having to remain within the 10.16.10.0/24 network range, which subnet address could be assigned to the network containing 25 hosts?



a. 10.16.10.160/26
b. 10.16.10.128/28
c. 10.16.10.64/27
d. 10.16.10.224/26
e. 10.16.10.240/27
f. 10.16.10.192/27

30. Given the network address of 192.168.5.0 and a subnet mask of 255.255.255.224, how many total host addresses are unused in the assigned subnets?

a. 56
b. 60
c. 64
d. 68
e. 72



Part 2: Fill-in-the-Blank

1. Suppose a group of 4 nodes are connected to a 10 Mbps Ethernet hub. The average bandwidth available to each node is _______ Mbps. Now suppose these 4 nodes are connected to a 4-port, 10 Mbps Ethernet Switch, the maximum bandwidth available to each node is _______ Mbps. The aggregate capacity of the switch is _______Mbps

2. A TCP sender is sending a full window of 2^{16} Bytes over a 1 Gbps channel that has a 1msec propagation delay.

   a. The link utilization is ____________ %

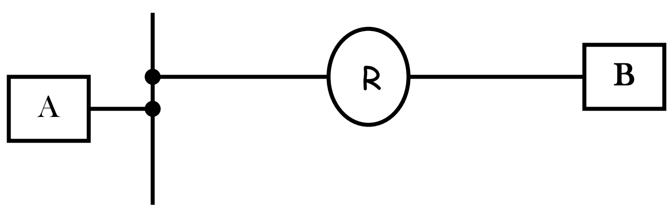
   b. The maximum throughput is ________________ Bytes/sec

3. Assume you have a 10 Mbps hub-based (i.e., shared) Ethernet network with 3 hosts. Each computer is connected to the hub with a cable of different length. Host H_1 is connected via a 100 m cable, Host H_2 is connected via a 200 m cable, and H_3 which is connected via a 300 m cable. The speed of propagation is $2x10^8$ m/sec. The minimum frame length used in this network so that CSMA/CD protocol will function correctly should be ___________ bits

4. Two nodes "A" and "B" that are attached at the opposite ends of 500 m Ethernet cable. They both have a 1000-bit frame to send to each other. Both nodes attempt to transmit at t = 0. Assume the transmission rate is 10 Mbps and that CSMA/CD is used. After the first collision, node "A" will retransmit immediately after it senses the medium is idle. Assume that the speed of propagation is $2.5x10^8$ m/sec. You can ignore the jamming signal. Collision occurs at t = _______ sec. Station A will retransmit at t = _______ sec. The throughput of node A is __________ bps. Assume that node A is successful the second time.

5. An e-mail client application on host A needs to send a 2500 Bytes image over TCP (TCP adds a header of 20 Bytes) which in turn runs over IP (IP adds a header of 20 Bytes) which runs over Ethernet which has an MTU of 1500 Bytes. A router connected to the Ethernet is connected to host B through a point-to-point connection with an MTU of 500 Bytes. Assume the TCP in host A knows that the MTU of the Ethernet is 1500 Bytes. Answer the following questions

   - The "minimum" number of segments created by TCP is _________
   - The payload size of each of these segments is (separate by comma if more than one segment) _____________________ Bytes.
   - The number of fragments delivered to B is _________
   - Their offsets are (separate by comma) ________________________



6. An ISP has the following Routing Table depicting the 4 prefixes he has as customers. What is the <u>smallest</u> number of prefixes he will need to advertise to the outside world announcing reachability to all its customers **but no other**? If more than one prefix, list them separated by commas (This question is about address aggregation)

   Prefix(es): ____

212.56.146.0/24
212.56.147.0/24
212.56.148.0/24
212.56.149.0/24

7. The following is the forwarding table of a router X using CIDR and longest prefix match

Destination Network	Subnet Mask	Outgoing Link Interface
11.0.0.0	/9	A
121.12.36.0	/23	B
121.12.37.64	/26	C
8.0.0.0	/5	D
121.32.0.0	/11	E
121.12.0.0	/16	F
120.0.0.0	/7	G
0.0.0.0 (Default)	/0	H

State, to what outgoing interfaces will these arriving packets, with the following destination IP addresses, be delivered?

a) Packet 11.132.66.224 delivered to ____________

b) Packet 121.12.37.73 delivered to ____________

c) Packet 121.12.38.68 delivered to ____________

d) Packet 121.32.2.5 delivered to ____________

e) Packet 192.168.37.11 delivered to ________________

8. Consider the wireless topology above, comprised of 6 nodes. Circles around each node illustrate their transmission range, e.g. A's range is shown by the dotted circle. Assume that the transmissions of two nodes will interfere at a location if and only if they transmit at the same time and their transmission areas overlap. When node A transmits to node B, list the potential hidden terminals from A (in either direction, i.e., those who might damage A's transmission or those who A's transmission might damage) and exposed terminals.

   Hidden terminals: _______________

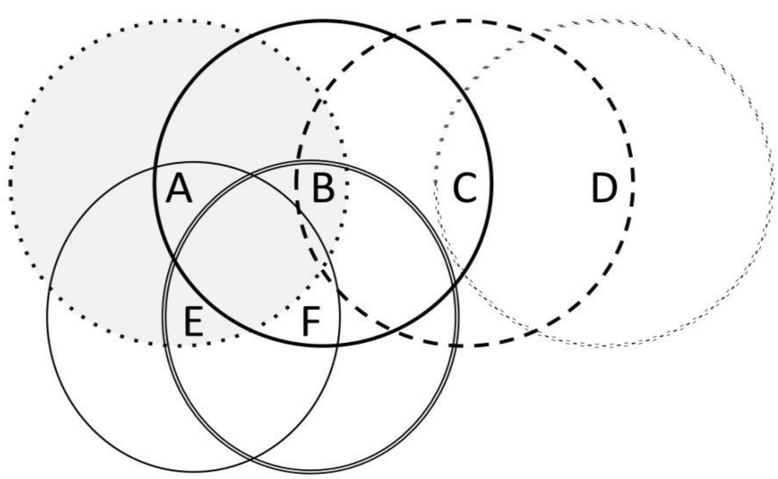
   Exposed terminals: ______________

   What about when node B transmits to node C?

   Hidden terminals: _________________

   Exposed terminals: _________________

   For case 1 only (i.e., when A is transmitting to B), if RTS/CTS is used, the hidden terminals: _______________.



9. The following table contains the link costs (in arbitrary units) between routers S, T, U, V, W, X, Y and Z. A dash (hyphen) entry indicates that there is no connection between these pairs of routers. Using Dijkstra's algorithm, the shortest path cost from X to Z is ______________ and from X to S is ________________.

	S	T	U	V	W	X	Y	Z
S	0	1	4	-	-	-	-	-
T	1	0	2	4	-	-	7	5
U	4	2	0	3	3	-	-	-
V	-	4	3	0	4	3	1	-
W	-	-	3	4	0	6	-	-
X	-	-	-	3	6	0	6	-
Y	-	7	-	1	-	6	0	12
Z	-	5	-	-	-	-	12	0

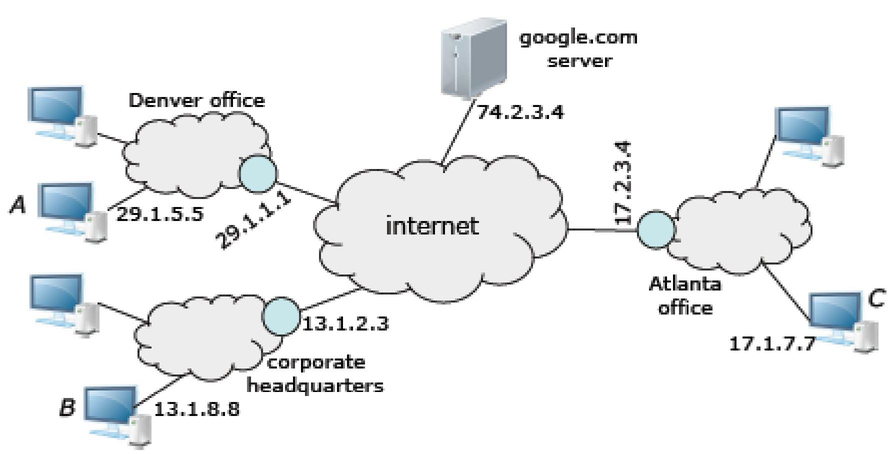
10. Consider the following Scenario. A corporate network with three sites connected by the internet. The company's network administrator has configured the gateway routers at the three sites to use IPsec to encrypt all traffic going between the three sites.

a. If host A sends a packet to host C, what are the source and destination address fields in the packet header as it passes through the public internet? (Separate them by comma)

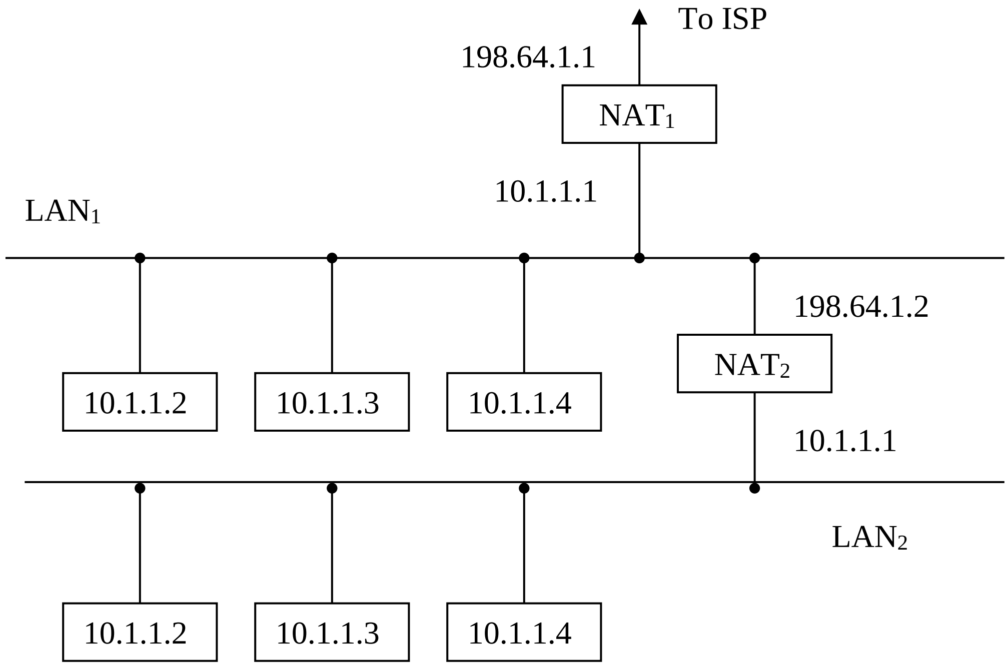
____

b. If host B sends a packet to the Google server shown, what are the source and destination address fields in the packet header as it passes through the public internet? (Separate them by comma)

____



11. Suppose an organization has installed "nested NATs". NAT_1 with IP address 198.64.1.1 is connected directly to the ISP, while NAT_2 is connected internally as shown below. Both private networks are numbered from 10.0.0.0/8 private IP address space.



- If host 10.1.1.2 on LAN_2 sends an IP packet with destination address 10.1.1.3, which host (or hosts) will receive it? Identify the LAN

  Answer: ________________________________

- If host 10.1.1.2 on LAN_2 sends an IP packet with destination address 128.9.160.23, what source address will be on the packet when it arrives at the destination?

  Answer: ___________________________________

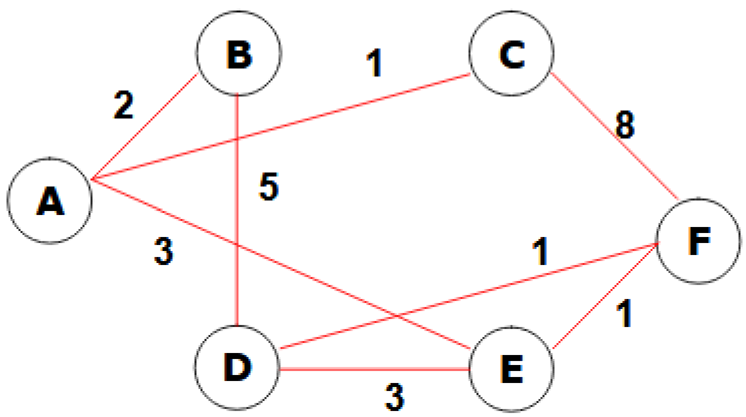
Work Sheet #1

Work Sheet #2

Work Sheet #3

Part 3 (Routing Algorithms)

a. Consider the following computer network where each node represents a router and the edge label is the corresponding link cost (Links are bi-directional). Use Dijkstra algorithm to find the shortest path from router "A" to every other router in the network. Show your work step-by-step (i.e. I am not interested in the final answer. I am interested in algorithm steps). **After you finish, Sketch the spanning tree.**



Work Sheet #4

b. This part is NOT related to part "a". Consider a Campus Network that runs RIP, where router R_1 has the following routing Table

Destination	Distance	Route
Net 1	0	Direct
Net 2	0	Direct
Net 4	8	R_2
Net 17	5	R_3
Net 24	6	R_4
Net 30	2	R_5
Net 42	2	R_4

Router R_1 receives the following routing tables from R_3 and R_4 respectively

From R_3	Destination	Distance
	Net 2	1
	Net 4	2
	Net 17	6
	Net 21	4
	Net 24	5
	Net 30	7
	Net 42	3
From R_4	Destination	Distance
	Net 1	2
	Net 4	3
	Net 17	2
	Net 21	4
	Net 24	5
	Net 42	3

What will be R_1 Routing Table (3 columns as shown above) be after it incorporates this update from Router R_3 and R_4? Note: The information given in problem should enable you to figure out the distance between R_1 and R_3 and between R_1 and R_4.

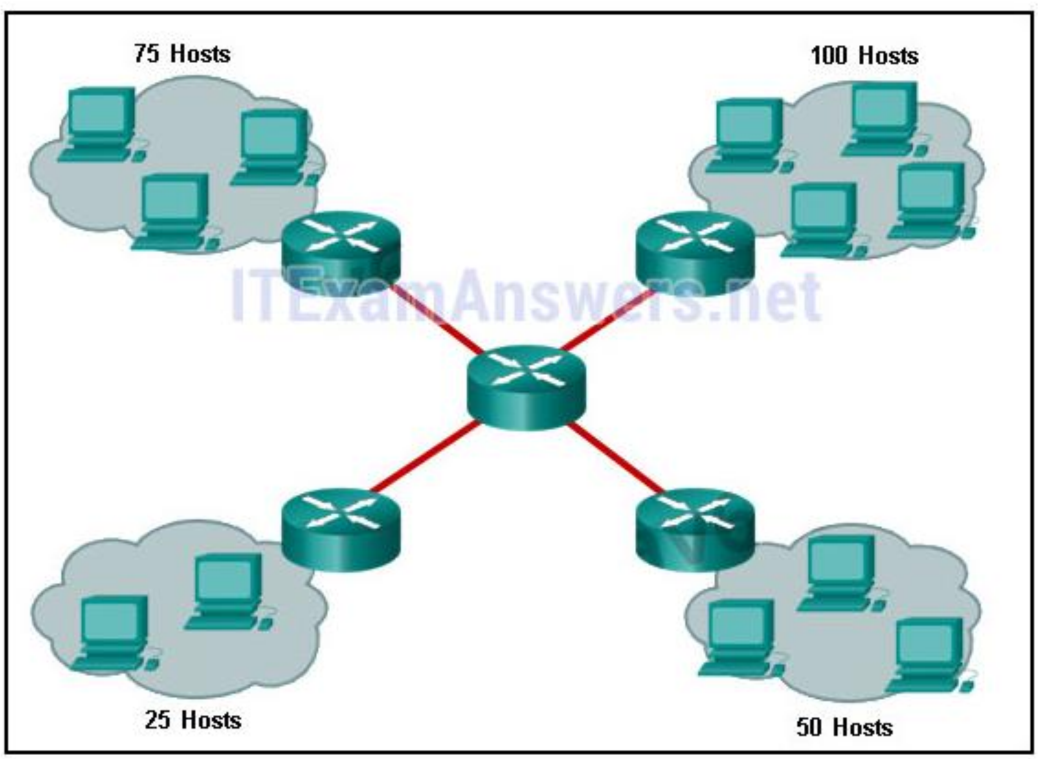
Work Sheet #5

Part 4: Subnetting/Addressing

An organization has the following CIDR block:128.107.0.0/16. The organization wants to create for different departments as shown

Department A: Requires 75 Addressable devices
Department B: Requires 100 Addressable devices
Department C: Requires 50 Addressable devices
Department D: Requires 25 Addressable devices

All departments are connected; using routers (Label the routers as R_1, R_2, R_3, R_4 and R_5 as the middle router). You are required to create "**8 subnets"** (in the form of a.b.c.d/n), **which will result in the "minimum waste" of the address space**. Identify the Subnet address, the subnet Mask and the broadcast address for each of these subnets (Construct a Table). How many addresses are reserved (i.e., available from the original block) for future use? Note: The all 0's and the all 1's can **NOT** be used in the host bits. Identify the Subnet address, the subnet Mask and the broadcast address for each of these subnets (Construct a Table)



Subnet	**Subnet Address**	**Subnet Mask**	**Broadcast Address**

Work Sheet 6

<u>Part 5: TCP Congestion Control</u>

Assume a TCP connection is established over a 1.2 Gbps link with an RTT of 4 msec. Assume that when a group of segments is sent, only a Single Acknowledgement is returned (i.e. cumulative). We desire to send a file of size 2MByte. The Maximum segment length is 1 Kbyte. Congestion **occurs** when the number of Bytes transmitted exceeds the Bandwidth x Delay product (expressed in Bytes). Two types of TCP congestion control mechanisms are considered. <u>For each type sketch the congestion window vs. RTT diagram.</u>

a) TCP implements **AIMD** (with **<u>NO</u>** slow start) starting at window size of 1 MSS. When congestion occurs, the window size is set to half its previous value. Will congestion occur? If yes, when? If no, why not? Find the throughput of the session and the link utilization in this case.

b) TCP implements <u>slow start</u> procedure **ONLY** (i.e., **No** congestion avoidance phase). Again, it starts with a window size of 1 MSS and doubles every RTT. When congestion occurs, the window size is reset to 1 MSS again. Will congestion occur? If yes, when? If no why not? Find the throughput of the session and the link utilization in this case.

<u>Useful Series</u>:

$$\sum_{i=1}^{n} i = \frac{n(n+1)}{2}$$

Work Sheet 7

Work Sheet 8