CPE 348 **Exam #1 (50 + 3 pts)** **February 17, 2020**

Name Solution

All answers must have supporting work. Any answer without support will receive no credit

1) (4 pts) A message **M = 101001** is to be transmitted from node A to node B using CRC coding. The CRC generator polynomial is G(x) = $x^3 + 1$ (bit sequence **1001**)

a) **(2 pts)** What is the transmitted code word? Perform the polynomial long division to find this result.

```
          101100
1001 ) 101001000
       1001
       ----
         1101
         1001
         ----
          1000
          1001
          ----
           100
```

$\boxed{100}$

b) **(2 pts)** Assume node B receives the following code word: **11010001**. By using the CRC, does node B detect any bit errors introduced by the link? Use the generator polynomial from part a.

```
          11001
1001 ) 11010001
       1001
       ----
        1000
        1001
        ----
           1001
           1001
           ----
              0
```

No remainder!

No Error!

2) (11 pts) Answer the following short answer questions.

a) **(2 pts)** What are the **2** problems of using Non-Return to Zero (NRZ) encoding?

Baseline wander

clock sync.

b) **(2pts)** What is the difference between a connection-less service and a connection-oriented service?

Src. knows the route/path to dest. before data transmission in connection-oriened service.

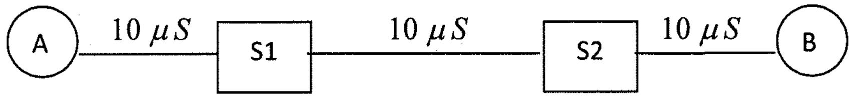
c) **(2 pts)** Explain the stop and wait ARQ (automatic repeat request) protocol. What is its main drawback?

efficiency is low

f) **(5 pts)** In the following 2 dimensional parity problem, 6 bit words are used. If even parity is being used, fill in the missing bit values with a 1 or 0. If it is not possible to correctly determine the bit, put a ? in the box.

0	0	1	0	0	1
1	0	1	1	0	1
0	1	0	1	0	0
1	0	0	1	0	0
0	1	0	1	0	0

3) (12 pts) Consider the <u>hypothetical</u> **25Mbps (25,000,000 bps) network** shown



The propagation delay between any two hosts (A, B or a switch) is $10\,\mu s$. The frame to transmit from node A to node B consists of **2,000 bits**. Each switch can start retransmission of a frame $10\,\mu s$ **after receiving the <u>last</u> bit** of a frame.

a) (**4 pts**) What is the time necessary to transmit the data as a single frame from A to B (time from the first bit transmitted by node A until last bit is received at node B)?

$$T = t_{tx} \times 3 + (10+10+10) + (10 \times 2)$$

← queueing

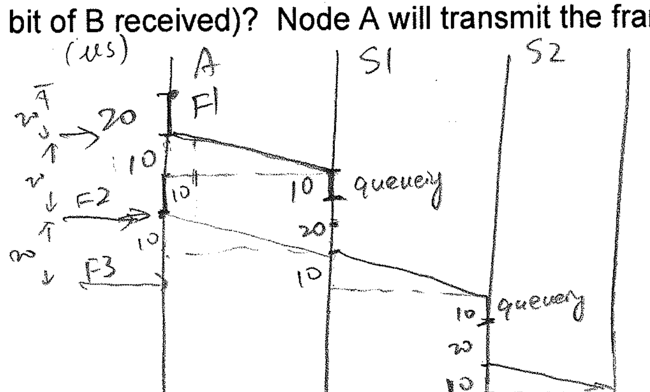
↖ prop.

$$= \frac{2000}{25} \times 3 + 50 = 290\ \mu s$$

b) (**3 pts**) What is the effective data rate for this one frame from A to B (number of bits sent divided by time to send the bits) in bits per second(bps) for the network as analyzed in part a?

$$r = \frac{2000}{290 \times 10^{-6}} = 6.897\ \text{Mbps}$$

c) (**4 pts**) If the original frame is split into 4 frames so that each frame consists of **500 bits**, what is the time necessary to transmit all bits in all frames from A to B (time from first bit of A sent to last bit of B received)? Node A will transmit the frames one right after the other.



$$T_{base} = (20+10) + (10+20+10) \times 2$$
$$= 110\ \mu s$$

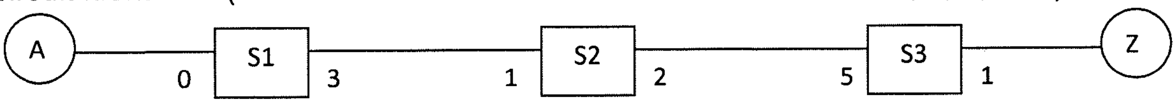
$$T_{tot} = 110 + 20 \times 3 = 170\ \mu s$$

d) (**3 pts**) For the four frames sent from A to B in part c, what is the effective data throughput rate in bits per second(bps) for the network as analyzed in part c?

$$r = \frac{2000}{170 \times 10^{-6}} = 11.76\ \text{Mbps}$$

4) (10 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 switch 1 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 1 and 2 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	1
S1	3	3
S2	1	4
S2	2	0
S3	1	2
S3	5	5

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 ~~3~~ 6 for Host A (as the receiver) and a next VCI of ~~4~~ 2 for Host Z (as the receiver).**

Virtual Circuit Table for Switch 1 (S1)

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

Virtual Circuit Table for Switch 2 (S2)

Setup message creating entry	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	1	4	2	5
Z to A	2	0	1	3

Virtual Circuit Table for Switch 3 (S3)

Setup message creating entry	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	5	5	1	2
Z to A	1	2	5	0

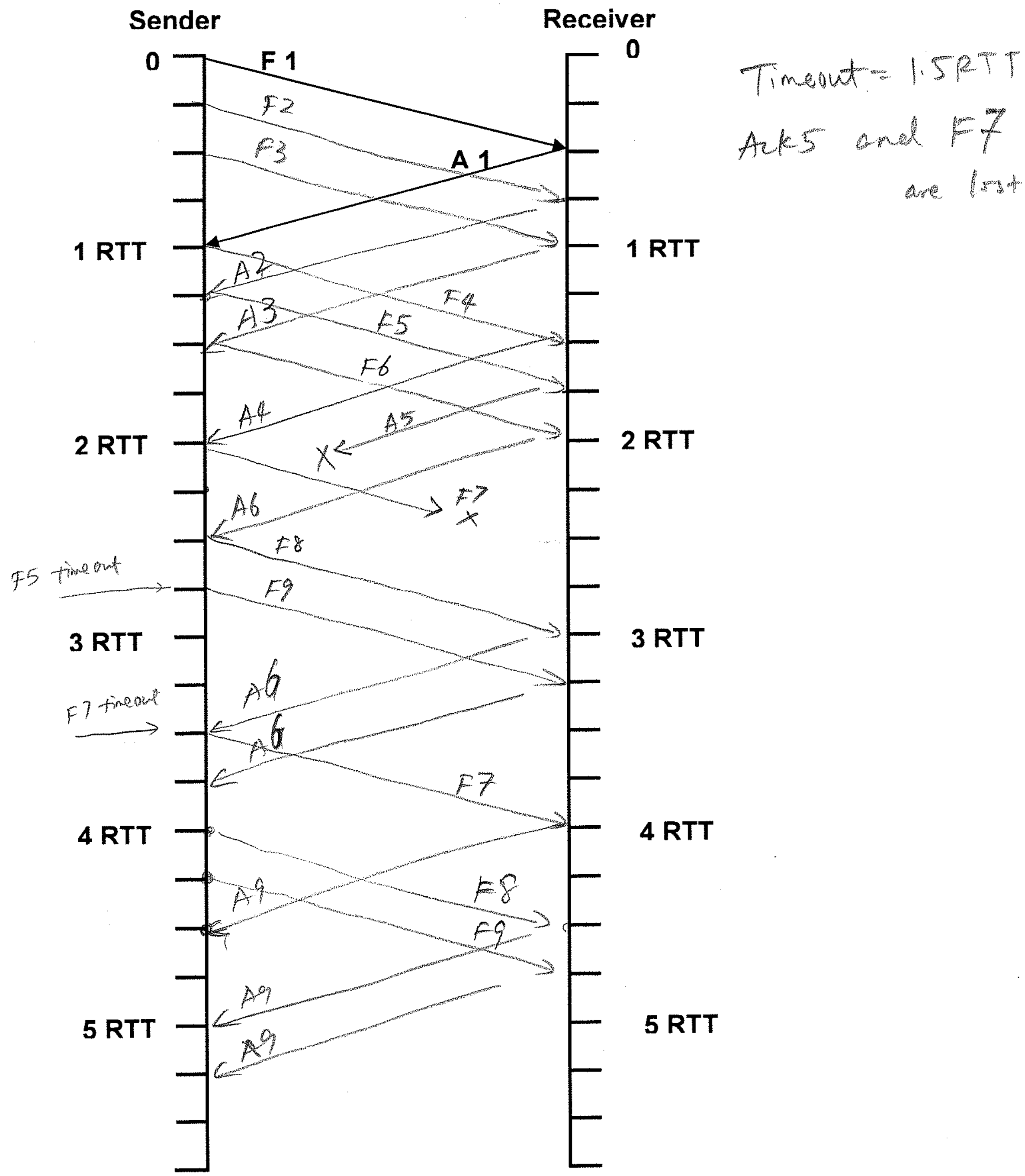
5) (13 pts) a particular ARQ protocol is being implemented with a sending and receiving window size of 3 frames (SWS = RWS = 3). Frames are sequenced using numbers 1, 2, 3, etc. Acknowledgments are sent for each frame that is received in order. If a higher sequence numbered frame is received out of order, that frame is not acknowledged until all earlier frames have been acknowledged. For example, frames 1, 2 and 3 are sent, and frame 1 is received (ACK1 sent back), frame 2 is delayed and frame 3 is received. Upon receiving Frame 3, the receiver retransmits ACK1. When frame 2 arrives, ACK3 is transmitted (acknowledges frames 2 and 3 being received).

Complete the timeline for this protocol given the following information:

- Sender needs to send 9 frames only with sequence numbers 1 through 9. **Show all transmissions (frames and acks) that will occur when transmitting these nine frames and ack9 is received by the sender**
- **During transmissions, ACK 5 and Frame 7 are lost on their first transmission attempt** ←
- Bandwidth is infinite, so transmit time of frames is instantaneous (Frames are transmitted and received instantly – though they still have a propagation time)
- The sender (when allowed) will transmit one frame every ¼ of a RTT – transmission time is instantaneous, but the sender can only perform one transmission every ¼ of a RTT
- A frame experiencing no delay is received ½ of a RTT after transmission starts (propagation delay) (Frame 1 and ACK 1 are shown) and processing time is instantaneous.
- At a specific time, frames or ACKs are received and processed(instantly) before a transmission decision occurs
  - receiver receives a frame and then sends the ACK if required
  - sender receives an ACK and then determines if a timeout has occurred; it then determines the next frame to transmit (provided the SWS has not been exhausted)
- If the receiver receives a frame that it has already acknowledged, the receiver repeats its most recent acknowledgment. For example, the last ACK sent by the receiver is ACK6. If frame 5 is received again, ACK6 is repeated.
- **The timeout period is 1.5 Round Trip Times (1.5 RTT)**
- **Timing diagram is on the next page.**

❖ **The grading is based on checking the action at 1RTT, 2RTT, ..., 5RTT in both sender and receiver; partial credits will be given for correctness at other time instants.**

Name ______________________________



6) (Bonus 3pts) What do you expect the course to change in the following semester to better facilitate your learning?

Midterm

You started this quiz near when it was due, so you won't have the full amount of time to take the quiz.

This is a preview of the published version of the quiz

Started: Mar 1 at 11:51am

Quiz Instructions

Here are midterm1 questions. You will need Lockdown browser and a webcam to take the exam. Upon finish, you MUST scan and upload your answer sheet (in a single PDF file) to the "Midterm 1 File submission" tab in the "Assignment".

Don't upload any file while taking the exam, though each exam question asks your file submission.

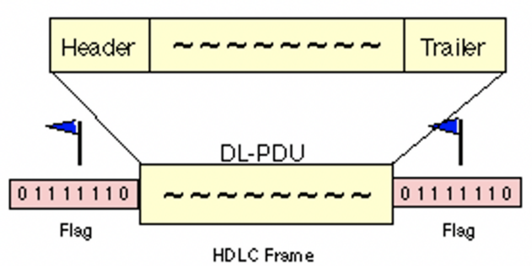
Question 1

0 pts

Suppose a link layer frame has a header **H = 10011** and a payload **M = 1110110.** It is to be transmitted from node A to node B using CRC coding. The CRC generator polynomial is $G(x) = x^3 + x + 1$

a) **(3 pts)** What is the generated CRC code? (Hint: Error detection algorithm only applies to the payload.)

b) **(3 pts)** Suppose only CRC code is added to the frame as the tail (**T**) and now we have the frame as **H+M+T** (i.e., DL-PDU in the following figure). If we use HDLC protocol to transmit it, what is the transmitted code? (Hint: remember the bit-stuffing.)



Upload Choose a File

1\. a)

```
         1100010
1011 ) 1110110.000
       1011
       ----
        1011
        1011
        ----
           1000
           1011
           ----
            110
```

CRC = 110

b) 01111110.1001111100110110.01111110

stuffed bit

You started this quiz near when it was due, so you won't have the full amount of time to take the quiz.

Question 2

0 pts

Answer the following short answer questions.

a) **(2 pts)** What is the name of 3rd layer in the OSI model? (Hint: counting from bottom)

Network layer

b) **(2 pts)** What are the **2** problems of the Non-Return to Zero (NRZ) encoding?

Baseline wander / Clock recovery

c) **(2 pts)** Explain why CSMA/CD cannot be used in wireless environment?

hidden node problem

d) **(5 pts)** In the following 2 dimensional parity problem, 6 bit words are used. If odd parity is being used, fill in the missing bit values with a 1 or 0. If it is not possible to correctly determine the bit, put a ? in the box.

0	0	1	0	0	0
1	1	1	1	0	0
0	1	0	0	1	0
1	0	0	1	0	1
1	0	1	1	1	*

d) 1 ; 0 ; 0; 0; 1

e) **(2 pts)** Suppose a sliding window algorithm is implemented using a SWS=4 and a RWS = 3, will 6 sequence numbers (i.e. 0, 1, 2, 3, 4, 5) be sufficient to correctly distinguish all packets that are received? Explain your answer.

Yes, no prblem

Upload

You started this quiz near when it was due, so you won't have the full amount of time to take the quiz.

Question 3

0 pts

A **hypothetical network** has an end to end length of 5000 meters with a propagation speed of 2.5×10^8 m/s. The bandwidth of the link is 40 Mbps (40,000,000 bps). The maximum frame size for transmission on this network is 2400 bits.

a) **(2 pts)** What is the transmission time for a maximum sized frame on the network?

$t_{tx} = 2400 / 40E6 = 60 \, NS$

b) **(2 pts)** What is the **one-way** (from one end to the other) propagation delay for the network?

$t_{prop} = \frac{5000}{2.5E8} = 20 \, NS$

c) **(2 pts)** How long does it take to transmit a maximum sized frame from one end of the network to the other? (This time is the time from when the first bit is transmitted to the last bit received)

$t = t_{tx} + t_{prop} = 80 \, NS$

d) **(3 pts)** For this network, is the maximum frame size sufficient for CSMA/CD? Explain

$t_{tx} > 2 t_{prop}$ $60 < 40$ so yes!

Upload

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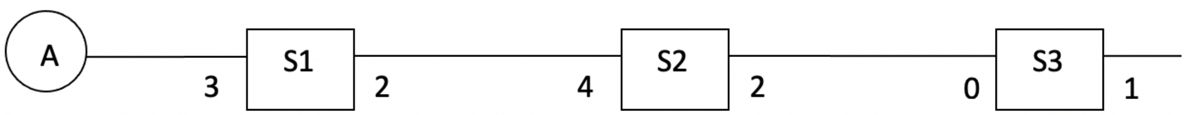
Ques

You started this quiz near when it was due, so you won't have the full amount of time to take the quiz.

0 pts

(10 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 2 and 4 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	Outgoing Interface	Next VCI to Use
S1	2	1
S1	3	2
S2	2	8
S2	4	5
S3	0	2
S3	1	3

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. **Host A uses VCI = 4 for its transmitted frame while Host Z uses VCI = 7.**

Virtual Circuit Table for Switch 1 (S1)

Setup message

Switch 1 (S1)

4.

Msg	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A→Z	3	4	2	1
Z→A	2	5	3	2

Switch 2 (S2)

Msg	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A→Z	4	1	2	8
Z→A	2	2	4	5

Switch 3 (S3)

Msg	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A→Z	0	8	1	3
Z→A	1	7	0	2

Upload Choose a File

Question 5

0 pts

A particular ARQ protocol is being implemented with a sending and receiving window size of 3 frames (SWS = RWS = 3). Frames are sequenced using numbers 1, 2, 3, 4, 5, 6, 1, ... Receiver keeps a pointer **SeqNumToAck.** An ACK is sent to represent that all frames with smaller sequence number are well received. If error happens, receiver holds ACK till the frame of **SeqNumToAck** is received**.** For example, firstly, frames 1, 2 and 3 are sent, and frame 1 is received (ACK1 is returned), frame 2 is lost and frame 3 is received. Then, **SeqNumToAck=2** and the receiver returns ACK1 again upon receiving frame 3. After timeout, the sender retransmits frame 2 and the receiver returns ACK3 to indicate frame 2 and 3 have correctly received.

Answer the following questions and (or) complete the timeline for partial credits.

- **During transmissions, ACK 4 and Frame 5 are lost at their first transmission attempt!**

- Bandwidth is infinite, so transmit time of frames is instantaneous (Frames are tran

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e)
- The
transmission time is instantaneous, but the sender can only perform one transmission every ¼ of a RTT
- A frame experiencing no delay is received ½ of a RTT after transmission starts (propagation delay) and processing time is zero.
- At a specific time, frames or ACKs are received and processed (instantly) before a transmission decision occurs
  - receiver receives a frame and then sends the ACK if required
  - sender receives an ACK and then determines if a timeout has occurred; it then determines the next frame to transmit (provided the SWS has not been exhausted)
- The timeout period is 2 Round Trip Times (2.0 RTT)
- **Show steps for partial credits. Answer with no steps will receive zero credits.**

a) (4 pts) At what time the first timeout expires?

b) (4 pts) What are inside the sending window (the frame numbers) at time instant 5 RTT?

c) (4 pts) What is the **SeqNumToAck** at time instant 5 RTT?

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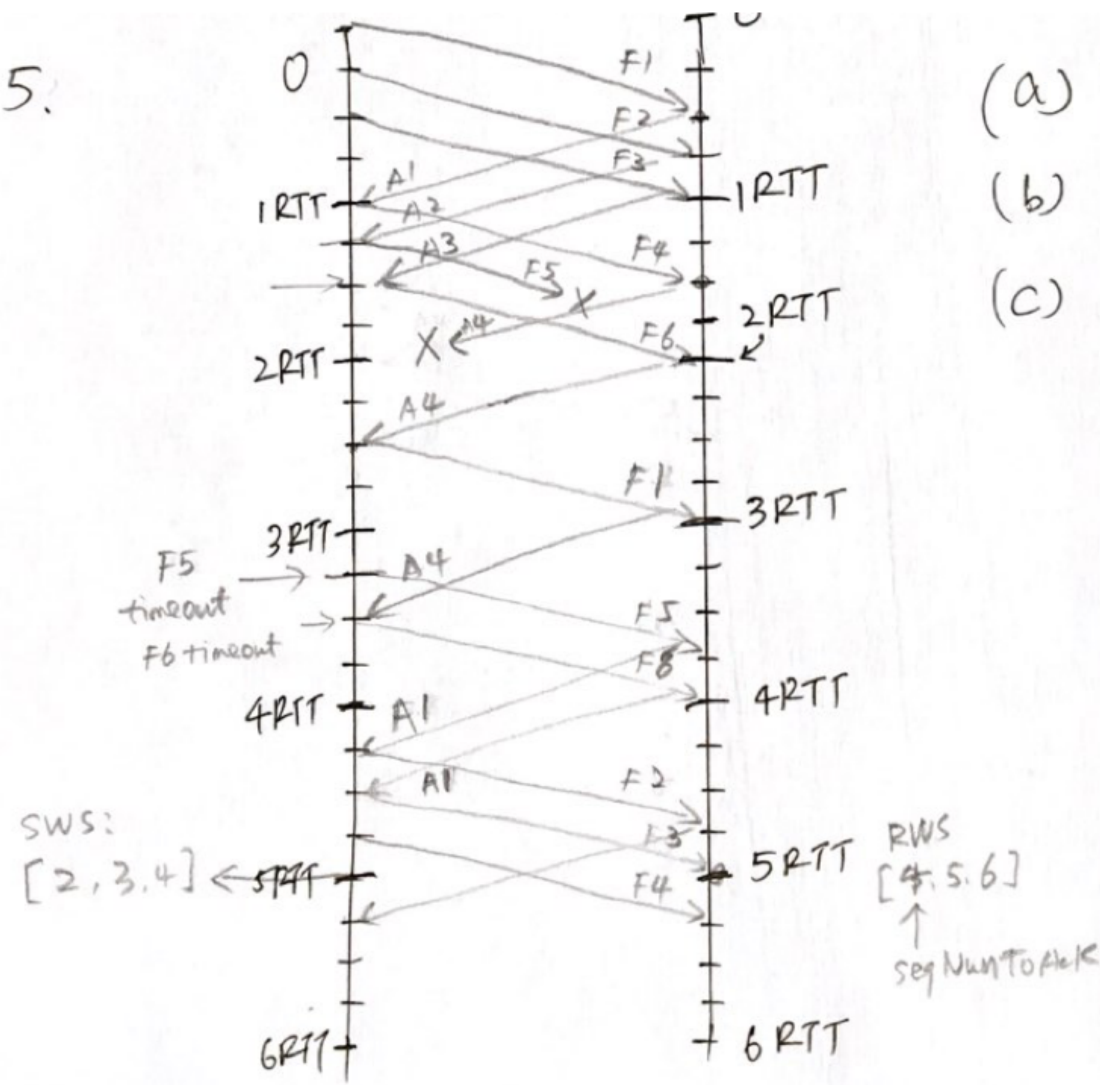
Question 6

0 pts

(3pts) What do you expect the course to change in the following semester to better facilitate your learning?

5.



(a) 3 1/4 RTT

(b) 2, 3, 4

(c) 4

CPE 348 Exam #1 (50 pts) March 03, 2021

Name Solution

1) (8 pts) Suppose a link layer frame has a data **M = 111011** to be transmitted from node A to node B**.** Please answer the following question. It is to be transmitted from node A to node B using CRC coding.

a) **(4 pts)** If you are asked to derive the CRC code for **M** given that the generator polynomial is $G(x) = x^2 + 1$, what is your answer?

G = 101

```
         110110
101 ) 11101100
      101
      100
      101
        111
        101
          100
          101
           [10]
```

b) **(2 pts)** If you are asked to derive the 3-bit checksum code for **M**, what is your answer? (Hint: In our project, we used 8-bit checksum. Here, operations will be the same and the only difference is the size.)

```
  111          010
  011          001
 ----         ----
 1010  then → [011]  → complementary  [100]
 carry
```

c) **(2 pts)** If you are asked to derive the 1D even parity code for **M**, what is your answer? (Hint: Consider every 7 bits as a cohort. Pad 0s if less than 7 bits.)

1

2) (14 pts) Answer the following short answer questions.

a) **(2 pts)** Which layer in the OSI model does the HTTP protocol belongs to?

Application layer (or 7^{th} layer)

b) **(2 pts)** What are the **2** steps in the 4B/5B encoding?

(1) 4 bits are mapped to 5 bits

(2) encode use NRZI

c) **(2 pts)** The following bits are from the data payload field in a HDLC-based network frame. Please mark errored bits and stuffed bits if there are any.

...10111100011111010110111111101...

stuffed bit error bit

d) **(2 pts)** Why the sliding window protocol is advantageous over the stop-and-wait protocol?

Keep sending data while waiting for ACKs ;

OR

better ~~char~~ Bandwidth utilization efficiency.

e) **(2 pts)** How can hidden nodes be detected/informed by in 802.11 networks (a.k.a. WiFi)?

RTS/CTS

j) **(4 pts)** Consider that the sliding window protocol runs over a 40-km point-to-point fiber link. The speed of light is 2×10^8 m/s in the fiber and the bandwidth of this fiber link is 1Gbps (1,000,000,000 bits/s).

(1) What is a suitable timeout value for this protocol?

$$RTT = \frac{40\times10^3}{2\times10^8} \times 2 = 0.4ms \; ; \; \boxed{Timeout \geq 0.4ms}$$

(2) What is the maximum allowed sending window size? Assume frame size is 4Kb (4,000 bits). (Hint: maximum sending window size can make the pipe full)

$$RTT \times bandwidth = 0.4\times10^{-3} \times 10^9$$

$$= 4\times10^5 \text{ bits}$$

$$SWS = \frac{4\times10^5}{4\times10^3} = \boxed{100}$$

3) (8 pts) A **hypothetical network** has an end-to-end length of 1,000 meters with a propagation speed of 2×10^8 m/s. A store-and-forward switch sitting in the middle introduces a queuing delay of 2.5 μS to transmissions in both directions. The bandwidth of the link is 500 Mbps (500,000,000 bps). The maximum frame size for transmission on this network is 5000 bits.

a) **(2 pts)** What is the transmission time for a maximum sized frame on the network?

$$t_{tx} = \frac{5000}{500 \times 10^6} = \boxed{10\ \mu s}$$

b) **(3 pts)** How long does it take to transmit a maximum sized frame from one end of the network to the other? (Hint: remember to include the switch's transmission time.)

$$t_{one\text{-}way} = t_{tx_1} + t_{prop} + t_{queue} + t_{tx_2}$$

$$= 10 + \frac{1000}{2 \times 10^8} + 2.5 + 10$$

$$= \boxed{27.5\ \mu s}$$

d) **(3 pts)** Assume CSMA/CD (carrier sense multiple access with collision detection) is used on this network. Using the answer your find in Part b), what is the minimum number of bits in a frame that can be used such that a transmitting node is guaranteed of detecting a collision?

$$RTT = 2 \cdot (t_{prop} + t_{queue}) + t_{tx}$$

$$= 2\,(5 + 2.5) + 10$$

$$= 25\ \mu s$$

$$\text{(minimum) frame size} \geq RTT \times BW = 25 \times 10^{-6} \times 500 \times 10^6$$

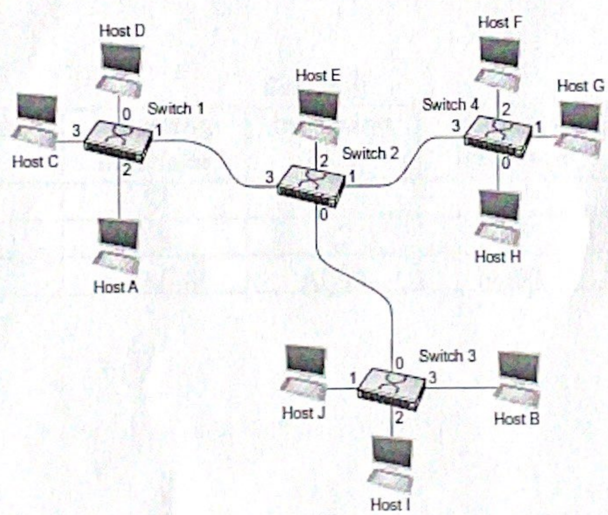
$$= \boxed{12{,}500 \text{ bits}}$$

5) (10 pts) Consider the following virtual circuit network. The network already has some existing connections which are not shown. In light of it, some Virtual Circuit Identifiers (VCIs) have been allocated. Note that the network follows the rule that the VCI assignment always picks the lowest available value. The following table shows that the next VCI to use for some interfaces that are of interest.

Switch	Incoming Interface	Next VCI to use
S1	1	1
S1	2	3
S2	0	2
S2	2	5
S2	3	~~3~~ 4
S3	0	0
S3	1	1
S3	3	0

At one moment, some new connections are about to be initiated. Assume that the sequence of connections is cumulative; that is, the first connection is still up when the second connection is established, and so on. Please provide the VC table for all the switches after each of the following uni-directional connections is established.

1) From Host A to Host J
2) From Host B to Host E
3) From Host E to Host A



Please fill out the following table. If a connection does not pass that switch, please fill **N/A**. A sample work has been done for Switch 1, and you can use it for a start. **Hint:** remember the chain effect, that is the outgoing VCI of a switch should be equal to the incoming VCI of another switch.

Switch 1:

Connection	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
1)	2	3	1	4
2)	N/A	N/A	N/A	N/A
3)	1	1	2	0

Switch 2:

Connection	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
1)	3	4	0	0
2)	0	2	2	3
3)	2	5	3	1

Switch 3:

Connection	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
1)	0	0	1	2
2)	3	0	0	2
3)	N/A	N/A	N/A	N/A

6) (10 pts) A particular ARQ protocol is being implemented with a sending and receiving window size of 3 frames (SWS = RWS = 3). Frames are sequenced using numbers 1, 2, 3, 4, 5, 6, 1, ... Receiver keeps a pointer **SeqNumToAck.** An ACK is sent to represent that all frames with smaller sequence number are well received. If error happens, receiver holds ACK till the frame of **SeqNumToAck** is received. For example, firstly, frames 1, 2 and 3 are sent, and frame 1 is received (ACK1 is returned), frame 2 is lost and frame 3 is received. Then, **SeqNumToAck=2** and the receiver returns ACK1 again upon receiving frame 3. After timeout, the sender retransmits frame 2 and the receiver returns ACK3 to indicate frame 2 and 3 have correctly received.

Answer the following questions and (or) complete the timeline for partial credits.

- **During transmissions, ACK 3 and Frame 6 are lost at their first transmission attempt ←**
- Bandwidth is infinite, so transmit time of frames is instantaneous (Frames are transmitted and received instantly – though they still have a propagation time)
- The sender (when allowed) will transmit one frame every ¼ of a RTT – transmission time is instantaneous, but the sender can only perform one transmission every ¼ of a RTT
- A frame experiencing no delay is received ½ of a RTT after transmission starts (propagation delay) and processing time is zero.
- At a specific time, frames or ACKs are received and processed (instantly) before a transmission decision occurs
  - receiver receives a frame and then sends the ACK if required
  - sender receives an ACK and then determines if a timeout has occurred; it then determines the next frame to transmit (provided the SWS has not been exhausted)
- The timeout period is 1.5 Round Trip Times (1.5 RTT)
- Timing diagram is on the next page.

a) **(4 pts)** At what time the first timeout expires?

3 ½ RTT

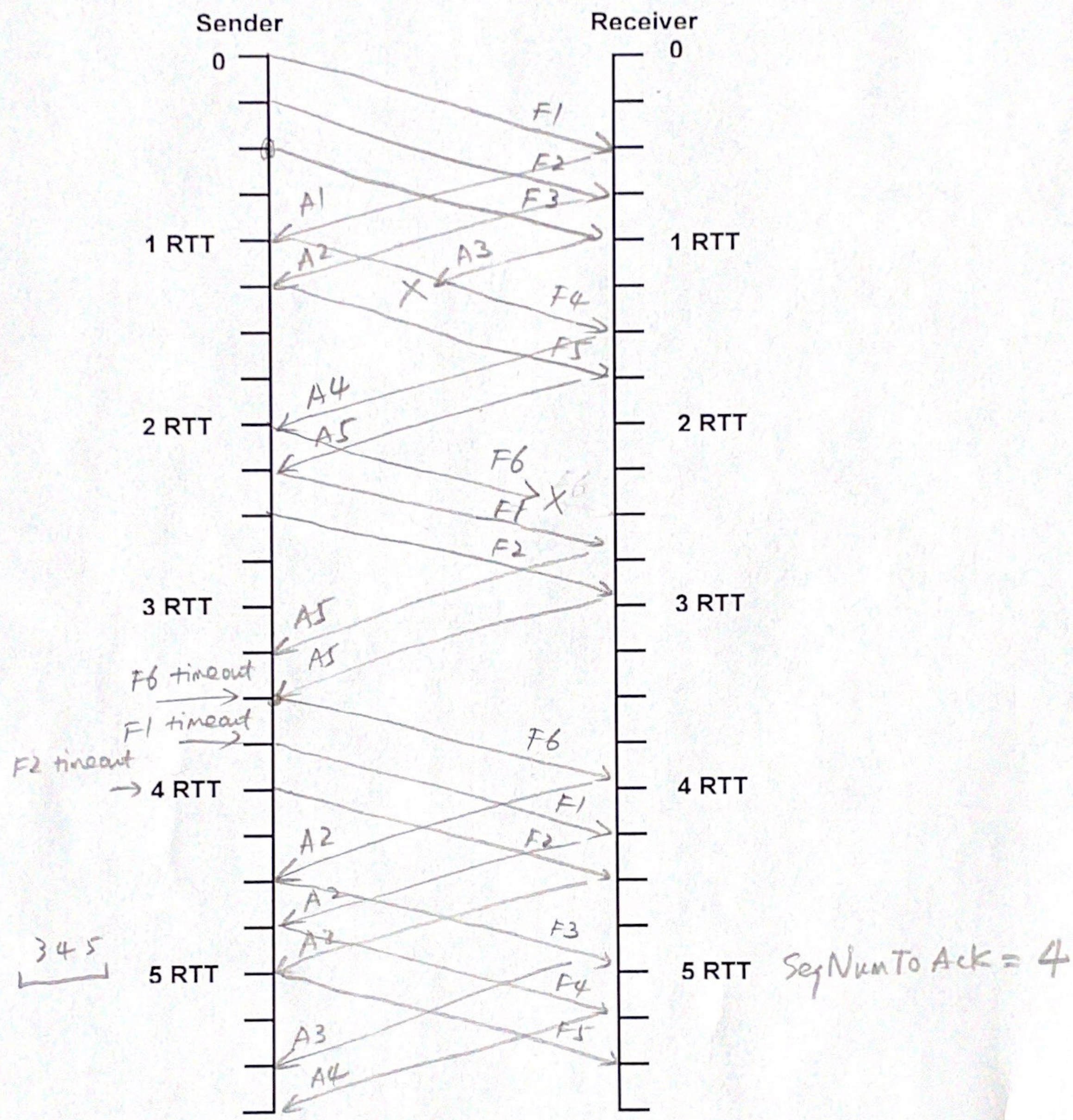
b) **(3 pts)** What are inside the sending window (the frame numbers) at time instant 5 RTT?

3, 4, 5

c) **(3 pts)** What is the **SeqNumToAck** at time instant 5 RTT?

4

Name ______________________________



7) (2 pts Bonus) What do you expect the course to change in the following semester to better facilitate your learning?

CPE 348 **Exam #2 (50 pts)** **November 04 2019**

Name Solution

1) (6 pts) You are designing a reliable byte stream transport layer protocol (not TCP) to operate over a 1×10^7 bps network and it is using a sliding window for flow control. The time for keeping the transmission pipe full is taken to be the RTT of the network which is 50ms. Each number in the advertised window or sequence number represents 2 Bytes of data.

a) **(2pts)** What is the minimum number of bits necessary for the Advertised Window field of your protocol header? Provide this minimum number as a whole number (round your answer up to the next whole value. i.e. if you calculate 20.67 bits necessary, then the answer is 21)

$$\text{delay} \times BW = (50 \times 10^{-3}) \times (1 \times 10^7) = 5 \times 10^5 \text{ bits}$$

$$2^X \cdot 2 \cdot 8 \geq 5 \times 10^5$$

$$2^X \geq 31250 \qquad X \geq 14.93 \qquad \text{Then } \boxed{X = 15} \text{ bits}$$

b) **(2pts)** How would you choose the Sequence number size in accordance with the Advertised Window size determined in a)?

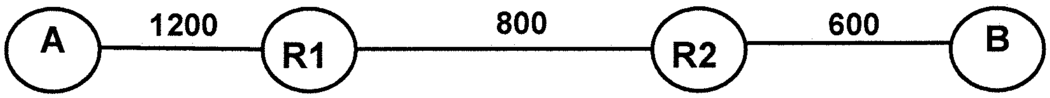
At least Twice as large as Advertised Window.

$\boxed{16 \text{ bits}}$

c) **(2pts)** Given this sequence number size, how long will it take for it to wrap around?

$$\frac{2^{16} \times 2 \times 8}{1 \times 10^7} = 0.1 \text{ s}$$

2) (4 pts) Fragmentation. Consider a packet that is transmitted from host A to host B in the following network. The maximum transmission unit (MTU) size in Bytes is shown on each link. **The header length for a packet sent on any link is 40 Bytes**. The MTU value includes this header value (i.e. if the MTU is 1200 Bytes, then 40 Bytes are header information and 1160 Bytes are data). **Note: routers strip off headers** from the received packets and then apply a new header to the data when the packet is forwarded.

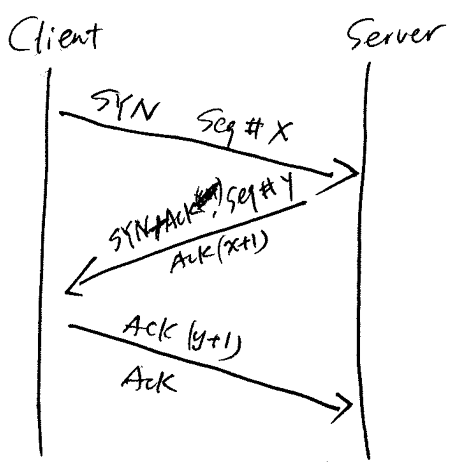


Host A is transmitting packets with a data size of 1560 Bytes (transmitted packet size is 1600 Bytes: 40 Bytes of header and 1560 Bytes of data). For a single data packet transmitted from A to B, determine for each link the number of packets that are sent and the amount of **data** each packet holds.

A → R1	R1 → R2	R2 → B
~~1600 (~~	800 (760)	600 (560)
1200 (1160)	440 (400)	240 (200)
440 (~~360~~) 400	440 (~~360~~) 400	440 (400)
		440 (400)

3) (12 pts) Answer the following short answer questions.

a) (3 pts) Draw the three-way handshake used to initiate a TCP connection.



b) (2 pts) How to overcome the count-to-infinity problem in the distance vector-based routing algorithm?

Split horizon

OR

Set an upper-bound.

c) (3 pts) For each of the following applications, determine whether you would use TCP or UDP.

i. File transfer
ii. Watching a real-time streamed video
iii. Canvas login

i> TCP
ii> UDP
iii> TCP

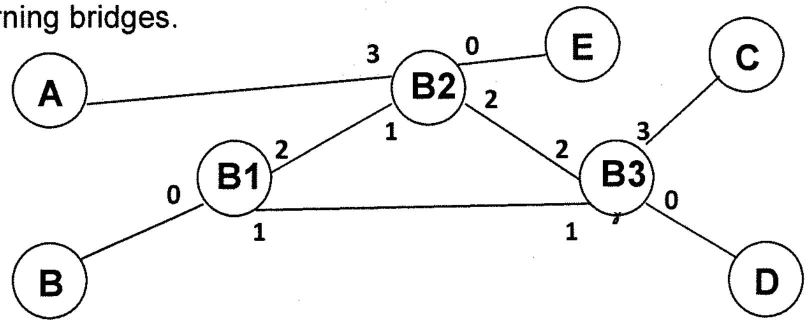
d) (4 pts) A router has the following (CIDR) entries in its routing table:

Address/mask Next hop
135.46.56.0/22 Interface 0
135.46.60.0/22 Interface 1
192.53.40.0/23 Router 1
default Router 2

For each of the following addresses, what will the router do if a packet with that address arrives?

i. 135.46.63.10 → Interface 1
ii. 135.46.52.2 → default Router 2

4) (8 pts) Consider the following network where A, B, C, D and E are nodes and B1, B2 and B3 are learning bridges.



Assume that the forwarding tables for the three bridges are all empty when the four **transmissions below are made in the order shown**. After the transmissions have been made, what are the contents of the forwarding tables for the three bridges? If a bridge learns the location of a node on multiple interfaces, use the interface with the lowest number. In the above network, B1 has interfaces 0, 1 and 2. If it learns about Node D on interfaces 1 and 2, then put 1 into the table.

Transmissions:
1) B transmits to A 2) C transmits to B 3) A transmits to C 4) E transmits to B

Fill in the table below for the three Bridges. If a destination node is unknown for a bridge, **write unknown** for the interface (in that case the bridge would forward a packet for that destination out on all outgoing interfaces). **The tables below are to be filled in with the interface number that the bridge would use to forward a packet to the destination specified.** The bridges learn this information as nodes make transmissions on the network.

Bridge B1		Bridge B2		Bridge 3	
Destination	**Interface**	**Destination**	**Interface**	**Destination**	**Interface**
A	2	A	3	A	2
B	0	B	1	B	1
C	1	C	unknown	C	3
D	unknown	D	unknown	D	unknown
E	2	E	0	E	unknown

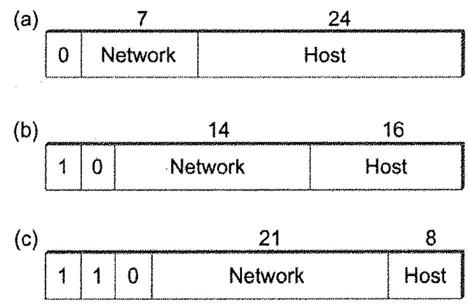
5) (10 pts) Link State: Perform the Link State Routing Algorithm (Dijkstra's or forward search algorithm) for node A by completing the confirmed and tentative list columns. The link state packets sent by the nodes in the network are shown below. **Link state packets are in the form of (destination, cost, next hop).** When finished, provide the routing table for node A.
For a cost tie in the tentative column, chose the lower letter node first [i.e. if tentative list contains (A,4,E) and (C,4,D) select (A,4,E) over (C,4,D)]

Node A	Node B	Node C	Node D	Node E	Node F
B,4,B	A,4,A	A,2,A	B,1,B	A,3,A	C,3,C
C,2,C	D,1,D	F,3,F	E,1,E	D,1,D	E,1,E
E,3,E				F,1,F	

Confirmed	Tentative
(A, 0, -)	(B,4,B), (C,2,C), (E,3,E)
(A, 0, -), (C,2,C)	(B,4,B), (E,3,E), (F,5,C)
(A, 0, -), (C,2,C) (E,3,E)	(B,4,B), (D,4,E), (F,4,E)
(A, 0, -), (C,2,C) (E,3,E), (B,4,B)	(D,4,E), (F,4,E)
(A, 0, -), (C,2,C) (E,3,E), (B,4,B), (D,4,E)	(F,4,E)
(A, 0, -), (C,2,C) (E,3,E), (B,4,B), (D,4,E), (F,4,E)	

Node A Routing Table		
Destination	**Cost**	**NextHop**
B	4	B
C	2	C
D	4	E
E	3	E
F	4	E

6) (10 pts) You are the CTO of a startup and have to get IP addresses to connect 1,200 computers to the Internet. You can get IP addresses from two providers, IPMart and EastSideIP. IPMart sells class A, class B and class C blocks, while EastSideIP sells CIDR blocks. As the IPv4 address space is scarce, you want to save money and get the smallest number of addresses possible. Assume all 0-255 can be used in one IP address. The class A-C format is shown below.



a) **(3pts)** If you get **one** block from IPMart, which class do you have to get? What is the problem with that?

Class B.

Efficiency: $\frac{1200}{2^{16}} = 1.83\%$ Low!

b) **(2pts)** If you are not limited to the number of blocks you can buy from IPMart, which class and how many of them do you get so that the address utilization efficiency is the highest?

Class C.

$x \cdot 2^8 \geq 1200$

$x \geq 4.68$ Then $\boxed{x=5}$

c) **(2pts)** If you get **one** block from EastSideIP, how many bits are there in the mask (e.g., is it a /8, /22)? How many addresses are wasted?

$$2^{32-x} \geq 1200$$

$$32-x \geq 11$$

$$x \leq 21 \quad \text{Then, } \boxed{\text{mask} = /21}$$

number of wasted address: $2^{11} - 1200 = \boxed{848}$

d) **(3pts)** Suppose you can get **two** blocks from EastSideIP, and they can be of different sizes. How many bits are there in the masks for each of the blocks? How many addresses are wasted now?

$1024 + 256$ or $2^{10} + 2^{8}$

Then, $\boxed{/22}$ and $\boxed{/24}$ blocks

80 wasted.

7) Bonus (3 pts) What would expect the course to change or to keep?

Name ______________________________ Class: 348

1) (4 pts) The original algorithm for computing a timeout value for a TCP connection is being used with the parameter $\alpha = .75$. If the current estimated RTT is 50 milliseconds and the sample RTT for the most recent transmission is 40 milliseconds.

a) (2 pts) What is the new estimated RTT?

$$NewRTT = \alpha \times EstRRT + (1-\alpha) \times Samp\,RTT$$
$$= 0.75 \times 50 + 0.25 \times 40$$
$$= \boxed{47.5\ ms}$$

b) (2 pts) What is the timeout time used for this new estimated RTT?

$$Timeout = 2 \times 47.5 = \boxed{95\ ms}$$

2) (8 pts) TCP is operating over a 1.28×10^9 bps link. This link has an RTT of 100 ms.

a) (3 pts) What is the minimum Advertised Window size (in bits) for this network setting?

$$Delay \times BW = 0.1 \times 1.28 \times 10^9 = 1.28 \times 10^8 \text{ bits} = 1.6 \times 10^7 \text{ Byte}$$
$$2^n > 1.6 \times 10^7, \quad n > 23.93, \quad \boxed{n = 24 \text{ bits}}$$

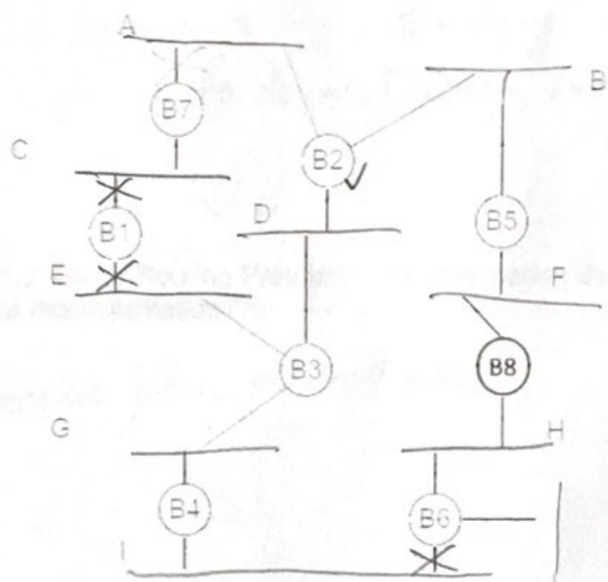
b) (3 pts) If TCP utilizes the full bandwidth (keeping the pipe full), how long will it take for the 32-bit sequence number to wrap around?

$$\frac{2^{32} \times 8}{1.28 \times 10^9} = \boxed{26.84\ s}$$

c) (2 pts) If each sequence number is modified to represent 4 bytes of data instead of 1 byte, how long will it take for the 32-bit sequence number to wrap around?

$$\frac{2^{32} \times 4 \times 8}{1.28 \times 10^9} = \boxed{107.36s}$$

3) (6 pts) Given the extended LANs connected by 8 bridges shown below, indicate the trimmed network by the spanning tree algorithm to avoid possible loops. Suppose **B2** is elected as the root. (You may just mark them on the graph.)



4) **(18 pts)** Answer the following short answer questions.

a) (3 pts) What makes the correct estimation of RTT in TCP difficult or even impossible?

distance is long. too many
intermediate devices (routers. switches)
congestion happens anywhere that causes
packets to drop.

c) (2 pts) For the Distance Vector Routing Protocol, what information does a node exchange and which nodes receive this information?

cost/distance infor. to its neighbours.

d) (2 pts) For the Link State Routing Protocol, what information does a node exchange and which nodes receive this information?

cost/distance infor. to all other nodes.

e) (3 pts) How to address the triangle routing problem in the mobile IP?

share care-of-address

f) (4 pts) Alice decides to start a small company. She asks her ISP, GoChargers, to give her enough addresses for 1000 hosts. GoChargers has the following available address range for Alice.

192.1.0.*
192.1.1.*
192.1.2.*
192.1.3.*
192.1.4.*

$\underline{4\times256} > 1000$

In order to save money, what should Alice claim under CIDR to get fewest number of address possible to cover her hosts? (please use address & prefix format, e.g., 128.2/16) (3pts)

And how many unused IP address will be incurred under this kind of purchase? (1pts)

192.1.0.0 — 192.1.3.231

0000,0000 0000 0011

$\boxed{192.1.0/22}$ $2^{10} - 1000 = \boxed{24}$

g) (4 pts) A router has the following (CIDR) entries in its routing table:

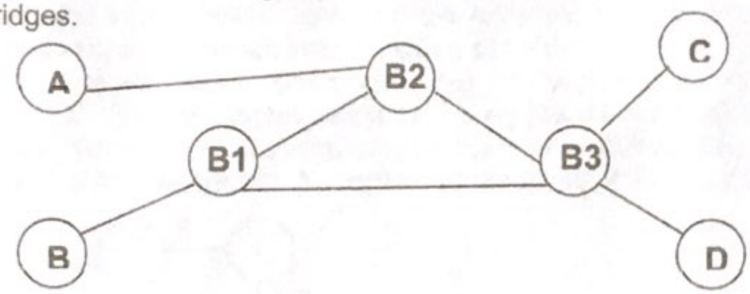
Address mask	Next hop
135.46.56.0/22	Interface 0
135.46.60.0/22	Interface 1
192.53.40.0/23	Router 1
default	Router 2

56: 001110|00
60: 000111|00
40: 0010100|0

For each of the following addresses, what will the router do if a packet with that address arrives?

i. 135.46.52.2 → 00110100 → No Match → $\boxed{\text{Router 2}}$
ii. 192.53.56.7 → 00111000 → No Match → $\boxed{\text{Router 2}}$

6) (6 pts) Consider the following network where A, B, C and D are nodes and B1, B2 and B3 are learning bridges.



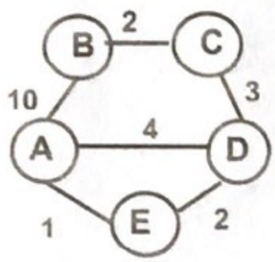
Assume that the forwarding tables for the three bridges are all empty when the three **transmissions below are made in the order shown**. When the transmissions have been made in the following consecutive order, identify if terminal A, B, C, D can overhear the ongoing transmission on its network interface.

Transmission: 1) D transmits to B 2) C transmits to D 3) A transmits to C

If a node can receive that packet for that transmission, please put **Y**; otherwise, put **N**. For the respective initiator (i.e., sender) of each transmission, **N/A** is already placed in the table.

Transmission 1)		Transmission 2)		Transmission 3)	
Node	**Hear Transmission?**	**Node**	**Hear Transmission?**	**Node**	**Hear Transmission?**
A	Y	A	N	A	N/A
B	Y	B	N	B	Y
C	Y	C	N/A	C	Y
D	N/A	D	Y	D	N

7) (8 pts) Distance Vector: The Distance Vector Routing Algorithm is to be performed starting with the initial table shown below. Entries in the table are in the **form of cost/next hop.** So the initial table indicates which nodes are neighbors of a particular node (i.e. neighbors that will provide updated information to a particular node). In this problem, node A receives vectors from nodes B, D and E. Fill in the tables below for the results after one exchange of vectors and after two exchanges. Give entries in the table in the **form of cost/next hop** as shown in the initial table. For each of the distance vector tables, complete the known routing table for node B.



Info at Node	Distance to reach node – initial table				
	A	B	C	D	E
A	---	10/B	∞	4/D	1/E
B	10/A	---	2/C	∞	∞
C	∞	2/B	---	3/D	∞
D	4/A	∞	3/C	---	2/E
E	1/A	∞	∞	2/D	---

Node B Routing Table		
Destination	Cost	NextHop
~~B~~ A	10	A
C	2	C
D	—	—
E	—	—

Info at Node	Distance to reach node – after 1 exchange				
	A	B	C	D	E
A	---	10/B	7/D	3/E	1/E
B	10/A	---	2/C	5/C	11/A
C	7/D	2/B	---	3/D	5/D
D	3/E	5/C	3/C	---	2/E
E	1/A	11/A	5/D	2/D	---

Node B Routing Table		
Destination	Cost	NextHop
~~B~~ A	10	A
C	2	C
D	5	C
E	11	A

Info at Node	Distance to reach node – after 2 exchanges				
	A	B	C	D	E
A	---	9/D	6/E	3/E	1/E
B	9/C	---	2/C	5/C	7/C
C	6/D	2/B	---	3/D	5/D
D	3/E	5/C	3/C	---	2/E
E	1/A	7/D	5/D	2/D	---

Node B Routing Table		
Destination	Cost	NextHop
~~B~~ A	9	C
C	2	C
D	5	C
E	7	C

CPE 348 **Exam #2 (50+3 pts)** **November 4 2020**

Name ________________________________

1) (6 pts) TCP is operating over a 1.28×10^9 bits per second link.

a) (3 pts) If TCP utilizes the full bandwidth continuously, how long will it take for the 32 bit sequence number to wrap around?

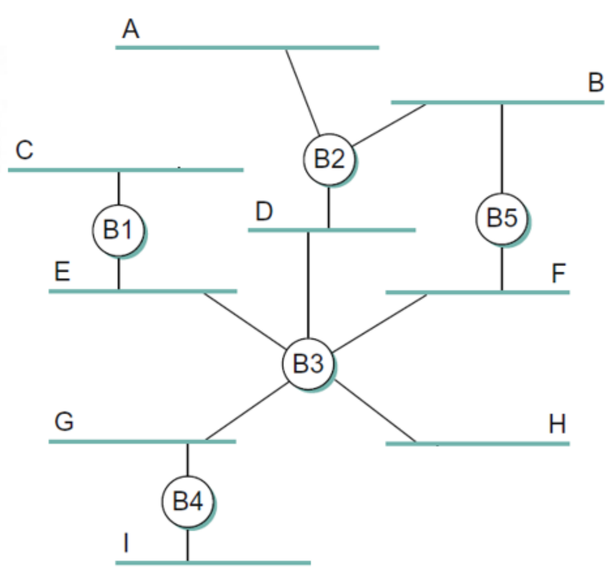
$$t = \frac{2^{32} \times 8}{1.28 \times 10^9} = \boxed{26.84 \text{ sec}}$$

b) (3 pts) If each sequence number is modified to represent 2^n bytes of data instead of 1 byte, what is the smallest value of n such that wraparound does not occur before 120 seconds?

$$t = \frac{2^{32} \times 8 \times 2^n}{1.28 \times 10^9} > 120$$

2) (3 pts) Given the extended LANs connected by 5 bridges shown below, indicate the trimmed network by the spanning tree algorithm to avoid possible loops. (e.g., answer should in this format: B4 → I, indicating that the connection between B4 and LAN I is trimmed.)

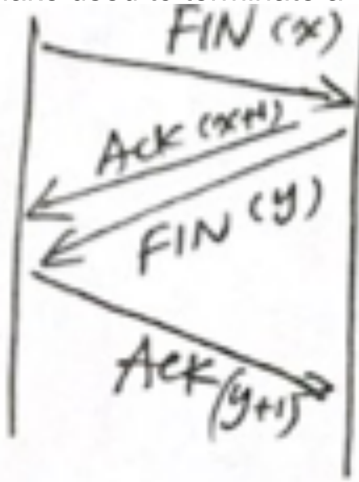
B5 → B is trimmed.
B5 → F



2) (13 pts) Answer the following short answer questions.

a) (3 pts) Draw the four-way handshake used to terminate a TCP connection.

a)



b) (2 pts) What is the goal that the boarder gateway protocol (BGP) promises to achieve?

b) BGP is to find a reachable path to an autonomous system (AS).

c) (2 pts) In what kind of situation would you choose the PIM – Sparse Mode rather than the PIM – Dense Mode?

c) Sparse Mode: when there are not many subscribers/receivers.

d) (2 pts) In which application do you prefer UDP to TCP?

c) sparse mode

d) UDP: streaming services that do not require high reliability.

e) (2 pts) what is the potential problem using distance-vector based routing algorithm? List a couple of solutions to addressing this problem.

e) count-to-infinity problem.
split horizon & set an upper bound for cost.

f) (2 pts) Briefly explain how VPN (virtual private network) works.

f) edge router puts an additional header and enables a IP tunnel to transmit packets to the destination edge router.

4) (8 pts) A router has the following (CIDR) entries in its routing table

Address/mask	Next Hop
160.80.0.0/18	Interface 0
160.80.64.0/18	Interface 1
160.80.128.0/19	Interface 2
160.80.160.0/19	Router 1
160.80.208.0/20	Router 2
Default	Router 3

What is the next hop that the router selects when it receives IP packets with the addresses shown below. **Show all of your work or explain how you determined the next hop.**

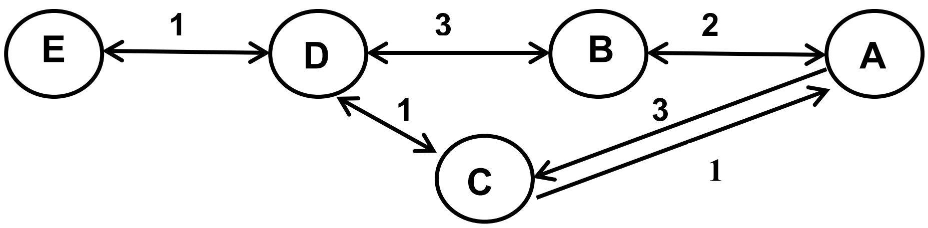
a) **160.80.176.5** **Next Hop** Router 1

b) **160.80.232.8** **Next Hop** Router 3 / Default

c) **160.80.44.25** **Next Hop** Interface 0

d) **160.80.156.144** **Next Hop** Interface 2

5) (8 pts) The Distance Vector Routing Algorithm is to be performed on the network shown. Note that cost is measured in **delay** and link **may not be symmetric**. Fill in the first three tables. For each of the distance vector tables, complete the known routing table for node C. (Hint: cost can be simply added up.)



Info at Node	Cost to reach node – initial table				
	A	B	C	D	E
A	---	2	3	∞	∞
B	2	---	∞	3	∞
C	1	∞	---	1	∞
D	∞	3	1	---	1
E	∞	∞	∞	1	---

Node C Routing Table		
Destination	Cost	NextHop
A	1	A
B	–	–
D	1	D
E	–	–

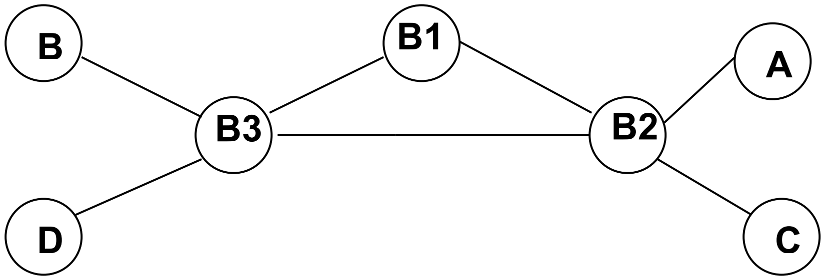
Info at Node	Cost to reach node – after 1 exchange				
	A	B	C	D	E
A	---	2	3	4	∞
B	2	---	4	3	4
C	1	3	---	1	2
D	2	3	1	---	1
E	∞	4	2	1	---

Node C Routing Table		
Destination	Cost	NextHop
A	1	A
B	3	A
D	1	D
E	2	D

Info at Node	Cost to reach node – after 2 exchanges				
	A	B	C	D	E
A	---	2	3	4	5
B	2	---	4	3	4
C	1	3	---	1	2
D	2	3	1	---	1
E	3	4	2	1	---

Node C Routing Table		
Destination	Cost	NextHop
A	1	A
B	3	A
D	1	D
E	2	D

6) (12 pts) Consider the following network where A, B, C and D are nodes and B1, B2 and B3 are learning bridges.



Assume that the forwarding tables for the three bridges are all empty when the **four transmissions below are made in the order indicated.** After the transmissions have been made, what are the contents of the forwarding tables for the three bridges? Indicate a port(interface) on a bridge by the node or bridge that it is connected to. For example, B3 has a B interface, a D interface, a B2 interface and a B1 interface.

Transmissions:
#1) A transmits to C #2) B transmits to D #3) C transmits to A #4) D transmits to C

Fill in the table below for the three Bridges. If a destination node is unknown for a bridge, write **unknown** for the interface (in that case the bridge would forward a packet out on all outgoing interfaces).

If a bridge learns about a node from more than one bridge, give the bridge that first sent the packet to the bridge. For example, B3 forwards a packet being transmitted from D to an unknown destination. B1 receives the packet from B3 and B2. Since B3 sends the packet to B1 (1 hop away) before B2 (packet travels 2 hops – B3 to B2 then B2 to B1), B1 will list B3 as the interface for contacting D.

Bridge B1		Bridge B2		Bridge 3	
Destination	**Interface**	**Destination**	**Interface**	**Destination**	**Interface**
A	B2	**A**	A	**A**	B2
B	B3	**B**	B3	**B**	B
C	Unknown	**C**	C	**C**	Unknown
D	B3	**D**	B3	**D**	D

7) Bonus (3 pts) How do you like this course so far? Is there any change you recommend?

Name Solution **Class: 348**

1) **(5 pts) You are designing a** reliable byte stream transport layer protocol (not TCP) to operate over a $1x10^7$ bps network and it is using a sliding window for flow control. The time for keeping the transmission pipe full is taken to be the RTT of the network which is 50ms. Each number in the advertised window or sequence number represents 2 Bytes of data.

a) **(3 pts)** What is the minimum number of bits necessary for the Advertised Window field of your protocol header? Provide this minimum number as a whole number (round your answer up to the next whole value. i.e. if you calculate 20.67 bits necessary, then the answer is 21)

delay × BW

$= 50 \times 10^{-3} \times 1 \times 10^7$

$= 5 \times 10^5$ bits

$2^n \times 2 \times 8 \geq 5 \times 10^5$

$\boxed{n = 15}$

b) **(2 pts)** How would you choose the Sequence number size in accordance with the Advertised Window size determined in a)?

SeqNum $\geq 2 \times$ AW

$\boxed{= 16 \text{ bits}}$

2) (13 pts) Answer the following short answer questions.

a) **(2 pts)** What is the difference between flow control and congestion control in the TCP protocol?

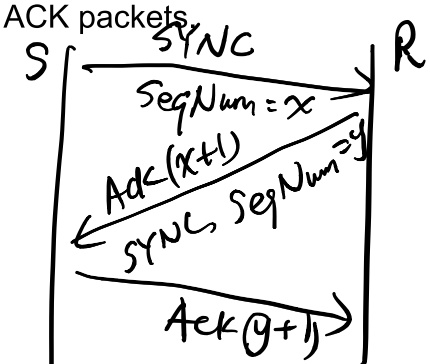
flow control: avoid receiver's buffer overflow

congestion control: avoid network devices' buffer overflow

b) **(2 pts)** Why does the boarder gateway protocol (BGP) only find a possible, but not optimal, path to the destination (or an autonomous system)?

different ASs have different cost metrics

c) **(3 pts)** Draw the three-way handshake used to establish a TCP connection. Show all SYN and ACK packets. Also show all sequence and acknowledgement numbers (as a variable) associated with the SYN and ACK packets.



d) **(2 pts)** What makes the estimation of RTT in TCP difficult?

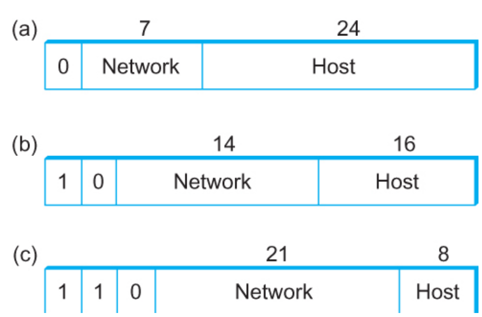
There are many intermediate devices for an end-end connection.

e) **(4 pts)** If you want to connect 1,200 devices to the Internet and you are only allowed to get **one** IP class block, which IP class will you get for the highest IP usage efficiency? What is the IP usage efficiency in this situation? Class A-C IP address formats are given below.

$2^{16} > 1200$, so class B.

eff: $\frac{1200}{2^{16}}$

$\boxed{= 1.83\%}$



3) (8 pts) A TCP packet has been encapsulated in an IP packet (IP header, TCP header, Data). Answer the questions about the following IP packet: (values shown are hexadecimal values, so each individual character represents 4 bits, and each grouping of 4 characters is 16 bits. All of the TCP data is not completely shown

```
4500 0047 0ff4 4000 7406 8682 c6aa cd22
92a5 643f fbd9 0050 bd51 a0f4 0000 0f21
7002 2238 1c80 0000 0204 05b4 0101 0402 …
```

A) What is the total length of this IP packet? Give your answer in the total number of bytes as a decimal number (not hex). **Hint: This information is contained in the "Length" field of the IP header**.

$\boxed{71 \text{ bytes}}$

B) Given the above finding, what is the percentage of effective (or meaningful) data in the IP packet? **Hint: it is the ratio between data payload size and the overall IP packet size. IP and TCP headers are not meaningful data.**

$$\text{eff}: \frac{71 - 12 \times 4}{71} = \boxed{32.4\%}$$

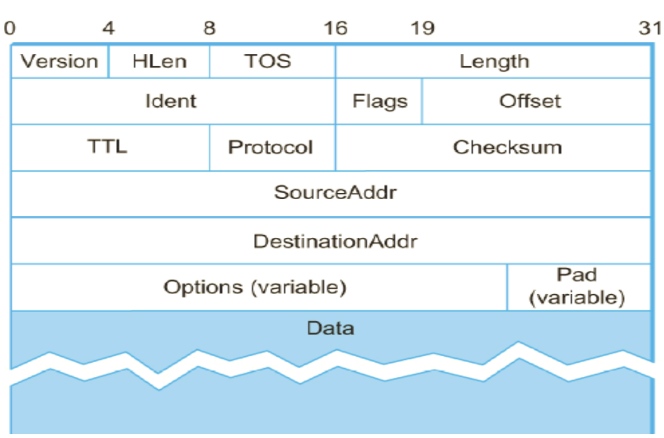
C) What is the destination IP address? Give this as decimal numbers in the form **#.#.#.#**

$\boxed{146.165.100.63}$

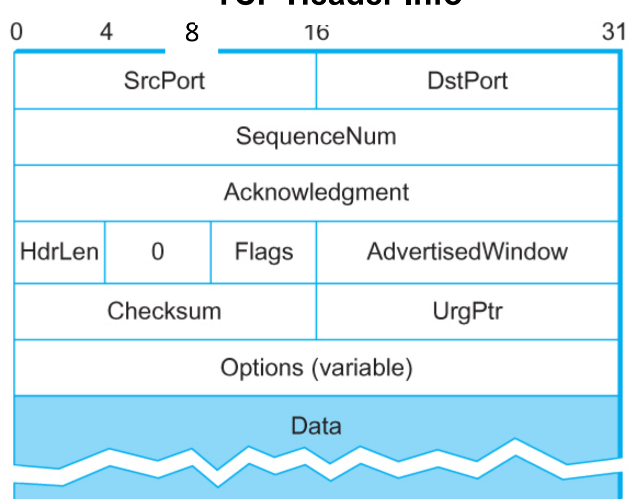
D) What is the destination port number? give this as a decimal number (not hex).

$\boxed{41204}$

IP Header Info



TCP Header Info



4) (8 pts) A router has the following (CIDR) entries in its routing table

Address/mask	Next Hop
156.87.64.0/22	Interface 0
156.87.72.0/22	Interface 1
156.87.56.0/21	Router 1
156.87.48.0/20	Router 2
Default	Router 3

What is the next hop that the router selects when it receives IP packets with the addresses shown below? **Show your work for full credits.**

a) 156.87.52.10

a) Next Hop R2

b) 156.87.85.14

b) Next Hop R3

c) 156.87.57.2

c) Next Hop R1

d) 156.87.69.7

d) Next Hop R3

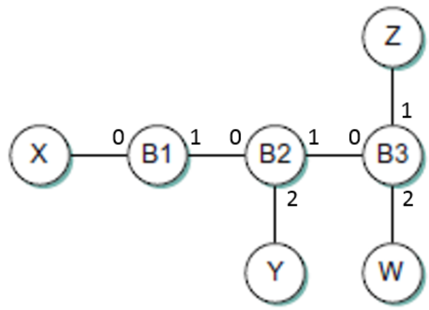
5) (8 pts) Link State: Perform the Link State Routing Algorithm for node A by completing the confirmed and tentative list columns. Note that costs are additive (e.g., latency, number of hops). The link state packets sent by the nodes in the network are shown below. **Link state packets are in the form of (destination, cost, next hop).** When finished, provide the routing table for node A.
For a cost tie in the tentative column, chose the lower letter node first [i.e. if tentative list contains (A,4,E) and (C,4,D) select (A,4,E) over (C,4,D)]

Node A	Node B	Node C	Node D	Node E	Node F
B,3,B	A,3,A	A,4,A	A,2,A	B,2,B	B,5,B
C,4,C	C,2,C	B,2,B	E,4,E	C,3,C	E,1,E
D,2,D	E,2,E	E,3,E		D,4,D	
	F,5,F			F,1,F	

Confirmed	**Tentative**
(A, 0, -)	(B,3,B) (C,4,C) (D,2,D)
(A, 0, -), (D,2,D)	(B,3,B) (C,4,C) (E,6,D)
(A, 0, -), (D,2,D), (B,3,B)	(C,4,C) (E,5,B) (F,8,B)
(A, 0, -), (D,2,D), (B,3,B) (C,4,C)	(E,5,B) (F,8,B)
(A, 0, -), (D,2,D) (B,3,B) (C,4,C), (E,5,B)	(F,6,B)
(A, 0, -), (D,2,D), (B,3,B) (C,4,C), (E,5,B), (F,6,B)	

Node A Routing Table		
Destination	**Cost**	**NextHop**
B	3	B
C	4	C
D	2	D
E	5	B
F	6	B

6) (8 pts) Consider the following network where W, X, Y and Z are nodes and B1, B2 and B3 are learning bridges. (Designed from HW3 Q2)



Assume that the forwarding tables for the three bridges are all empty when the three **transmissions below are made in the order shown**. After the transmissions have been made, what are the contents of the forwarding tables for the three bridges? In the above network, B1 has interfaces 0 and 1, B2 has interfaces 0, 1 and 2, and B3 has interfaces 0,1 and 2.

Transmissions:
1) X transmits to W 2) Z transmits to X 3) Y transmits to X

Fill in the table below for the three Bridges. If a destination node is unknown for a bridge, **write unknown** for the interface (in that case the bridge would forward a packet for that destination out on all outgoing interfaces). **The tables below are to be filled in with the interface number that the bridge would use to forward a packet to the destination specified.** The bridges learn this information as nodes make transmissions on the network.

Bridge B1		Bridge B2		Bridge B3	
Destination	**Interface**	**Destination**	**Interface**	**Destination**	**Interface**
W	unknown	W	unknown	W	unknown
X	0	X	0	X	0
Y	1	Y	2	Y	unknown
Z	1	Z	1	Z	1

7) Bonus (3 pts) What do you expect the course to change or to keep in the remaining semester?

CPE 348 Final Exam (100 pts) December 06, 2019

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.

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

b) **(2 pts)** Suppose Mission Control on Earth wishes to download a 25MB (1MB = 10^6 Bytes) 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?

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

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

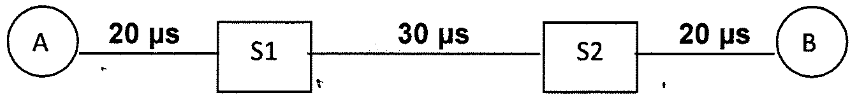
c) **(2 pts)** Using the RTT as the delay, calculate the delay*bandwidth product for the link.

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

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.

$$T = (20+30+20) + \left(\frac{2000}{10\times10^6}\times10^6\right)\times 3$$

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

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.

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

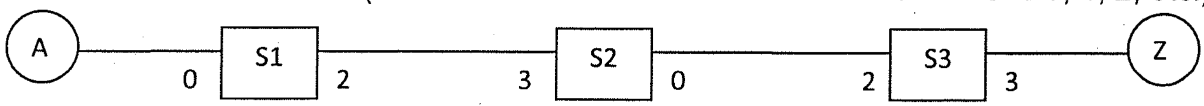
$$\text{delay} = 200 + \underset{20+20}{40} + \underset{20+30}{50} + \underset{20}{20}$$

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

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

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

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)

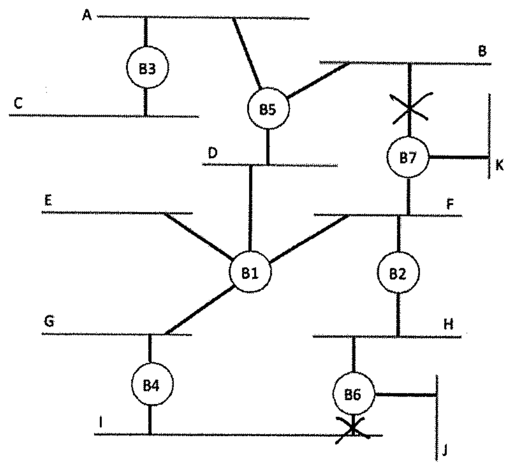
Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	3	9 ✓	0	1
Z to A	0	4 ✓	3	6

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.

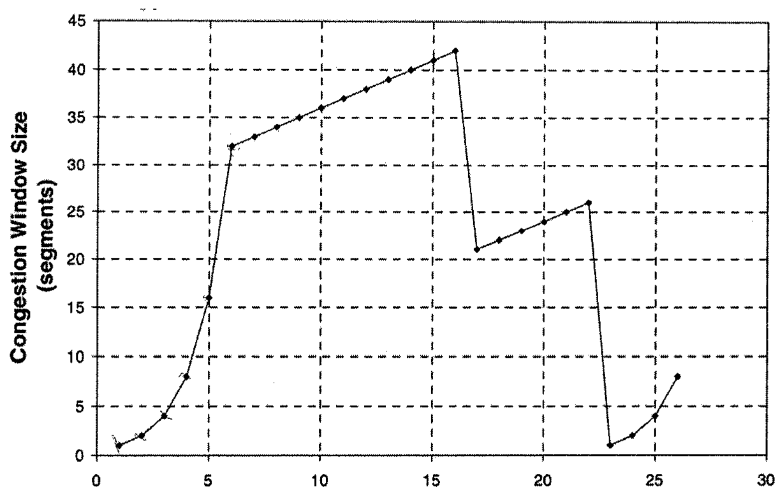
- DEC-bit
- RED

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, 22]

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

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

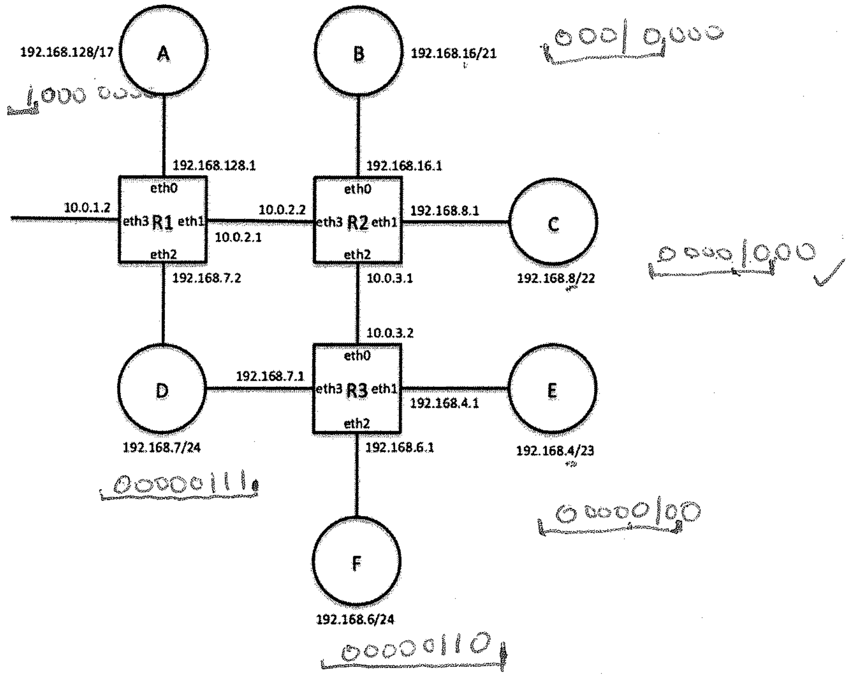
e) **(3 pts)** Repeat Part d) if A uses TCP's Slow Start with AIMD algorithm, given the **CT** in Part c).

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?

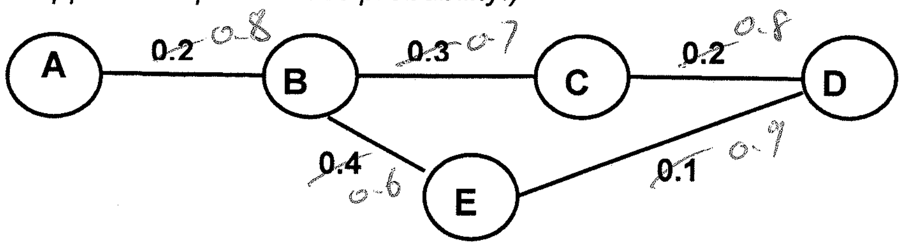
$2^{32-17} = 2^{15} = 32,768$

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
~~192~~ 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)

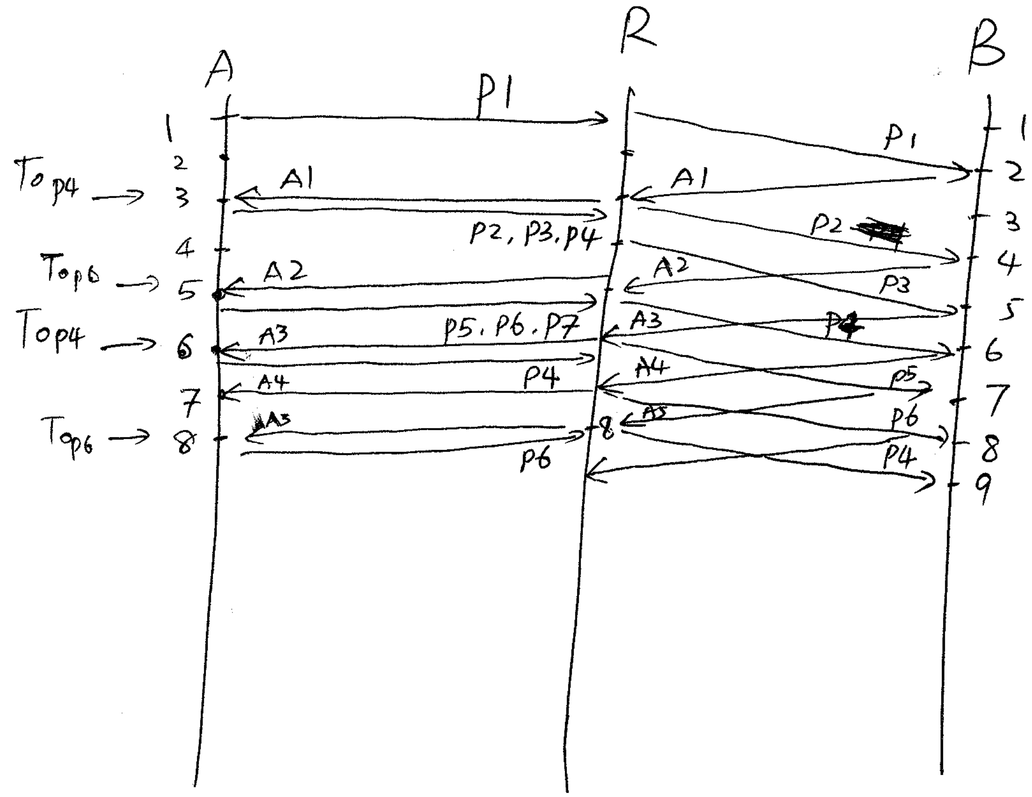
cw = 7

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)**



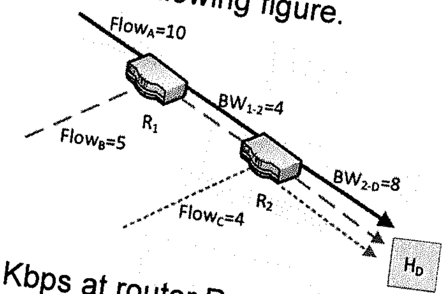
CW α

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?

<u>Note:</u> <u>Show steps (including modeling and solution) to get full/partial credits.</u>

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

Name ________________________________ **Class: CPE348-01**

1) (8 pts) A message **M = 1001011101** is to be transmitted from node A to node B using CRC coding. The CRC generator polynomial is $G(x) = x^4 + x^2 + 1$.

a) (4pts) What is the transmitted code word? Perform the polynomial long division to find this result

a)

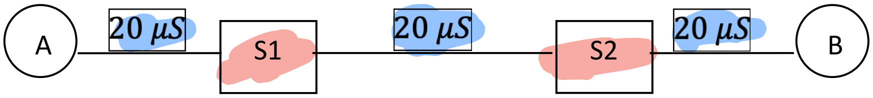
1011000001
10101 | 10010111010000
10101
11111
10101
10101
10101
10000
10101
$\boxed{0101}$ → CRC

b) (4pts) Assume node B receives the following code word: **11100100101**. By using the CRC, does node B detect any bit errors introduced by the link? Check using the generator polynomial above.

$\boxed{10101}$ → CRC

1101111
b) 10101 | 11100100101
10101
10011
10101
11000
10101
11011
10101
11100
10101
10011
10101
$\boxed{110}$ → remainder, Error

2) (14 pts) Consider the hypothetical **20Mbps (20,000,000 bps) network** shown



The propagation delay between any two hosts (A, B or a switch) is 20us. The frame to transmit from node A to node B consists of **4,000 bits**. Each switch can start retransmission of a frame 10us **after receiving the last bit** of a frame.

a) (4pts) What is the time necessary to transmit the data as a single frame from A to B (time from the first bit of the frame transmitted by node A until last bit of the frame is received at node B)?

$t = t_{prop}\ (3) + t_{delay}\ (2) + t_{tx}\ (3)$

$t_{tx} = \text{Size}/\text{BW} =$

$4000/20\text{Mbps} = .2\text{ms}$

$60 + 20 + .0006\text{s}$

$= 80 + .0006 = 680\mu s$

b) (3pts) What is the effective data throughput rate for this one frame from A to B (number of bits sent divided by time to send the bits) in bits per second(bps) for the network as analyzed in part a?

$4000/680\mu s = 5882352.9$

c) (4pts) If the original frame is split into 2 frames so that each frame to be transmitted consists of **2000 bits**, what is the time necessary to transmit both frames from A to B? Node A will transmit the second frame 5us after finishing the transmission of the first frame.

$t_{tx} = 2000/20{,}000{,}000 = 0.1\text{ms}$

$t = t_{p1} + t_{p2} = (t_{prop} \cdot 3) + (t_{delay} \times 2) + (t_{tx} \times 3)$

$t = 20 \times 3 + 10 \times 2 + 2000/20\text{Mbps} \times 3 + 2000/20\text{Mbps} + 5\mu s$

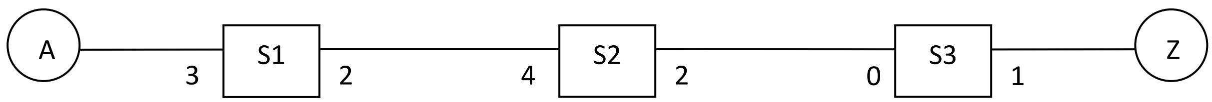
$t = 485\mu s$

d) (3pts) For the two frames sent from A to B in part c, what is the effective data throughput rate in bits per second(bps) for the network as analyzed in part c?

$dr = \frac{4000}{485\mu s} = 8247422\text{Mbps}$

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.

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	**2**	**1**
S1	**3**	**2**
S2	**2**	**8**
S2	**4**	**5**
S3	**0**	**2**
S3	**1**	**3**

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 4 for Host A and a next VCI of 7 for Host Z**

Virtual Circuit Table for Switch 1 (S1)

Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	3	2	2	5
Z to A	2	1	3	4

Virtual Circuit Table for Switch 2 (S2)

Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	4	5	2	2
Z to A	2	8	4	1

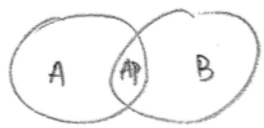
Virtual Circuit Table for Switch 3 (S3)

Setup message	Incoming Interface	Incoming VCI	Outgoing Interface	Outgoing VCI
A to Z	0	2	1	7
Z to A	1	3	0	8

4) (16 pts) Answer the following short answer questions.

a) (4pts) Explain the hidden node problem in a wireless network? How to overcome it?

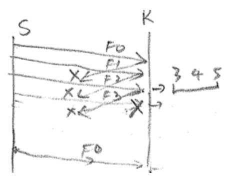
a)



A & B are out of another's range.
RTS / CTS to solve it.

b) (3pts) Suppose a sliding window algorithm is implemented using a SWS=4 and a RWS = 3, will 6 sequence numbers (i.e. 0,1,2,3,4,5) be sufficient to correctly distinguish all packets that are received? Explain your answer. (for example, an old sequence number of 0 is not mistaken for a new sequence number of 0)

c)



Yes. there is no problem!

Check actual Solution.

c) (3pts) What is the difference between flow control and congestion control?

d) flow control: avoid receiver's buffer overflow

congestion control: avoid router's buffer overflow

d) (3pts) What are the 5-tupe elements in any cryptography system?

f) < M. C. Enc, Dec, key >

e) (3pts) What is the protocol that handles inter-domain (that is between autonomous systems) routing?

stems) routing?

BGP

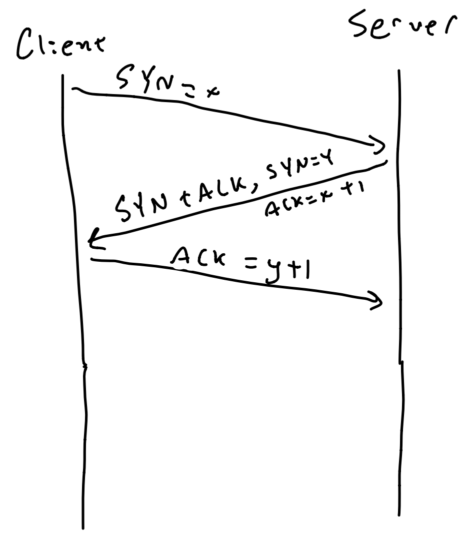
Inter ->

Intra ->

Cost metrics may not be the same

5) (12 pts) Answer the following questions on Transport-Layer basics.

a) **(**6pts) Draw the three-way handshake used to establish a TCP connection. Show all SYN and ACK packets. Also show all sequence and acknowledgement numbers (as a variable) associated with the SYN and ACK packets.



b) (6pts) **You are designing a** reliable byte stream transport layer protocol (not TCP) to operate over a 100×10^6 bps network and it is using a sliding window for flow control. The maximum segment lifetime for the network is 15 seconds. For this protocol, each sequence number represents 64 bytes of data. Spring 20 #2

What is the minimum number of bits necessary for the Sequence Number field of your protocol header? Provide this minimum number as a whole number (round up your answer to the next whole number. i.e. if you calculate 25.67 bits necessary, then the answer is 26)

BW = 100 Mbps

TTL = 15 s

64 bytes

BW x delay = 100 x 15 = 1500 Mbps

-> To 64 bytes:

1500 mbps / 8 = x / 64

x / 64 = 29 29 688

log(2) 29 29 688 = 21.48

= 22 bits

6) (8 pts) A router has the following (CIDR) entries in its routing table

Prefix : longest match to determine where we go.

Address/mask	Next Hop	
160.80.64.0/18	Interface 0	0 1 \] 0 0 0 0 0 0
160.80.128.0/18	Interface 1	1 0 \] 0 0 0 0 0 0
160.80.192.0/18	Interface 2	1 1 \] 0 0 0 0 0 0
160.80.32.0/19	Router 1	0 0 1 \] 0 0 0 0 0
160.80.160.0/19	Router 2	1 0 1 \] 0 0 0 0 0
Default	Router 3	

What is the next hop that the router selects when it receives IP packets with the addresses shown below? **Show all of your work or explain how you determined the next hop.**

a) **160.80.172.25** **Next Hop** router 2

172

1010 1100

☆ longest match

d) **160.80.68.178** **Next Hop** Interface 0.

0100 0100

7) (15 pts) Link State: The Link State Routing Algorithm (or Dijkstra's algorithm) is to be **performed for node C**. The link state packets sent by the nodes in the network are shown below. Cost is measured in **throughput!** When finished, provide the routing table for node C. Link state packets are in the form of **(destination, cost, next hop). Use the link state packet form for completing the information below. For a cost tie in the tentative column, chose the lower letter node first. (Hint: shortest path is the one that gives largest throughput.)**

Node A	Node B	Node C	Node D	Node E	Node F
B,5,B	A,5,A	B,2,B	C,2,C	D,4,D	B,3,B
	C,2,C	D,2,D	E,4,E	F,2,F	C,1,C
	F,3,F	F,1,F			E,2,E

Confirmed	**Tentative**
(C, 0, -)	(B 2 B) (D 2 D) (F 1 F)
(C, 0, -), (B 2 B)	(D 2 D) (F 2 B) (A 2 B)
(C, 0, -), (B 2 B) (A 2 B)	(D 2 D) (F 2 B)
(C, 0, -), (B 2 B) (A 2 B) (D 2 D)	(F 2 B) (E 2 D)
(C, 0, -), (B 2 B (A 2 B) D 2 D) (E 2 D)	(F 2 B)
(C, 0, -), (B 2 B) (A 2 B) (D 2 D) (E 2 D) (F 2 B)	

Node C Routing Table		
Destination	**Cost**	**NextHop**
A		
B		
D		
E		
F		

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). Packet is labeled by unique sequence numbers 0, 1, 2, 3, …, infinity.

- Packets are <u>instantly transmitted from A to the router or from the router to A</u>.
- It takes 1 second for a packet (data and ACK) to cross the link R to B or B to R. There is no propagation delay for the link A to R or R to A.
- 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.
- At any time instant, host A processes information in the following order: first process any ACKs, then process any timeouts and then send more packets if possible**. The whole processing takes 1 second.**
- ACK does **not** occupy the buffer space of the router.
- The router has enough **buffer space to hold two data packets including the one it is transmitting (so, total of only 2 data packets at the router).** When congestion occurs, the packets of higher sequence numbers will be dropped first.
- Host A is using an algorithm that **increments its congestion window by 1 packet <u>for each ACK received</u>**. Host A sets its sending window size equal to the congestion window size.
- The initial congestion window is 1 packet.
- **The timeout time is 4 seconds**. When a timeout occurs, the congestion window is reset to 1.

If the first packet (P0) sent by Host A occurs at time t=1 second,

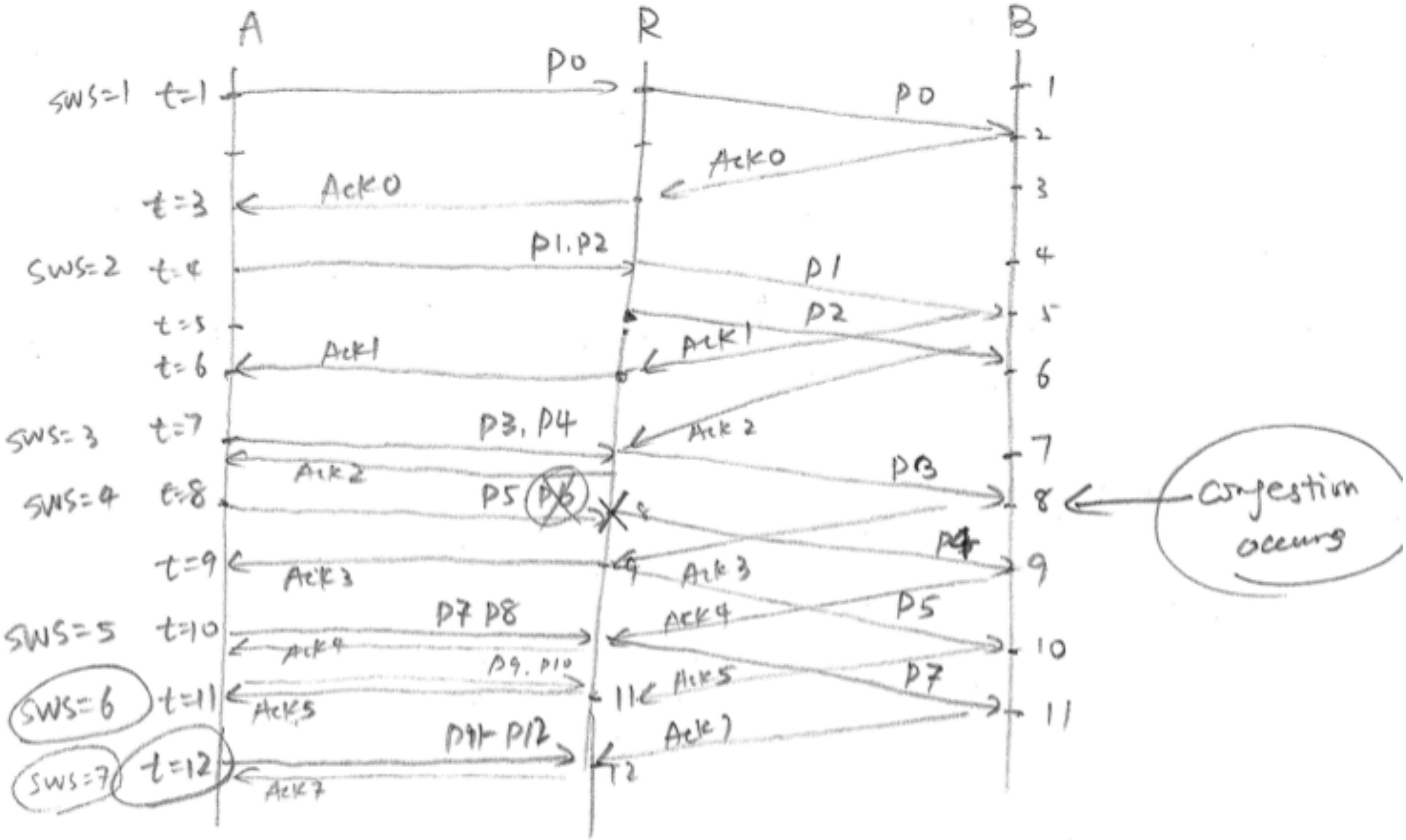
a) (5pts) at what time does a timeout of a packet first occur? What is that packet?

b) (5pts) at what time does the congestion first occur?

c) (5pts) 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 firstly incremented then dropped to 1.)

<u>* Draw transmission diagram for partial credits</u> (Hint: You should get all the answers by t=13.)

Extra Space for 8)



a) t=12 sec b) t=8 sec c) SWS=7.

P6

Name ________________________________ **Class: CPE348-01**

1) (10 pts) A message M = 101011 is transmitted from node A to node B using the CRC code. The CRC generator polynomial is $G(x) = x^3 + x^2 + 1$

a) (5 pts) What is the transmitted code word – perform the polynomial long division to find this result

a)

```
          110110
1101 ) 101011000
       1101
        1111
        1101
         1010
         1101
          1100
          1101
           110
```

So, transmitted words are:

$\boxed{101011\,110}$

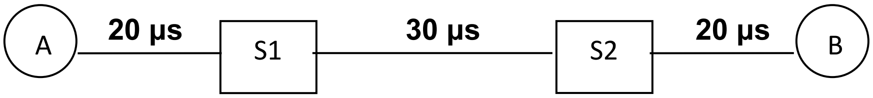
b) (5 pts) Node A transmits a code word to node B. The link used for transmission introduces bit errors into the original code word, and node B receives the code word: **111000110.** If the CRC generator polynomial being used is the one described above, does node B detect the bit errors introduced by the link? Explain your answer.

b)

```
          101001
1101 ) 111000110
       1101
         1100
         1101
           1110
           1101
             11
```

There is a remainder, so error can be detected.

2) (10 pts) Consider the **10 Mbps ($10x10^6$ 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**. Each switch is a store and forward switch that starts retransmission of a packet $10\,\mu s$ after receiving the last bit of a packet.

a) **(5 pts)** The data is split by host A into 5 packets so that each packet to be transmitted consists of **400 bits** of data. Node A will transmit the packets one right after the other. Switches can buffer packets if necessary. 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)?

2:

a) For a single pkt,

$$t_0 = \frac{400}{10\times10^6} + 20\times10^{-6} + 10\times10^{-6} + \cancel{30\times10^{-6}} + \frac{400}{10\times10^6} + 30\times10^{-6} + 10\times10^{-6} + \frac{400}{10\times10^6} + 20\times10^{-6} = 210\,\mu s$$

For a total of 5 pkts:

$$t_{tot} = t_0 + 4\times\frac{400}{10\times10^6} = 370\,\mu s$$

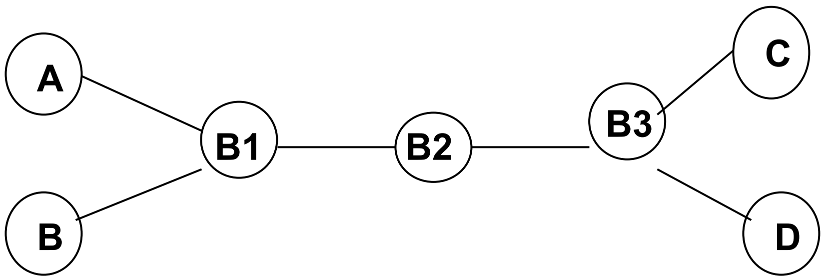
b) **(2 pts)** What is the effective data throughput rate in bits per second (bps) for the method analyzed in part a?

$$r = \frac{2000}{370\times10^{-6}} = 5.4\times10^6\ bps$$

c) **(3 pts)** Suppose switch S1 and S2 have finite buffer and they employ the random early drop (RED) mechanism for congestion avoidance. S1 has a larger buffer size so it applies **p1=0.05** to drop any received packet whereas S2 has a smaller buffer size so **p2=0.1** is used to drop any received packet. What are the chances that B can receive all 5 packets intact?

$$P = (0.95\times0.9)^5 = 0.457.$$

3) (12 pts) Consider the following network where A, B, C and D are nodes and B1, B2 and B3 are learning bridges.



Assume that the forwarding tables for the three bridges are all empty before the four transmissions below are made. After each transmission is made in the order indicated, determine whether a node can overhear that transmission. For example, when A transmits to B, A will not hear the transmission because it is the transmitter, while B will overhear the transmission because it is the destination. Therefore, we will type in **N** for A and **Y** for B after transmission (1). **Note that you still need to figure out whether C and D can overhear the transmission (1).**

Transmission:
(1) A transmits to B (2) C transmits to B (3) D transmits to C (4) B transmits to D

Fill in the table below. If a node can overhear the transmission, please type in **Y**. Otherwise, type in **N**.

Node	Transmissions			
	(1)	(2)	(3)	(4)
A	**N**	Y	N	Y
B	**Y**	Y	N	N
C	Y	N	Y	N
D	Y	Y	N	Y

4) (12 pts) Answer the following short answer questions.

a) (2pts) Please explain what problem(s) of NRZI encoding scheme can be addressed by the Manchester encoding.

Consecutive 0's
Baseline wander & clock recovery

b) (2pts) At least how many errored bits can 2D parity code guarantee to detect?

3-Bit

c) (2pts) Why CSMA/CD cannot be used in the wireless environment?

Hidden node and exposed node

d) (2pts) Explain one potential problem of relying on the home agent to find a travelling user in the mobile IP.

Triange routing

e) (2pts) List a couple of mechanisms for TCP congestion avoidance.

DEC Bit, RED

e) (2pts) List a mechanism to schedule the fair transmission among multiple queues in a router.

Round robin

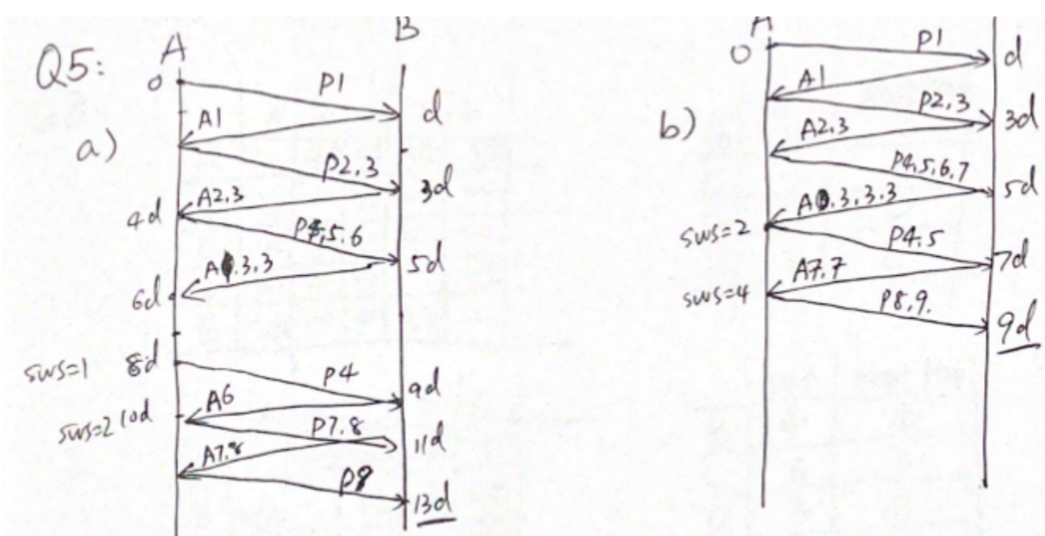
5) (12 pts) Host A sends a file consisting of 9 segments to Host B using TCP. Assume that the 4th segment in the transmission is lost. Assume the retransmission timeout is T, the one-way propagation time is d, and that T = 4*d. Ignore the transmission time of the segments and acknowledgements. Also, ignore any processing or queueing time. Suppose that the TCP three-way handshake has completed. No flow control or congestion control need to be considered. Sequence number has infinitely large space that starts from 1. A's sending window starts from 1.

Note that Host B keeps a pointer **SeqNumToAck.** An ACK is sent to represent that all segments with smaller sequence number are well received. If error happens, Host B holds ACK till the segment of **SeqNumToAck** is received**.** For example, firstly, segments 1, 2 and 3 are sent, and segment 1 is received (ACK1 is returned), segment 2 is lost and segment 3 is received. Then, Host B returns ACK1 again upon receiving segment 3.

a) (4 pts) Assume AIMD is used (sending window is incremented by 1 when ACK is received while reduced to 1 when timeout fires). Draw the time diagram showing each segment and acknowledgement until the entire file is transferred.

b) (4 pts) Assume fast retransmit and fast recovery is used (sending window is incremented following the slow start mechanism when ACK is received while reduced by half when receiving 3 same ACKs). Draw the time diagram showing each segment and acknowledgement until the entire file is transferred.

c) (4 pts) Calculate how much extra time efficiency (in percentage) is gained in the approach (b) compared with approach (a).



c) saved time: $\frac{13-9}{13} = 30.77\%$

6) (8 pts) A router has the following (CIDR) entries in its routing table

Address/mask	Next Hop
135.46.64.0/20	Interface 0
135.46.176.0/20	Interface 1
135.46.208.0/20	Router 1
135.46.240.0/20	Router 2
Default	Router 3

What is the next hop that the router selects when it receives IP packets with the addresses shown below. **Show all of your work or explain how you determined the next hop.**

a) 135.46.136.10 a) Next Hop router 3

b) 135.46.255.22 b) Next Hop router 2

c) 135.46.73.240 c) Next Hop I 0

d) 135.46.183.79 d) Next Hop I1

7) (12 pts) Consider a network where the sliding window protocol is in use with SWS = RWS = 2 frames and a one-way delay of 100ms (i.e. for a frame sent at time t, it arrives at t + 100ms). Assume that when multiple frames are all able to be sent according to the window size, that they are sent 20ms apart (i.e., frame 1 starts at time t, and frame 2 starts at time t + 20ms).

a) (4 pts) What would be a reasonable timeout value for this link? Why not something smaller? How about larger?

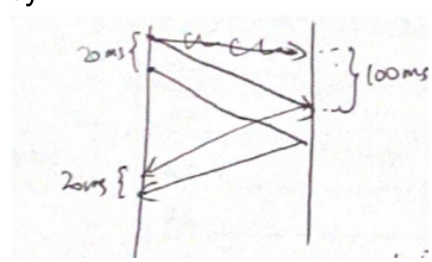
timeout > RTT which is 200 ms

timeout should b l bit over.

b) (4 pts) Can the selection of window size (i.e., SWS=RWS=2) fully utilized the link? If yes, please explain. If not, what is the channel utilization efficiency?

No,

$$SWS_{optimal} = \frac{200}{20} = 10$$

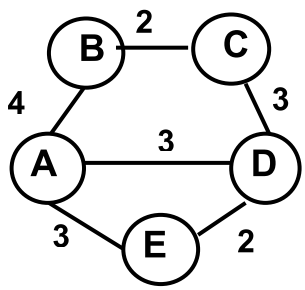


$2/10 = 20\%$ eff.

c) (4 pts) Now, assume that by sending a frame every 5ms we can saturate the link. In this case, determine the smallest SWS and RWS that maximizes throughput (i.e., keeps the pipe full).

$$SWS = RWS = \frac{200ms}{5ms} = 40$$

8) (12 pts) The Distance Vector Routing Algorithm is to be performed to derive routing tables. Entries in the table are in the form of cost/next hop. Cost is measured in **throughput**. Fill in the tables below for the results after one exchange of vectors and after two exchanges. Give entries in the table in the **form of cost/next hop** as shown in the initial table. For each of the distance vector tables, complete the known routing table for node A.



Info at Node	Distance to reach node – initial table				
	A	B	C	D	E
A	---	4/B	∞	3/D	3/E
B	4/A	---	2/C	∞	∞
C	∞	2/B	---	3/D	∞
D	3/A	∞	3/C	---	2/E
E	3/A	∞	∞	2/D	---

Node A Routing Table		
Destination	Cost	NextHop
B	4	B
C	–	–
D	3	D
E	3	E

Info at Node	Distance to reach node – after 1 exchange				
	A	B	C	D	E
A	---	4/B	3/D	3/D	3/E
B	4/A	---	2/C	3/A	3/A
C	3/D	2/B	---	3/D	2/D
D	3/A	3/A	3/C	---	3/A
E	3/A	3/A	2/D	3/A	---

Node A Routing Table		
Destination	Cost	NextHop
B	4	B
C	3	D
D	3	D
E	3	E

Info at Node	Distance to reach node – after 2 exchanges				
	A	B	C	D	E
A	---	4/B	3/D	3/D	3/E
B	4/A	---	2/C	3/A	3/A
C	3/D	2/B	---	3/D	2/D
D	3/A	3/A	3/C	---	3/A
E	3/A	3/A	2/D	3/A	---

Node A Routing Table		
Destination	Cost	NextHop
B	4	B
C	3	D
D	3	D
E	3	E

9) (12 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.
- Host A processes information in the following order: first process any ACKs, then process any timeouts and then send more packets if possible**. The whole processing takes 0 second.**
- ACK does **not** occupy the buffer space of the router.
- Host A sets its sending window size equal to the congestion window size.
- 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 1 packets for each ACK received**.
- The initial congestion window is 1 packet.
- **The timeout time is 4 seconds**. When a timeout occurs the congestion window is reset to 1.

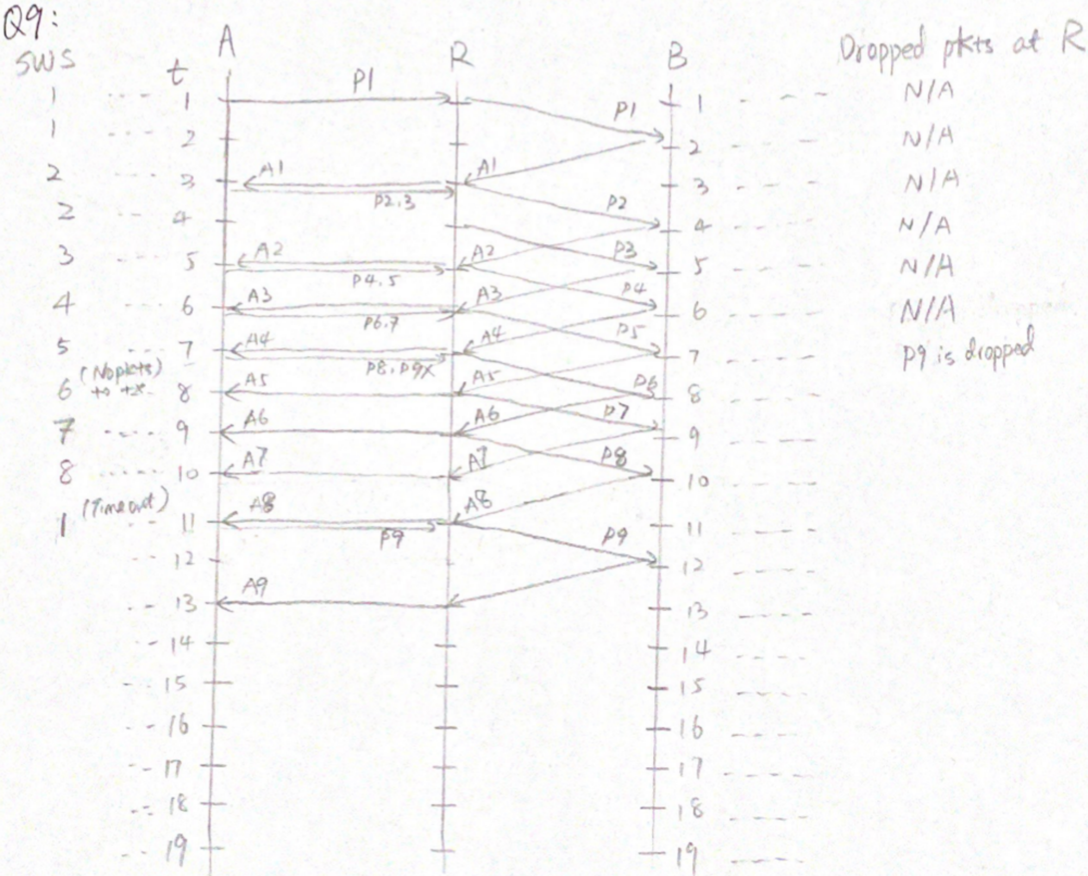
The first packet (P1) sent by Host A occurs at time t=1 second. Host A has 9 packets to transmit, draw a time diagram to show all the processes before completing all transmissions. **Answers without the time diagram will receive zero credits.**

a) (4pts) At what time does a timeout of a packet first occur?

b) (4pts) 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)

c) (4pts) At what time does Host B receive all 9 packets?

Q9:



a) t= ~~10~~ 11 sec

b) ~~7~~ 8

c) t= ~~12 sec~~ 11 12 sec