University of Southern California
EE450: Introduction to Computer Networks
Final Exam, 2:10 Hours
May 7, 2021

Last Name: Dong **First Name:** Cejingxian

Part 1 (T/F)	20%	
Part 2 (MC)	10%	
Part 3 (Fill-in-the-Blank)	30%	
Part 4 (Routing Algorithms)	20%	
Part 5: TCP Congestion Control	20%	
X-Credit: Addressing/Subnetting	10%	
Total	110%	

Notes:

- The exam is 2hours and 10 minutes plus an extra 30 minutes to be used for organizing (make sure to write your name and number your pages), scanning/printing, and uploading ONLY. **The drop box will close at 10:40 PM. I will NOT accept any exam via e-mail. One File and one upload ONLY.**
- You can work the problems in any order you wish, including the x-credit, 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. Anything I can NOT read, I will NOT grade

Rules:

- This is a closed book, closed notes exam. One 8"x11" containing formulas only is allowed along with a calculator. It is preferred if you use a dark pen rather than a pencil.
- 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.

Cejingxian Dong EE450

Part 1: True/False

F 1. Subnetting is the process of extracting the network address from an IP address

T 2. TCP has the property of slow start to probe the congestion level in the network

F 3. The MTU is the maximum number of Bytes that the IP packet can encapsulate

T 4. Communications can be initiated either from the private network or from the public network, if the private network is using a NAT mechanism

T 5. The following masks (in slash notation for simplicity) are only used as default masks: /8, /16 and /24
A B C

T 6. In link state routing, every router has the same link state database, but the routing tables are different in each router

neighbor.
F 7. In distance vector routing, each router receives distance vectors from every router in the network

T 8. Unlike Ethernet, wireless nodes may not be able to transmit and listen at the same time making collision detection impossible.

F 9. In TCP, A source's retransmission timeout value (RTO) is ~~always~~ set equal to the most-recently measured ~~RTT~~ → Est + 4x DevRTT

F 10. An ACK number of 500 in the TCP header, indicates that the receiver has received ~~499~~ Bytes, and the next byte it expects to receive is #500

T 11. The outcome of the routing process is used to populate the forwarding tables at the routers

F 12. If an IP fragment does not arrive at the destination, then only that fragment, ~~not~~ the entire packet, is retransmitted by the source host

T 13. The IP header changes each time a packet passes through an IP router TTL

T 14. Unlike in shared hubs, unicast frames are never flooded in switched Ethernet

③

Cejingxian Dong EE450

Bigger the coverage, longer Tp.

T 15. In 802.3 standard, if the maximum size (coverage) were increased, the minimum frame size would increase as well.

F 16. In 802.3 standard, if the bandwidth isincreased, the minimum ~~frame~~ size would increase as well.

F 17. In 802.3, if an ACK is not received within a specified time (timeout) the sender will retransmit the frame CD, No ACK.

T 18. In the case fragmentation is needed, the TCP/UDP headers always end up in the first fragment.

T 19. If a TCP and a UDP flows share the same "bottleneck", the UDP flow is more likely will get a greater percentage of the bandwidth priority, time sensitive.

T 20. In An Ethernet Adapter passes only non-corrupt frames that it receives up to the network layer

Cejingxian Dong EE450

(4)

Part 2: Multiple Choice Questions

D 1. 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

A, B 2. 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. Authentication → encrypted
b. Integrity → Digest.
c. Confidentiality
d. None of the above

B 3. A sender sends a message encrypted by a public key of the recipient. Which of the following is NOT provided in this scenario?

a. Confidentiality
b. Integrity → No Digest.
c. Authentication
d. All the above

A, B 4. A sender sends a message encrypted by his own private key. Which of the following is NOT provided in this scenario?

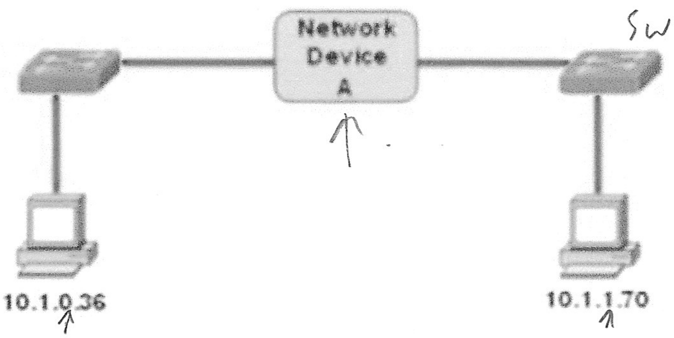
a. Integrity public.
b. Confidentiality √
c. Authentication √
d. All the above

Cejingxian Dong EE450

A,E 5. Replacing a Hub by a switch results in (Circle all that applies)

a. It increases the number of collision domains.
b. It decreases the number of collision domains.
c. It increases the number of broadcast domains.
d. It decreases the number of broadcast domains.
e. It makes smaller collision domains.
f. It makes larger collision domains.

B, D, E 6. Based on the following diagram choose all that applies to device A (circle all that applies)



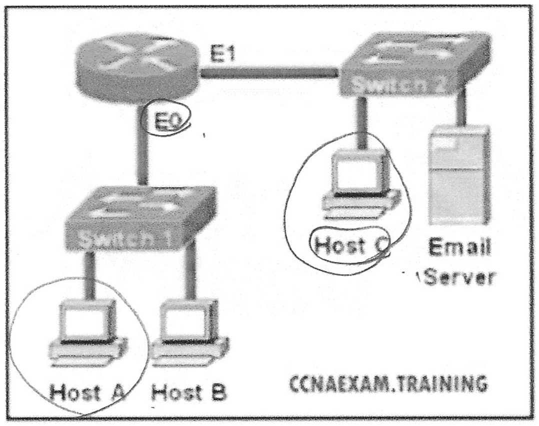
a. With a network wide mask of 255.255.255.128, each interface does not require an IP
b. With a network wide mask of 255.255.255.128, each interface does require an IP address.
c. With a network wide mask of 255.255.255.0, it must be a Layer 2 device for the PCs to communicate with each other.
d. With a network wide mask of 255.255.255.0, it must be a Layer 3 device for the PCs to communicate with each other.
e. With a network wide mask of 255.255.254.0, each interface does not require an IP address.

10.1.0 & 10.1.1 are in Same Net.

(6)

Cejingxian Dong EE450

C, F 7. In the following diagram, which destination addresses will be used by Host A to send data to Host C? (circle all that apply)



a. The IP address of Switch 1
b. The MAC address of Switch 1
c. The IP address of Host C*
d. The MAC address of Host C
e. The IP address of the router's E0 interface
f. The MAC address of the router's E0 interface

A, C 8. Which statement describes remote access VPNs? Select all that applies

a. Client software is usually required to be able to access the network.
b. Remote access VPNs are used to connect entire networks, such as a branch office to headquarters.
c. Remote access VPNs support the needs of telecommuters and mobile users
d. A dedicated line is required to implement remote access VPNs.
e. End users are not aware that VPNs exists.

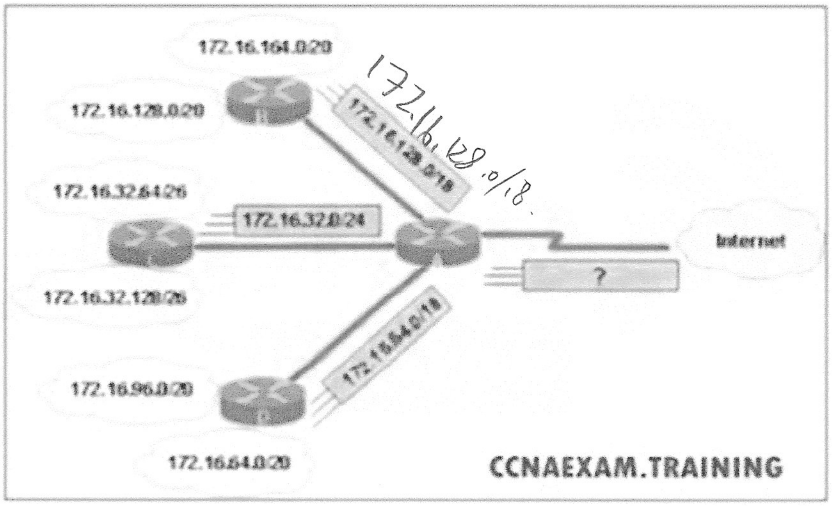
Need to login.

Cejingxian Dong EE450

C 9. Based on the VLSM addressing scheme, what prefix will RA advertise to the Internet

a. 172.16.0.0/20
b. 172.16.0.0/24
c. 172.16.0.0/16 -
d. 172.32.0.0/16 -
e. 172.32.0.0/17
f. 172.64.0.0/16 -

172.16.128.0/18.
172.16.32.0/24 ->
172.16.64.0/18. ->
16.



128

8/8 /

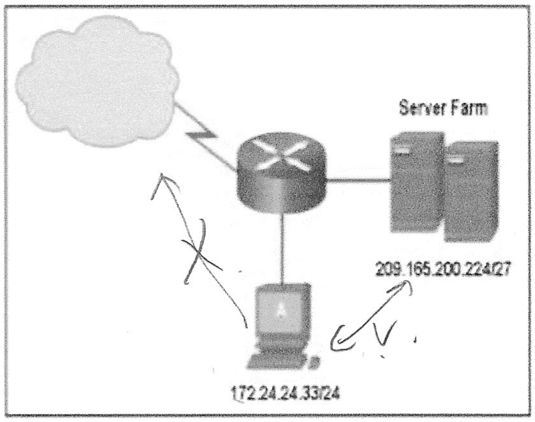
1 0 0 0 0 0 0 0.
32
0 0 1 0 0 0 0 0
~~0 0 1 1 0 1 1 0~~
0 1 0 0 0 0 0 0.

8

Cejingxian Dong EE450

C 10. A network administrator discovers that host A is having trouble with Internet connectivity, but the server farm has full connectivity. In addition, host A has full connectivity to the server farm. What is a possible cause of this problem?

a. Host A has an incorrect subnet mask. X
b. Host A has an incorrect default gateway configured. X
c. NAT is required for host A network.
d. Host A has an overlapping network address. X



Cejingxian Dong EE450

Part 2: Fill-in-the-Blank

1. Suppose a group of 10 stations are connected to a 10 Mbps Ethernet hub. The average bandwidth available to each station is __1__ Mbps. Now suppose these 10 stations are connected to a 10 Mbps Ethernet Switch, the maximum bandwidth available to each station is __10__ Mbps. The aggregate capacity of the switch is __100__ Mbps

524 288 bits

2. A TCP sender is sending a full window of 2^{16} Bytes over a 1 Gbps channel that has a 10msec round trip time.

    a. The link utilization is __5.24__ %

    b. The maximum throughput is __6.55 M__ Bytes/sec

3. Assume you have a 10 Mbps CSMA/CD network interconnecting ten 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 so on up to host H_{10} that is connected via a 1000 m cable (ignore the signal degradation problem). The speed of propagation is 2.5×10^8 m/sec. The minimum frame length used in this network so that CSMA/CD protocol will function correctly should be __152__ bits.

Max length = 1900 m. $T_p = 7.6\,\mu s$. $2T_p = 15.2$

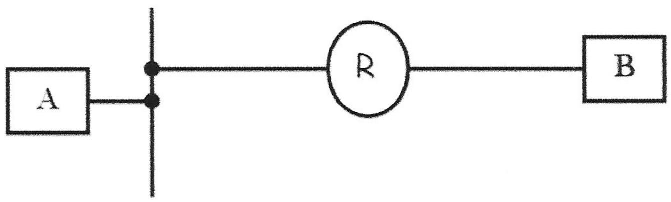
10Mbps = $0.1\,\mu s$/bits. $2T_p/0.1 = 152$ bits.

4. Two nodes "A" and "B" that are attached at the opposite ends of 1000 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. Station "B" will retransmit $\boxed{\text{50 msec}}$ after it senses the medium is idle. Assume that the speed of propagation is 2x108 m/sec. Ignore the jamming signal. Collision occurs at t = __2.5 µ__ sec. Station A will retransmit at t = __10 µ.__ sec.The throughput of node A is __8.7M__ bps.

10

5. A client application on host A needs to send a 1536 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 1200 Bytes. A router connected to the Ethernet is connected to host B through a point-to-point connection with an MTU of 512 Bytes. Assume the TCP in host A knows that the MTU of the Ethernet is 1200Bytes. Answer the following questions

   a. The "minimum" number of segments created by TCP is 2.
   b. The payload size of each of these segments is (separate by comma if more than one segment) 1156, 380 Bytes.
   c. The number of fragments delivered to B is 4..
   d. Their offsets are (separate by comma) 0, 61, 122, 147



6. An ISP has the following Routing Table depicting the 4. prefixes he has as customers. What is the smallest 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)

   a. # of Prefixes: 23.

   b. Prefix (es): 212.56.146.0/23, 212.56.148.0/23.

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

4.

(11)

7. The following is the forwarding table of a router X using CIDR

Destination Network	Subnet Mask	Outgoing Link Interface
135.46.56.0	/22	0
135.46.60.0	/22	1
192.53.40.0	/23	R_1
0.0.0.0	/0	R_2

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

a) Packet 135.46.63.10 delivered to ___1___

b) Packet 135.46.52.2 delivered to ___R2___

c) Packet 135.46.57.14 delivered to ___0___

d) Packet 192.168.10.10 delivered to ___R2___

e) Packet 192.53.40.7 delivered to ___R1___

12

8. Consider the wireless topology above, comprised of 6 nodes. All nodes have the same radio range indicated by circles centered at the node. 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.

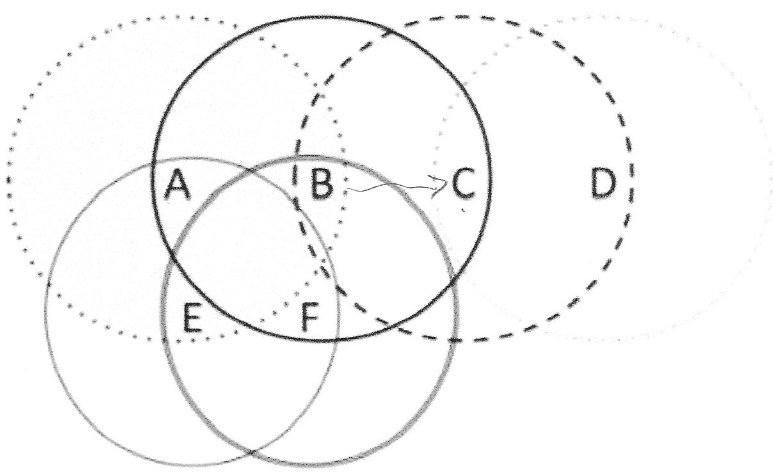
a. Hidden terminals: F, C

b. Exposed terminals: E

What about when node B transmits to node C?

a. Hidden terminals: D,

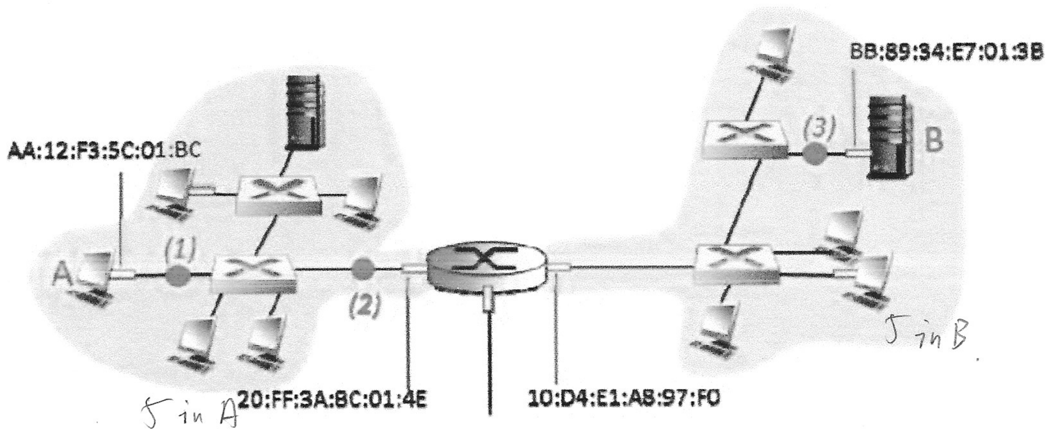
b. Exposed terminals: A, E, F



Cejingxian Dong EE450

A -> B

9. There are 4 switches and a Router. Suppose Host A is sending a Packet to host B. Assume that neither A nor B have sent any packet prior to that.



a. The # of hosts receiving a frame containing the packet sent by A is 10.

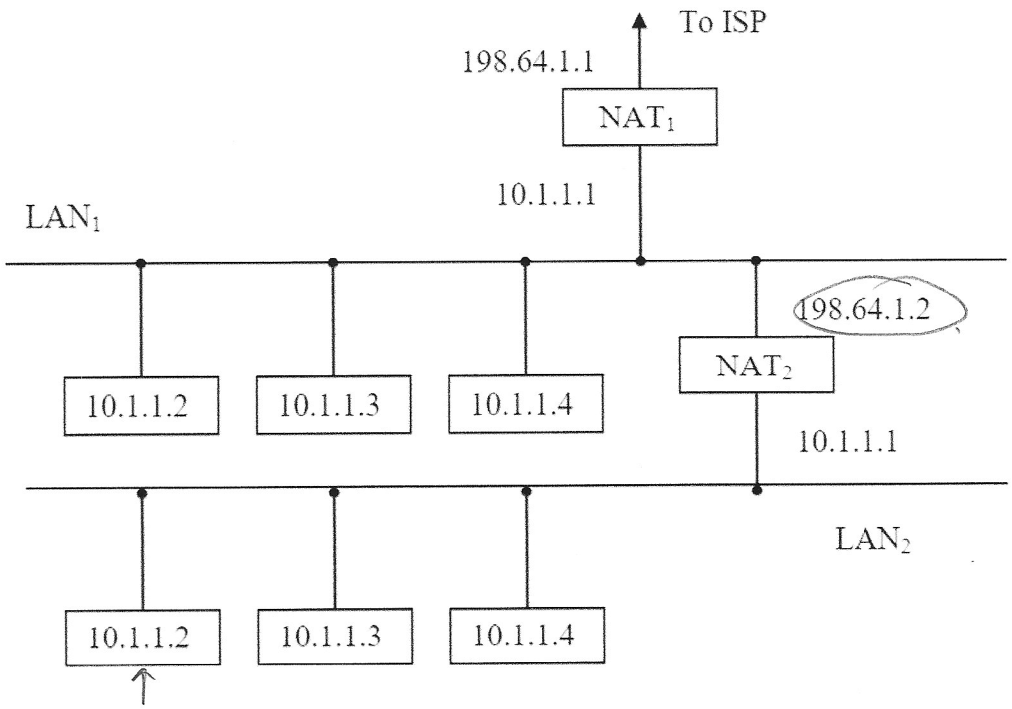
b. The # of hosts receiving the same frame containing the packet sent by A is 5.

c. Now suppose A sends out an ARP request to find the MAC address the server in the upper part of the left network. The number of hosts receiving the frame containing the ARP request is 5

d. Now suppose the server in the upper part of the left network sends an ARP response. The number of hosts that will be receiving the frame containing this ARP response is 1

14

10. 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 as well.

  Answer: 10.1.1.3 at LAN2

- 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: 198.64.1.1

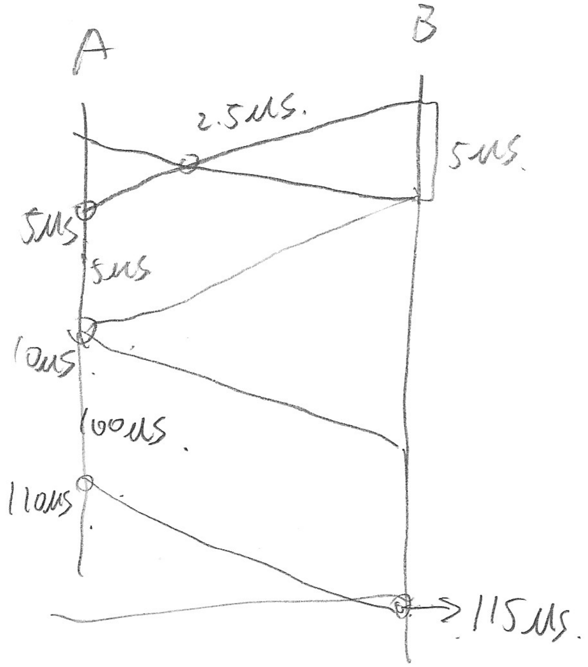
Cejingxian Dong EE450

Work Sheet #1

4. 1000 m.

Throughput = $\frac{1000 \text{ bit}}{115\ \mu s}$ = 8.69565×10^6 bps.

5μs.



5.

IP MTU.

1200B 512B

A —Eth.→ R —P-P→ B

1176+20=1196

512B−20=492 492/8=61.5

61×8=488 Max IP load

1200B −20B = 1180

1180/8=147.5, 147×8=1176 TCP

1176/488=2.4. → 3 frag.

TCP load = 1176−20 = 1156.

380+20 < 512 → 1 frag.

1536 B −1156 B = 380 B

488, 488,

0	147.	0	61	122	147
1176.	380	488	488.	200	380.

undefined

(18)

Work Sheet #2

6\. 146 = 10010010.
147 = 10010011
148 = 10010100.
149 = 10010101.

16+5=21.

7\. 56= 00111000. 122 → 6
60 = 00111100 122. → 6
40= 00101000 123 → 7.

} 135.64

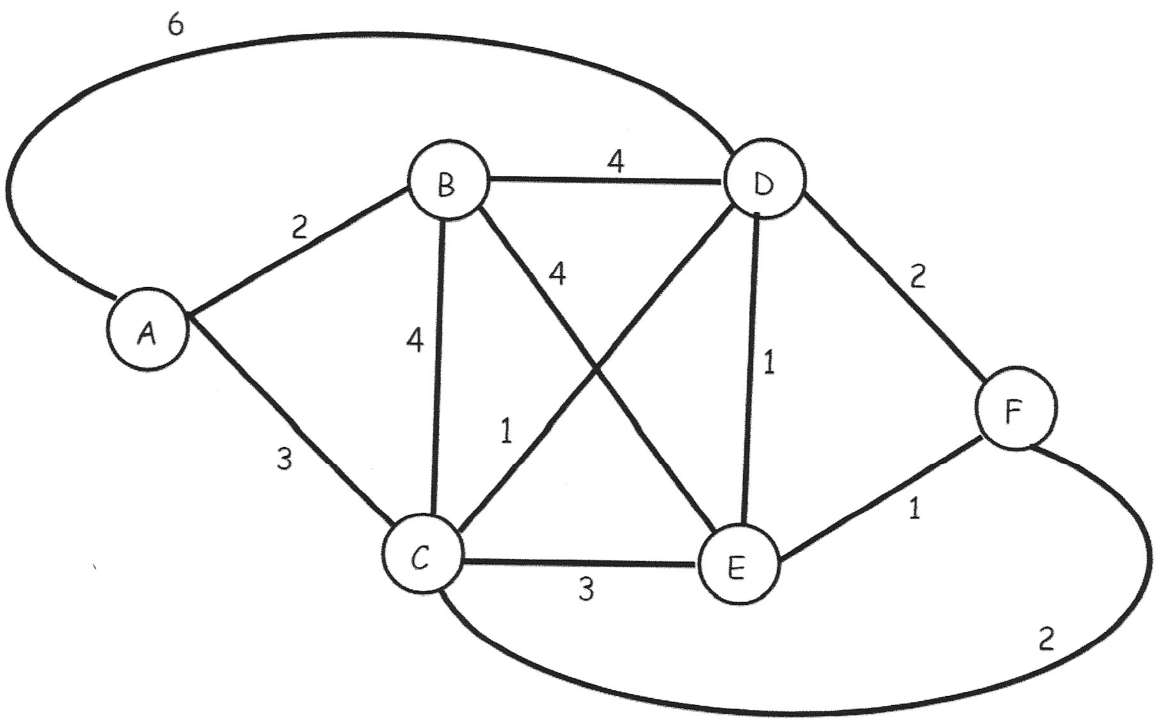
63= 00111111 → 60
52 = 00110100. → 0.
57 = 00111001 → 56.

9\.

Cejingxian Dong EE450

Part 4 (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.**



A B C D E F

a. Answer on Work sheet #4.

Work Sheet #4

#Step	SPT	D(B),P(B)	D(C),P(C)	D(D),P(D)	D(E),P(E)	D(F),P(F)
0	A	2, A ✓	3, A	6, D	∞	∞
1	AB		3, A ✓	6, D	6, B	∞
2	ABC			4, C ✓	6, B	5, C.
3	ABCD				5, D ✓	5, C
4	ABCDE					5, C ✓
5	ABCDEF					

Step #0 Get links of A. make B perminent since B have smallest cost.

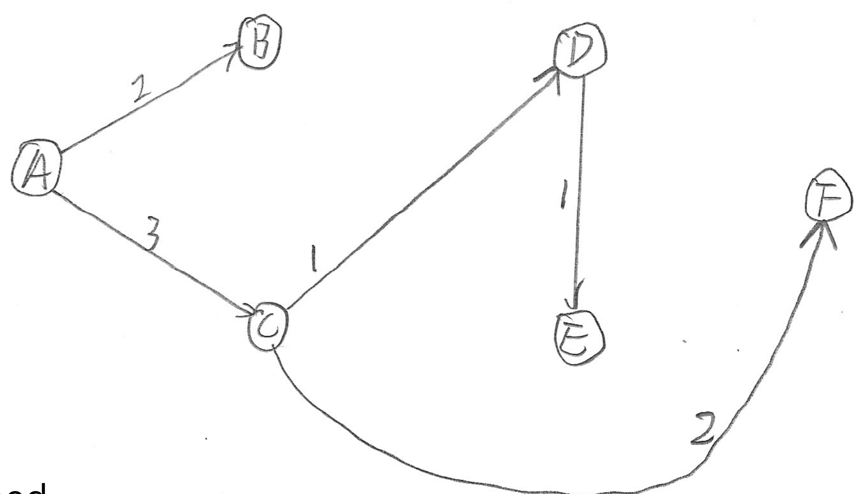
Step#1 Get links of B, Compare with orignal cost, make C perminent.

Step#2 Get links of C, Compare with last cost, make D perminent.

Step#3, Get links of D, Compore, Since the Cost of E and F are the same, Both can be fixed. Here I choose to make E perminent.

Step#4. Get links of E, Compare, and make F perminent.

Spanning Tree:



A → B

A → C

A → C → D

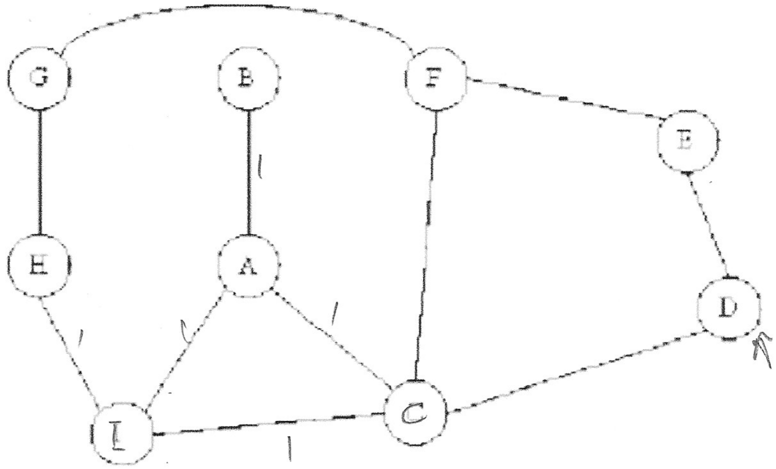
A → C → D → E

A → C → F.

b. This part is NOT related to part "a".

Bellmen-Ford.

In this problem, we need to find the distance vector in Router A using the Bellman-Ford algorithm. Assume the time is slotted (t = 1, 2, 3...) and that a node sends its distance vector to its neighbors at the beginning of a time slot, and it arrives at the end of that time slot. All distance vectors are computed using the most recently available information. What are node A's distance vectors at the beginning of each time slot and how many time slots are needed for the algorithm to converge? Fill-in the table shown below. Assume all links of the same length = 1).



Time Slot "Beginning"	A	B	C	D	E	F	G	H	I
1 A	0	1	1	—	—	—	—	—	1
2 A B C I	0	1	1	2	~	2	—	2	1
3 ABCIHFD	0	1	1	2	3	2	3.	2	1
4 ABCIHFDGE	0	1	1	2	3	2	3	2	1.

A will have (A0, B1, C1, D2, E3, F2, G3, H2, I1)
in 4 time slot.

Part 5: TCP Congestion Control (Parts a and b are related, Part c is NOT)

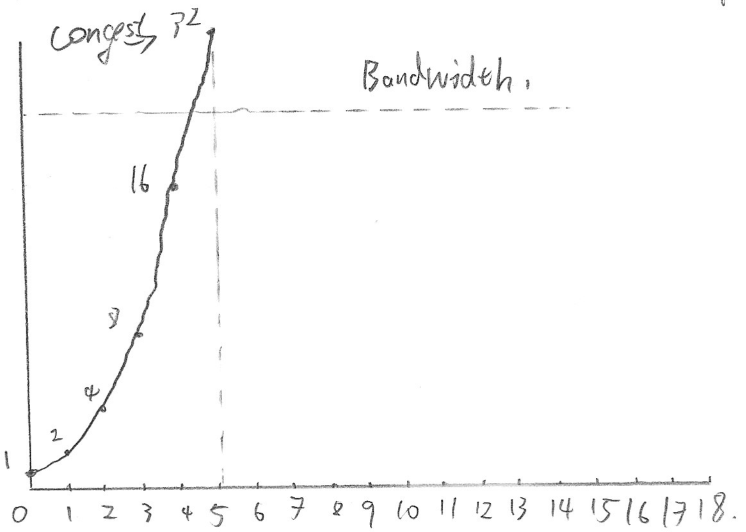
Two hosts A and B are communicating using a TCP connection. The maximum segment size (MSS) is 1kbyte and the size of the receiver window at B is 50 Kbytes. The link bandwidth is 1 MBps, the round-trip time is 20ms and the initial threshold of the Slow Start phase is set to 64 Kbytes.

a. If the 4th transmission round is timed out, how long does it take the sender to reach a congestion window of "maximum size" after the loss? What is the throughput and the link utilization? Clearly illustrate your work(By just giving me a number will earn you NO points)

b. Now assume that the link bandwidth has increased to 10 MBps. What would the maximum possible throughput and link utilization of the session?

MSS = 1KB. recv = 50KB. BW = 1MBps RTT = 20ms. SSth = 64 kB.

a.



BW × D = 1MBps × 20ms = 20KB.

Congestion occurs when

W_c = 20KB = 20MSS.

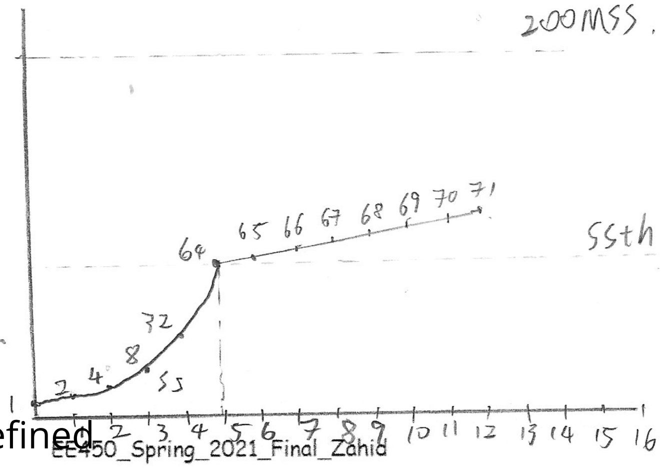
5RTT = $\boxed{100ms}$

Total MSS = 16 + 8 + 4 + 2 + 1 = 31

throughput = $\frac{31 MSS}{5RTT}$ = $\boxed{310kBps.}$

It will take 100ms for Congestion to happen. Throughput at Congestion is 310KBps.

B.



BW × D = 10MBps × 20ms
= 200KB

Congestion Occurs when W_c = 200kB = 200MSS.

SSth = 64kB.

200 − 64 = 136 RTT.

$\boxed{\text{Calculation in Work Sheet \#6.}}$

Cejingxian Dong EE450

21

Work Sheet #6

Part 5.

B. $BW \times D = 10MBps \times 20ms = 200kB$.

Congestion Occurs When $W_c = 200kB = 200MSS$.

At 5RTT, Window size reaches 64kB SS th.

$200 - 64 = 136$, Total RTT Before Congestion is $136 + 5 = 141$ RTT.

Total package sent $= 1+2+4+8+32+64+\frac{200(200+1)}{2} - \frac{64(64+1)}{2}$

$= 18131$ MSS.

$\text{Throughput} = \frac{18131 \text{ MSS}}{141 \text{ RTT}} = \boxed{6.43 \text{ MBps}}$.

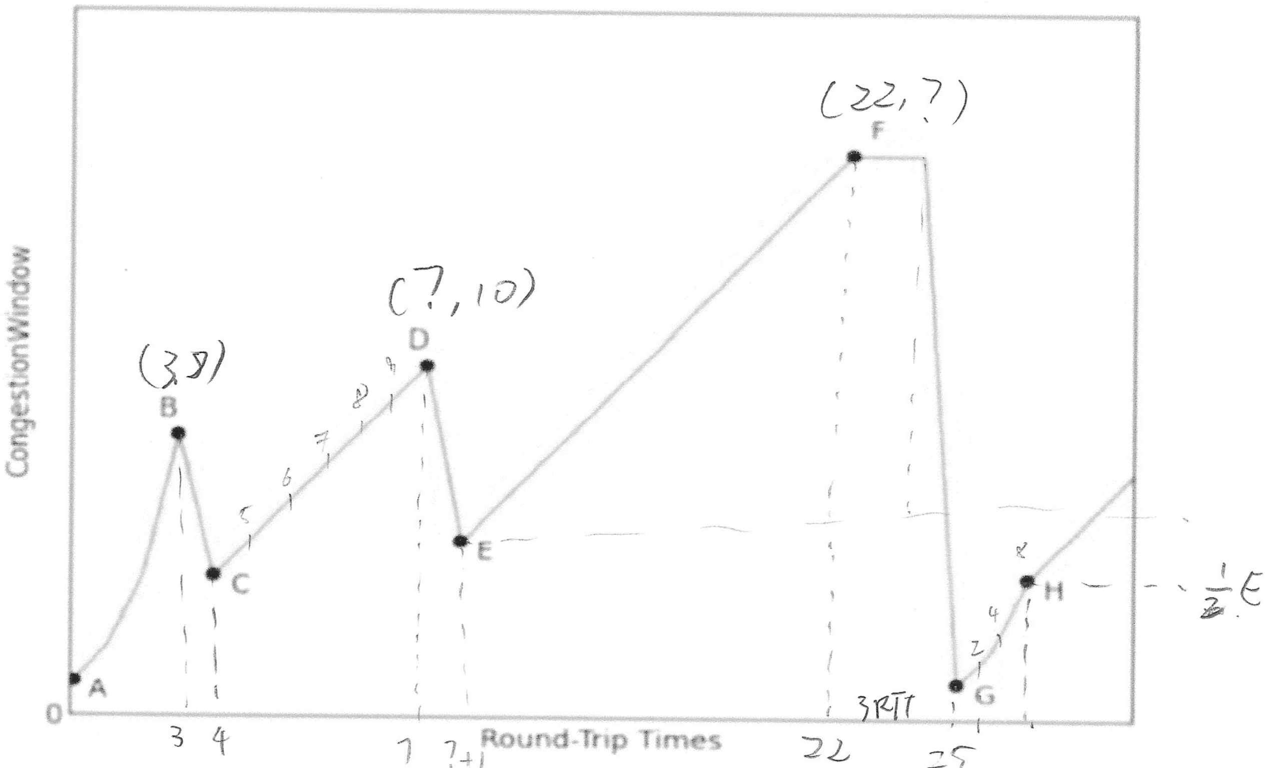
Max throughput is 6.43MBps.

Cejingxian Dong EE450

c. You are given the following trajectory of TCP Reno (ignore fast recovery phase) congestion window. Assume that the time-out is 3RTT. The sender starts by setting his congestion window to 1 MSS at t = 0. You are given the following information about the coordinates of the various points in the graph.

Point A: (0, 1)
Point B: (3, 8)
Point D: (?, 10)
Point F: (22,?)

Find the coordinates of the points: C, D, E, F, G and H, respectively



At C, SSth cut in half of B. So $\boxed{C(4,4)}$

It takes 6 RTT to reach D, So $\boxed{D(10,10)}$

At E, SSth cut in half of D, So $\boxed{E(11,5)}$

It takes 11 RTT to reach F, So window + 11, $\boxed{F(22,16)}$

After 3RTT, at G, window decrease to 1, $\boxed{G(25,1)}$

At H, SSth $= \frac{1}{2}F = 8$.

it takes, 1, 2, 4, 8 to reach H, 3RTTs.

So $\boxed{H(28,8)}$

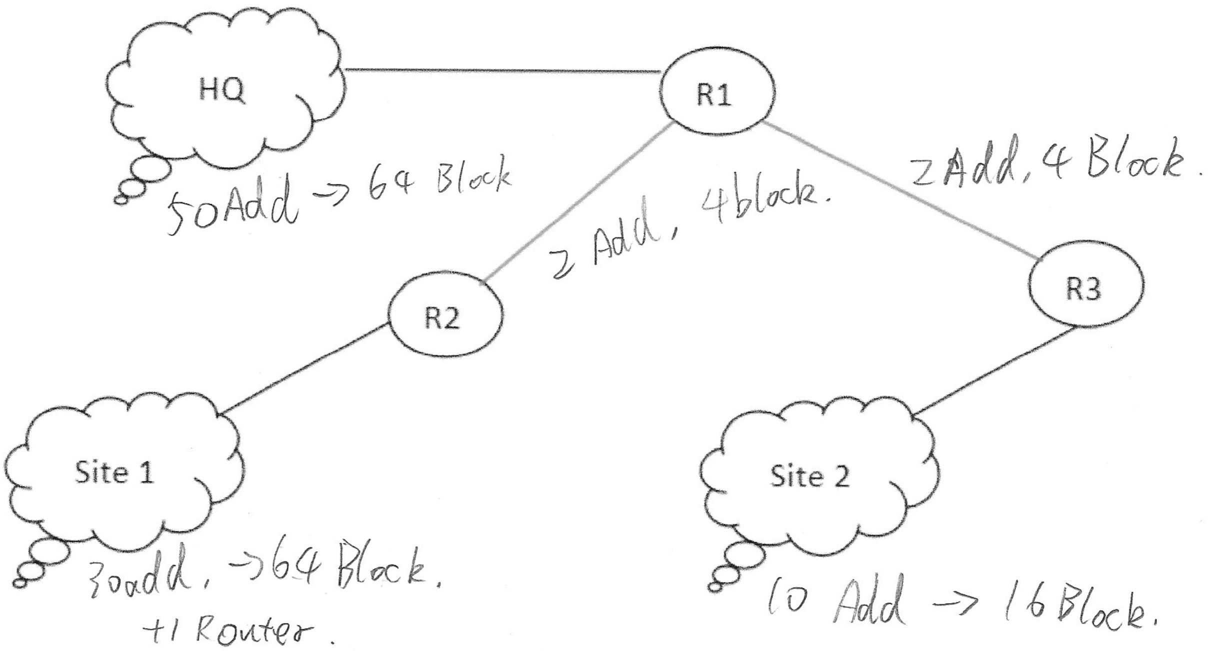
undefined

Cejingxian Dong EE450

23

X-Credit: Addressing/Subnetting

An organization has the following CIDR block: 192.168.1.0/24. The organization has a need for three LANs and 2 WANs as shown below:



A: Headquarter, requires 50 Addressable devices
B: Site 1, requires 30 Addressable devices
C: Site 2, requires 10 Addressable devices
D: WAN_1, Connects R_1 to R_2.
E: WAN_2, Connects R_1 to R_3.

Design a possible efficient addressing scheme for each department by filling the following table. How many addresses remain unused from the original block? How many addresses are left from the original block?

Subnet	Subnet Address	Subnet Mask	Broadcast Address	Max # of hosts
HQ	192.168.1.0	255.255.255.192	192.168.1.63	61
Site 1	192.168.1.64	255.255.255.192	192.168.1.127	61
Site 2	192.168.1.128	255.255.255.240	192.168.1.143	13
R_1-R_2	192.168.1.144	255.255.255.252	192.168.1.147	2
R_1-R_3	192.168.1.148	255.255.255.252	192.168.1.131	2

There are 45 Address unused,

104 Addresses left in Original Block.

Cejingxian Dong EE450

Work Sheet #7

X Credit:

16-10-2-1
= 3 Unused.

192.168.1.0/24
256.

192.168.1.0/25
128.

192.168.1.128/25
128

192.168.1.0/26.
HQ
64 ☆

64-50-2-1
= 11 Unused.

192.168.1.64/26
Site 1
64 ☆

64-30-2-1
= 31 Unused.

192.168.1.128/26
64

64

cut in 4.

192.168.1.128/28
Site 2, 16 ☆

192.168.1.144/28

16

16

192.168.1.144/28
16.

Cut in 4.

192.168.1.144/30
$R_1 - R_2$ 4 ☆

0 unused

192.168.1.148/30
$R_1 - R_3$ 4. ☆

0 unused.

4

4.

Unused = 11 + 31 + 3 = $\boxed{45}$

left = 4+4+16+16+64 = $\boxed{104}$

undefined