Name Solution **Class: CPE348-01**

1) (9 pts) Suppose a 100-Mbps (100×10^6 bps) point-to-point link is being set up between Earth and a new lunar colony. The distance from the moon to Earth is approximately 385,000 km, and data travels over the link at the speed of light $3*10^8$ m/s.

a) **(2 pts)** Calculate the minimum RTT for the link.

$$RTT = 2 \times \frac{385{,}000 \times 1{,}000}{3 \times 10^8} = \boxed{2.57\ s}$$

(1MB = 10^6 Bytes)

b) **(2 pts)** Suppose Mission Control on Earth wishes to download a 25MB image from a camera on the lunar base. What is the ~~minimum~~ amount of time that will elapse between when the request for the data goes out and the transfer is finished?

$$T = T_{tx} + RTT$$

$$= \frac{25 \times 10^6 \times 8}{100 \times 10^6} + 2.57 = \boxed{4.57\ s}$$

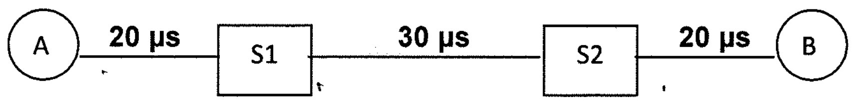
c) **(2 pts)** Using the RTT as the delay, calculate the delay*bandwidth product for the link.

$$2.57 \times (100 \times 10^6) = \boxed{2.57 \times 10^8\ bits}$$

d) **(3 pts)** Imagine that Mission Control requests one 25MB image and then waits until it starts receiving the file before sending another request (the size of the request is negligible). Use the delay*bandwidth product to determine what percentage of the link is utilized.

$$Ratio = \frac{25 \times 10^6 \times 8}{2.57 \times 10^8} = \boxed{77.8\%}$$

2) (12 pts) Consider the **10 Mbps (10×10^6 bps) Ethernet shown**



The propagation delay between any two hosts (A, B or a switch) is shown above. The data to transmit from node A to node B consists of **2000 bits**.

a) **(4 pts)** If the data is transmitted in **one packet**. What is the time necessary to transmit all of the data from A to B (time from transmission of first bit transmitted by A until the last bit is received at B)? Suppose each switch begins retransmitting immediately after it has finished receiving the packet.

$$T=(20+30+20)+\left(\frac{2000}{10\times10^6}\times10^6\right)\times3$$

$$\boxed{=670\ \mu s}$$

b) **(4 pts)** Repeat part (a) if each switch implements a store-forward switching that it starts retransmission of a packet $10\,\mu s$ after receiving the last bit of a packet.

$$T=10\times2+670$$

$$\boxed{=690\ \mu s}$$

c) **(4 pts)** Repeat part (a) if each switch implements a cut-through switching that it is able to begin retransmitting the packet after the first 200 bits have been received.

$$\cancel{\text{delay}=\frac{200}{10\times10^6}\times10^6=20\mu s}$$

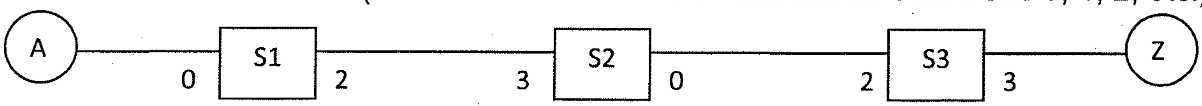
$$\text{delay}=200+\underbrace{40}_{20+20}+\underbrace{50}_{20+30}+\underbrace{20}_{20}$$

$$T=\cancel{20\times2+670}$$

$$\boxed{\cancel{=710\ \mu s}}$$

$$\boxed{=310\ \mu s}$$

3) (12 pts) Consider the following virtual circuit network and the table showing the next Virtual Circuit Identifier (VCI) to use for each interface. The outgoing and incoming VCI's can be the same for a given interface/port (i.e. interface 3 on a switch can have a VCI of 5 for incoming packets and a VCI of 5 for outgoing packets). An interface is the same as port, and only the interfaces of interest for each switch are shown (i.e. interfaces 3 and 0 on switch 2).
Note: the network does not show all of the interfaces available on all switches, and it does not show all of the other nodes in the network. Lastly, each interface has its own set of virtual circuit identifiers (i.e each interface on a switch has its own VCI's 0, 1, 2, etc.)



The next VCI to use for interfaces on the switches

Switch	Incoming Interface	Next VCI to Use
S1	0	3
S1	2	6
S2	0	4
S2	3	9
S3	2	1
S3	3	6

Host A starts a connection to Host Z by sending a **setup message**. A short while later (after connection from A to Z has been established), Host Z starts a connection with Host A by sending a setup message. Use the table above to complete the switch tables below **to show the new entries created** during these virtual circuit setups. Assume that all previous connections remain active during the setups. **Use a next VCI of 7 for Host A and a next VCI of 4 for Host Z**

Virtual Circuit Table for Switch 1 (S1)

Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	0	3	2	9
Z to A	2	6	0	7

Virtual Circuit Table for Switch 2 (S2)

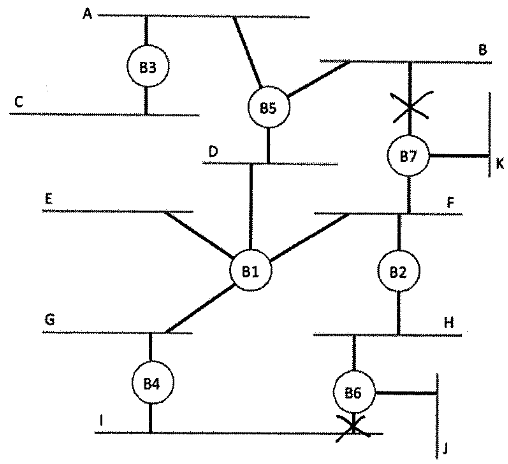
Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	3	9	0	1
Z to A	0	4	3	6

Virtual Circuit Table for Switch 3 (S3)

Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	2	1	3	4
Z to A	3	6	2	4

4) (15 pts) Answer the following short answer questions.

a) **(3 pts)** Consider the extended LAN shown below. Indicate **on the graph** which port(s) / connection(s) are not selected by the spanning tree algorithm.



b) **(3 pts)** Suppose CRC error detection scheme applies a generator polynomial $G(x) = x^7 + x^5 + x^2 + 1$. What is the bit-length of the generated CRC code?

7

c) **(3 pts)** What are the three objectives any cryptosystems aim to achieve?

C. I. A

d) **(3 pts)** Name at least two techniques/algorithms for TCP congestion avoidance.

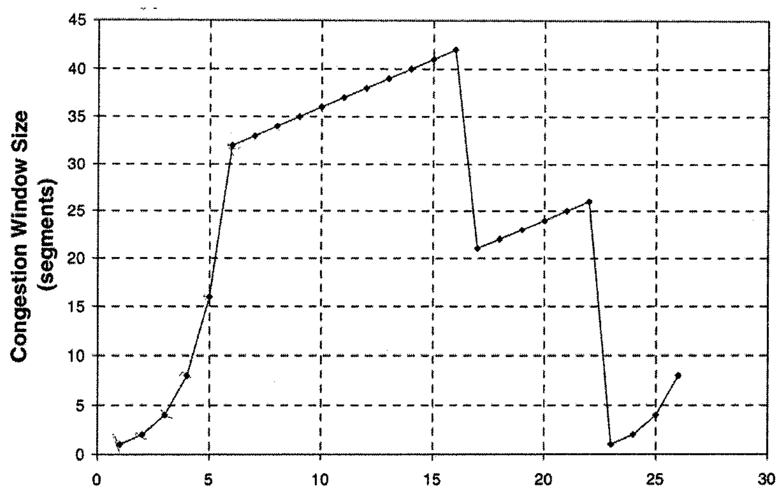
- DEC-bit
- RED

e) **(3 pts)** What is the 8 bit ip-checksum (perform the ip checksum 8 bits at a time instead of 16) for the following 4 bytes of hexadecimal data? **Data:** **B9 44 C4 2F**

B9
+ 44
FD
+ C4
1 C1
C2
+ 2F

$F1 \xrightarrow{\text{complement}} \boxed{0E}$

5) (12 pts) Suppose we have two nodes, A and B, connected through the Internet with bandwidth of 1 Mbps (1×10^6 bps) and RTT of 100ms. A applies a transport layer protocol for transmission and its runtime congestion window size with respect to time is shown below. The segment size is 500 bits. Answer the following questions.



a) **(2 pts)** Identify the intervals of time when TCP slow start is operating.

[1-6], [23-26]

b) **(2 pts)** Identify the intervals of time when TCP AIMD is operating.

[6-16], [17-22] OR [6, 23]

c) **(2 pts)** What is the initial value of **CongestionThreshold (CT)** at the first transmission round?

32 or 31

d) **(3 pts)** If A uses TCP's Slow Start algorithm, in how many round-trip times does A grow the window (from 1) to the **ideal** window size for this link? *(Hint: use delay*bandwidth factor)*

ideal window size $= \frac{\text{delay} \times BW}{500} = \frac{1\times10^6 \times 100 \times 10^{-3}}{500} = 200$

$2^n \geq 200$ $\boxed{n=8}$

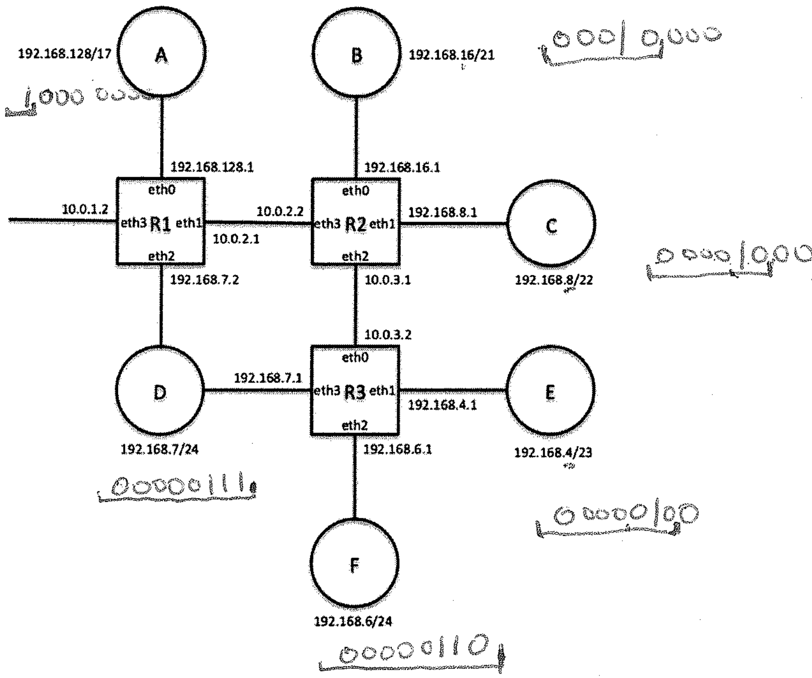
e) **(3 pts)** Repeat Part d) if A uses TCP's Slow Start with AIMD algorithm, given the **CT** in Part c).

6 rounds via slow start to 32

$32 + x \cdot 1 \geq 200$, $x = 168$

So, total $= \boxed{174}$

6) (10 pts) Consider the network diagram below. Each router (a square in the figure) is labeled with the names of its interfaces (e.g., eth0) and the IP addresses assigned to each. Each network (a circle) is labeled with its network name and prefix length.



a) **(3 pts)** Alice sends a file to Bob whose IP address is 192.168.9.12. To which of the networks above is Bob connected?

0000 1001

C

b) **(2 pts)** What is the subnet mask Bob's machine should use?

255. 255. 252. 0

c) **(2 pts)** How many unique IP hosts network A can support?

$2^{32-17} = 2^{15} = 32,768$

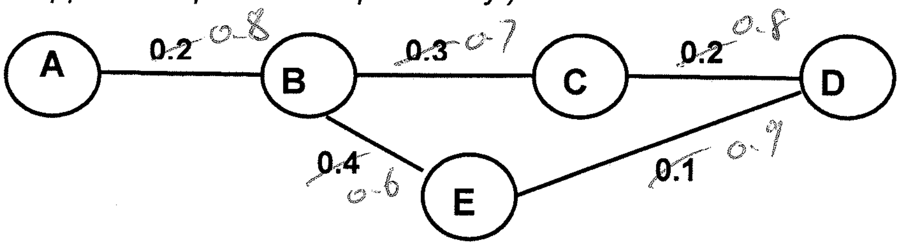
c) **(3 pts)** What is the most concise CIDR block R2 can use to describe the networks reachable through R3?

0000 0111 -- D
0000 0100 -- E
0000 0110 -- F

4

192.168.4/22

7) (15 pts) Distance Vector: The Distance Vector Routing Algorithm is to be performed on the network shown to find the end-to-end path that gives the highest reliability. Cost is measured in **packet loss probability**. Fill in the first three tables (initial distance table, the table after one exchange and the table after two exchanges.) Give entries in the table in the **form of cost/next hop.** An example as shown in the initial table. For each of the distance vector tables, complete the known routing table for node C. *(Hint: for a link, reliability is the opposite of packet loss probability.)*



Info at Node	Distance to reach node – initial table				
	A	B	C	D	E
A	---	0.8/B	0	0	0
B	0.8/A	---	0.7/C	0	0.6/E
C	0	0.7/B	---	0.8/D	0
D	0	0	0.8/C	---	0.9/E
E	0	0.6/B	0	0.9/D	---

Node C Routing Table		
Destination	Cost	NextHop
A	0	—
B	0.7	B
D	0.8	D
E	0	—

Info at Node	Distance to reach node – after 1 exchange				
	A	B	C	D	E
A	---	0.8/B	0.56/B	0	0.48/B
B	0.8/A	---	0.7/C	0.56/C	0.6/E
C	0.56/B	0.7/B	---	0.8/D	0.72/D
D	0	0.56/C	0.8/C	---	0.9/E
E	0.48/B	0.6/B	0.72/D	0.9/D	---

Node C Routing Table		
Destination	Cost	NextHop
A	0.56	B
B	0.7	B
D	0.8	D
E	0.72	D

Info at Node	Distance to reach node – after 2 exchanges				
	A	B	C	D	E
A	---	0.8/B	0.56/B	0.448/B	0.48/B
B	0.8/A	---	0.7/C	0.56/C	0.6/E
C	0.56/B	0.7/B	---	0.8/D	0.72/D
D	0.448/C	0.56/C	0.8/C	---	0.9/E
E	0.48/B	0.6/B	0.72/D	0.9/D	---

Node C Routing Table		
Destination	Cost	NextHop
A	0.56	B
B	0.7	B
D	0.8	D
E	0.72	D

8) (15 pts) Suppose that the TCP connection between A and B goes through router R (A to R then R to B). **Bandwidth on all links is infinite** which means packets travel as a single point (it takes 0 seconds to place/receive a packet on/from the link).

- Packets are instantly transmitted from A to the router or from the router to A.
- It takes 1 second for a packet to completely cross the link from the router to B (data packets) or B to the router (ACKs).
- The router transmits one packet to B every second and upon receipt of a packet, B immediately starts transmission of an ACK back to the router.
- **Every second, Host A processes information in the following order: first process any ACKs, then process any timeouts and then send more packets if possible.**
- The only restriction on host A transmitting is the congestion window.
- For the link between the router and Host B, the router has enough **buffer space to hold two packets in addition to the one it is transmitting (total of three packets at the router).** When buffer overflows, router starts to drop packets of high SeqNum till buffer goes back to normal. **Router applies FIFO queueing discipline.**
- Host A is using an algorithm that **increments its congestion window by 2 packets for each ACK received**.
- The initial congestion window is 1 packet.
- **The timeout time is 3 seconds**. When a timeout occurs the congestion window is reset to 1.

If the first packet (P1) sent by Host A occurs at time t= 1 seconds,

a) **(3 pts)** at what time does a timeout of a packet first occur?

T = 6 sec

b) **(4 pts)** Which packet number (packet numbering starts at 1) is the one that times out first?

pkt index = 4

c) **(4 pts)** What is the congestion window value (value before being reduced to 1) when this timeout occurs? (according to rules above, if an ACK has been received at the same time the timeout occurs, the window is incremented before the timeout is processed)

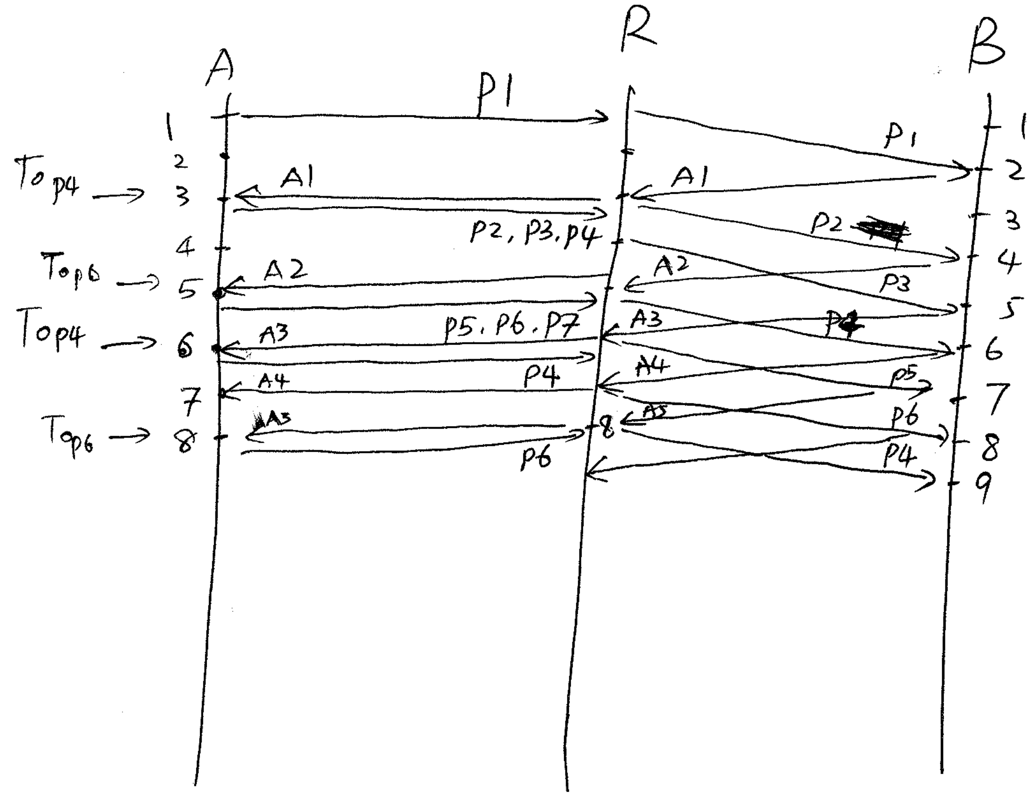
cw = 7

d) **(4 pts)** How many packet(s) are at Router at time t = 8 seconds?

2 (P4 & P6)

Note: No credits will be given if answers are not supported by the transmission diagram!

Extra space for **8)**



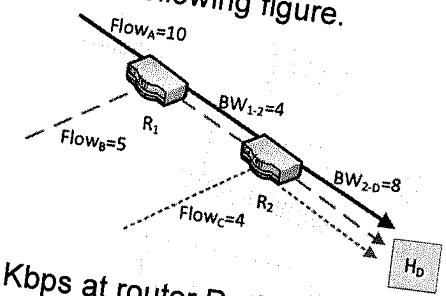
CW α

buffer#	t	cw
1	1	1
0	2	1
3	3	3
2	4	3
× P7 4→3	5	5
3	6	7→1
2	7	3

t = 8: Router ha
p4 & P6

9) Bonus Question (5 pts)

Consider the network depicted in the following figure.



Flow$_A$ transmits at a rate of 10 Kbps at router R_1. Flow$_B$ transmits at a rate of 5 Kbps at R_1. Both are competing for the same outgoing link at R_1 and that link has 4 Kbps of available bandwidth (represented by BW_{1-2} in the figure). At R_2, Flow$_A$ is competing with Flow$_B$ and Flow$_C$. If network service provider wants to maximize the overall throughput of these flows while ensuring **equal** end-to-end data rate them, how much bandwidth will each flow be allocated at R_2?

__**Note:** Show steps (including modeling and solution) to get full/partial credits.__

$f_1 = f_2 = f_3 = \underline{2 \text{ kbps}}$