UNIVERSITY OF WATERLOO

Department of Electrical and Computer Engineering

ECE 358 – Computer Networks

Midterm Exam + Solution

Fall 2019

October 24, 2019
8:30 - 9:45 AM

Instructors: **Albert Wasef** **Time Allowed: 75 Minutes**

First Name:	**Last Name:**
I.D. Number:	

Instructions:

1. This exam has 12 pages including this cover. Keep all sheets stapled.
2. This is a **closed book** examination; no notes are to be used.
3. Calculators with cleared memory are allowed.
4. Place your WATCARD on the table and sign the attendance sheet when provided.
5. Answer all questions. **Clearly show all steps used in the solution process. No marks will be given for numerical results unless accompanied by a correct solution method.**
6. No question will be answered during the exam. Should there be a need, **make reasonable assumptions, write them down in your exam paper** and proceed.
7. Giga means 10^9, "Mega" means 10^6, and "Kilo" means 10^3.
8. All acronyms have their standard expansions as explained in class.

You may use the backsides of all the facing pages for rough works.

Question	Marks	Marker
1	/25	AS / JL / AA / RM / ARS
2	/20	AS / JL / AA / RM / ARS
3	/10	AS / JL / AA / RM / ARS
4	/20	AS / JL / AA / RM / ARS
5	/25	AS / JL / AA / RM / ARS
Total	/100	

Question 1 [25 Marks]: Concepts

Briefly answer the following questions.

(a) What is an access network? (1 mark)

It is the network that connects end systems (hosts) to their first hop router.

(b) What is packet switching? Explain its advantages and disadvantages. (3 marks)

In packet switching, hosts break application-layer messages into packets which are transmitted independently using the full link capacity.

Advantages: Resource sharing, no call setup

Disadvantage: Packet delay, congestion, packet loss.

(c) What are the advantages and disadvantages of encapsulation in the Internet protocol stack? (3 marks)

Advantage: Protect upper layers data, modularization, easy maintenance.

Disadvantage: Overhead

(d) Briefly explain the main idea of the carrier sensing in a CSMA protocol. (2 marks)

Main idea is to listen before you talk. A node willing to transmit will listen on the broadcast channel before transmitting. If the channel is busy, keep trying until the channel is idle then transmit.

(e) Compare ARP tables with MAC tables. (3 marks)

ARP is mapping between IP addresses and MAC addresses.

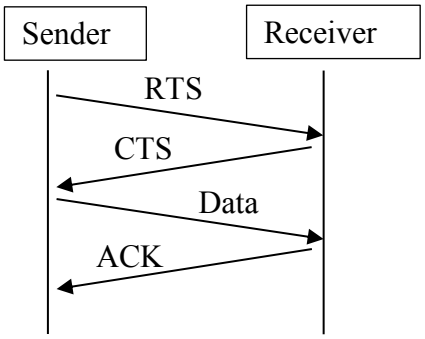
MAC is mapping between a MAC address and a switch interface.

ARP Table		
IP	MAC	TTL

MAC Table		
MAC	Interface	TTL

(f) What are the two basic modes of operations of a WiFi network (WLAN running an IEEE 802.11)? Describe the role of the Access Point in each with ONLY one sentence. (4 marks)
The two modes are:
1- PCF (Point Coordination Function): AP acts as the central controller where it controls which node is going to transmit.
2- DCF (Distributed Coordination Function): AP is a normal node.

(g) Draw a figure that indicates the basic operation of the handshake mode of data transmission in a WiFi network. Ignore timing. (2 marks)



(h) What is carrier sensing and what is virtual carrier sensing in WLAN? (3 marks)

Carrier sensing the (physical) power sensing on the link.

Virtual carrier sensing is the value of the Network Allocation Vector (NAV) which is an integer value that indicates the likelihood that a nearby node is transmitting.

(i) Explain the importance of SIFS < PIFS < DIFS. (4 marks)
SIFS is smaller than PIFS and DIFS in order to prevent a node including the AP from interrupting an ongoing transmission.

PIFS > DIFS in order to allow the AP to switch the WiFi from DCF mode to PCF mode.

Question 2 [20 marks]: Packet-Switching

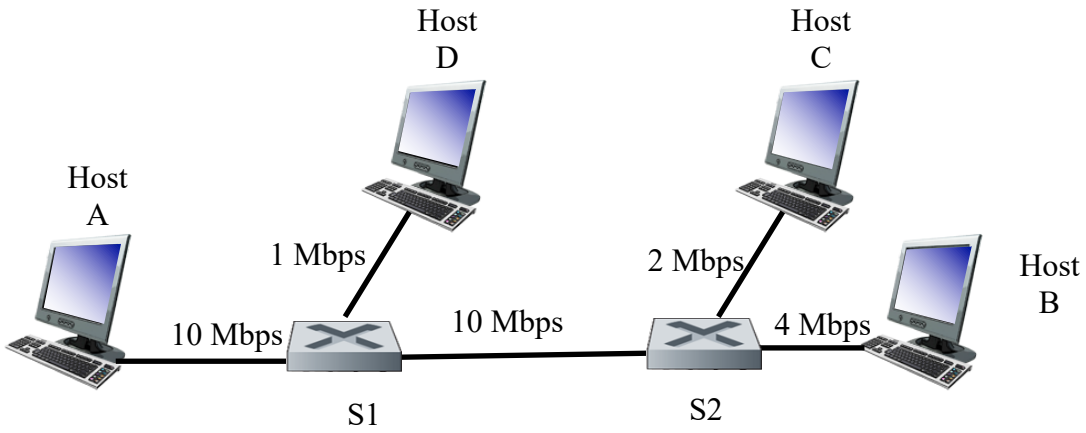


Figure 1. Question 2.

In the packet-switched network shown in Figure 1, each link has its speed as shown in Figure 1. S1 and S2 are link-layer switches. Ignore the processing, propagation and queuing delays at all the switches.

Host A will broadcast a file of size 100 KBytes. Host A has a fixed packet size of 1 KBytes. Consider that the transmission of packet 1 will start at **time 0**.

Answer the following questions, (a)—(f).

(a) When will Host D completely receive the first packet? (3 marks)

$$T_{D-1st-packet} = d_{trans-10M} + d_{trans-1M}$$

$$T_{D-1st-packet} = \frac{1000 \times 8}{10 \times 10^6} + \frac{1000 \times 8}{10^6}$$

$$T_{D-1st-packet} = 0.8 + 8$$

$$T_{D-1st-packet} = 8.8\ msec$$

(b) When will Host C completely receive the first packet? (3 marks)

$$T_{C-1st-packet} = d_{trans-10M} + d_{trans-10M} + d_{trans-2M}$$

$$T_{C-1st-packet} = \frac{1000 \times 8}{10 \times 10^6} + \frac{1000 \times 8}{10 \times 10^6} + \frac{1000 \times 8}{2 \times 10^6}$$

$$T_{C-1st-packet} = 0.8 + 0.8 + 4$$

$$T_{C-1st-packet} = 5.6\ msec$$

(c) When will Host B completely receive the first packet? (3 marks)

$$T_{B-1st-packet} = d_{trans-10M} + d_{trans-10M} + d_{trans-4M}$$

$$T_{B-1st-packet} = \frac{1000 \times 8}{10 \times 10^6} + \frac{1000 \times 8}{10 \times 10^6} + \frac{1000 \times 8}{4 \times 10^6}$$

$$T_{B-1st-packet} = 0.8 + 0.8 + 2$$

$$T_{B-1st-packet} = 3.6\ msec$$

(d) When will Host C completely receive the file? (4 marks)

$$Number\ of\ packets = \frac{100K}{1K} = 100\ packets$$

$$T_{C-complete} = T_{C-1st-packet} + (number\ of\ packets - 1) \times d_{trans-2M}$$

$$T_{C-complete} = 5.6 + (100 - 1) \times 4$$

$$T_{C-complete} = 401.6\ msec$$

(e) When will Host B completely receive the file? (3 marks)

$$T_{B-complete} = T_{B-1st-packet} + (number\ of\ packets - 1) \times d_{trans-4M}$$

$$T_{C-complete} = 3.6 + (100 - 1) \times 2$$

$$T_{C-complete} = 201.6\ msec$$

(f) Which Host out of Host B and Host C will have better average throughput. Justify your answer. (4 marks)

$$Throughput_C = \frac{100\ Kbytes}{T_{C-complete}} = \frac{100K}{401.6 \times 10^{-3}} = 249\ Kbytes/sec$$

$$Throughput_B = \frac{100\ Kbytes}{T_{B-complete}} = \frac{100K}{201.6 \times 10^{-3}} = 496.04\ Kbytes/sec$$

Host B has higher throughput than that of C (almost double) as the last link in the connection is bottleneck link (4 Mbps vs 2 Mbps).

Question 3 [10 marks]: Error detection

Let the link layers of two computers, A and B, use the CRC error detection technique using a common generator, G = 10011. Let A's data bits, D, be 1101101.

(a) Determine the frame, F, transmitted by A. (6 marks)
The size of G = 5 bits, then the size of CRC = 4 bits

```
          1100111
        ----------
10011 | 11011010000
        10011
        -----
         1000010000
         10011
         -----
          001110000
          00000
          -----
           01110000
           00000
           -----
            1110000
            10011
            -----
             111100
             10011
             -----
              11010
              10011
              -----
               1001
```

Transmitted frame = 1101101**1001**

(b) Let B receive a frame F' = 11000011111. Show all the calculations done by computer B to make a decision after it receives F'. (4 marks)

```
          1101010
        ----------
10011 | 11000011111
        10011
        -----
         1011011111
         10011
         -----
          010111111
          00000
          -----
           10111111
           10011
           -----
            0100111
            00000
            -----
             100111
             10011
             -----
              00001
              00000
              -----
               0001
```

Since the remainder does not equal 0, then the frame is in error and it will be dropped.

Question 4 [20 marks]: Hop-by-hop communication

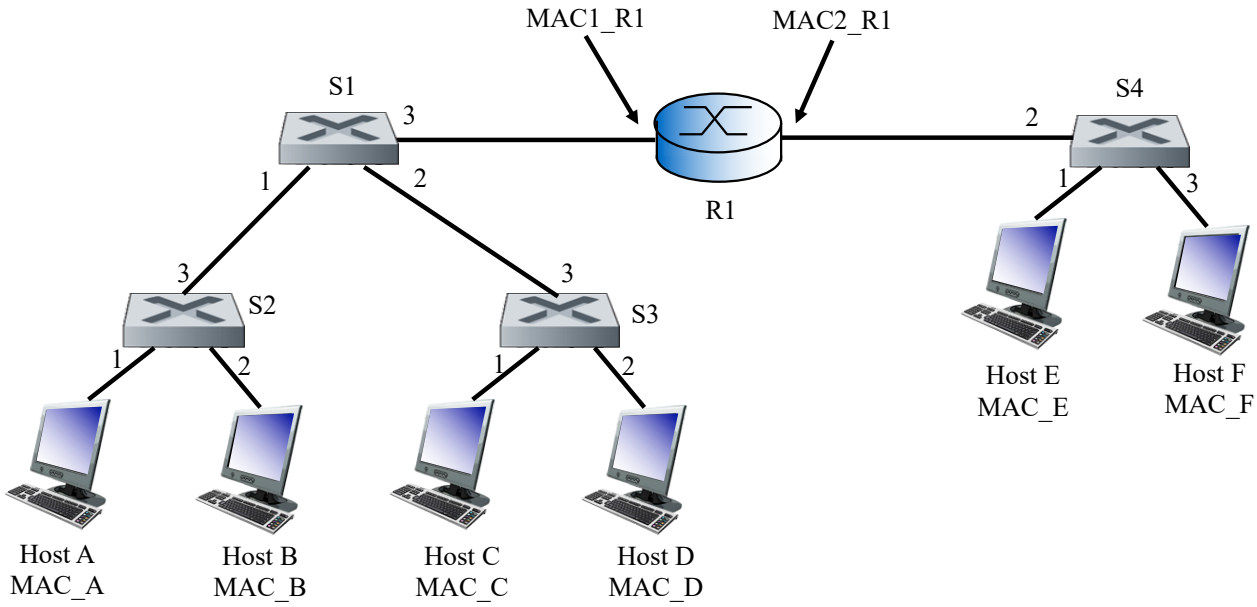


Figure 2. Question 4.

Consider the network shown in Figure 2. Hosts A-F have **MAC addresses** as indicated in Figure 2. R1 is a router and its MAC addresses are indicated in the figure. S1-S4 are link layer switches where their **switching tables** are initially **empty**.

(1) **If host C is sending a packet to host F**.

a. What will be the destination and source MAC addresses as the packet is moving from host C to R1? (4 marks)

Destination MAC: MAC1_R1
Source MAC: MAC_C

b. What will be the destination and source MAC addresses as the packet is moving from R1 to S4? (4 marks)

Destination MAC: MAC_F
Source MAC: MAC2_R1

c. Show the switching tables in the switches S1-S4 after the packet transmitted by host C is delivered to host F. **All the switching tables are initially empty**. (6 marks)

S1	
MAC	Interface
MAC_C	2

S3	
MAC	Interface
MAC_C	1

S2	
MAC	Interface
MAC_C	3

S4	
MAC	Interface
MAC2_R1	2

(2) After host F received the packet transmitted by C, host E will transmit a packet to host C. Show the switching tables in the switches S1-S4 after the packet transmitted by host E is delivered to host C. (6 marks)

S1	
MAC	Interface
MAC_C	2
MAC1_R1	3

S3	
MAC	Interface
MAC_C	1
MAC1_R1	3

S2	
MAC	Interface
MAC_C	3

S4	
MAC	Interface
MAC2_R1	2
MAC_E	1

Question 5 [25 marks]: Ethernet and WiFi protocols

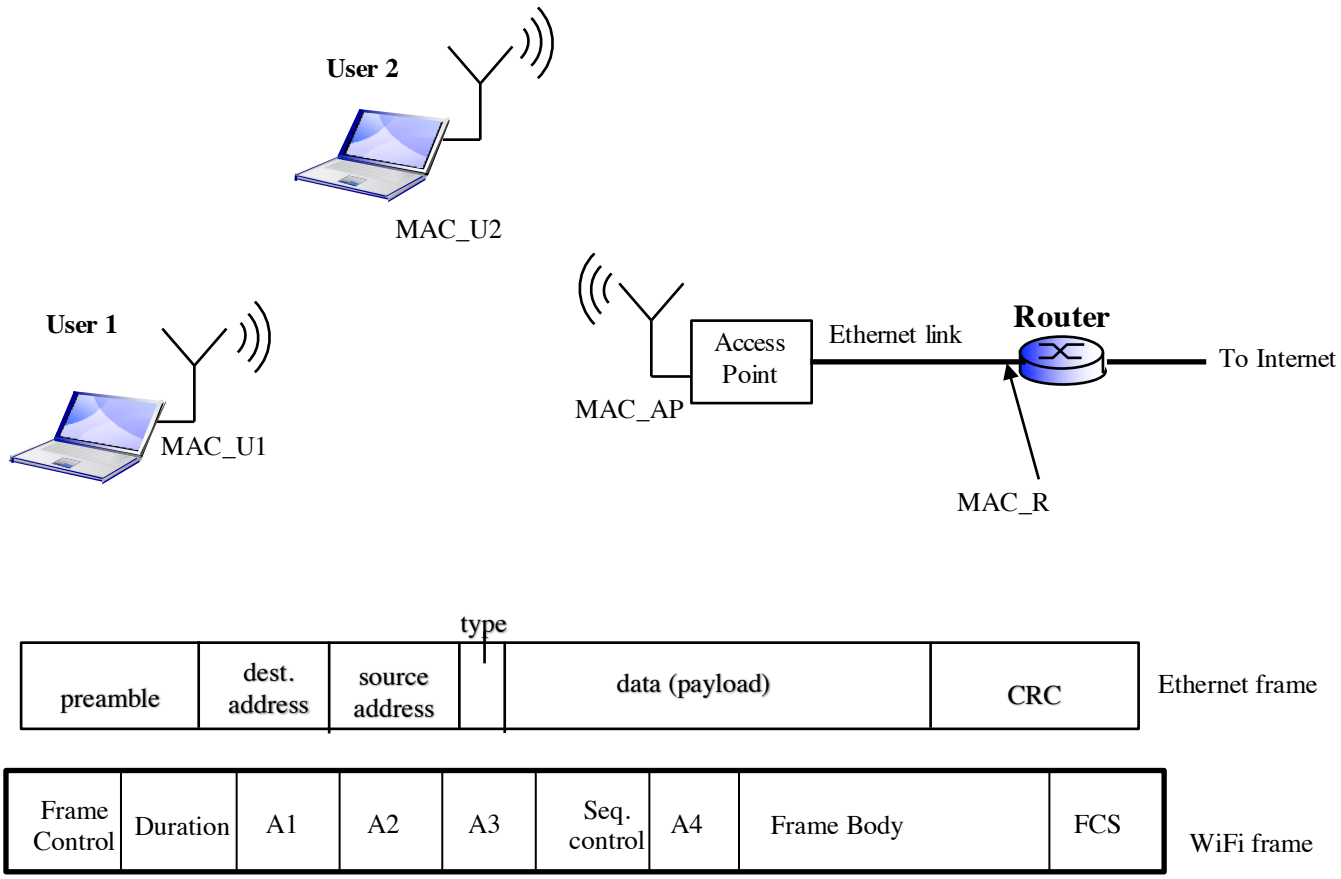


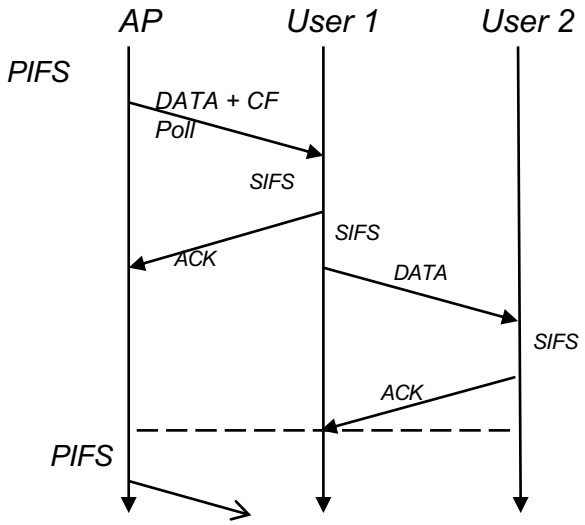
Figure 3. Question 4.

In the network shown in Figure 3, User 1, User 2 and the access point (AP) are in the same Basic Service Set (BSS). The AP in turn is connected through Ethernet link to a router which is connected to the Internet.

The WiFi link speed is **1 Mbps**.
The AP is currently operating in the **PCF** mode.
The WiFi has **aSlot = 20 µs** and **SIFS = 10 µs**.
"CF Poll + Data" frame has an **overhead of 34 bytes**. A **Data frame** has an **overhead** of **34 bytes**.
ACK frames are **14 bytes**.

Assume that at **time 0 sec**, the AP has a **datagram of size 400 bytes** to send to user 1 and at the same time it will **poll** user 1 to allow that user to transmit its data if it has any. In order to do this task, the AP will use "CF Poll + Data" frame. Assume that user 1 has a **datagram of size 300 bytes** to transmit to user 2.

(a) Draw a simple graph that explains the data exchange sequence described in the problem, i.e., what frames will be exchanged between AP, user 1 and user 2. Add symbolic timing to the figure, e.g., SIFS. Use the next page for your answer. (4 marks).



(b) When will the AP start transmitting the "CF poll + Data" frame? (2 marks)

$$T_{AP-start} = PIFS = SIFS + aSlot = 10 + 20 = 30\ \mu s$$

(c) When will user 1 completely receive the date sent by the AP? (3 marks)

$$T_{u1-AP-data} = T_{AP-start} + transmission\ delay\ of\ frame\ from\ AP\ to\ user\ 1$$

$$T_{u1-AP-data} = 30 + \frac{(400 + 34) \times 8}{10^6}$$

$$T_{u1-AP-data} = 3502\ \mu s$$

(d) When will user 1 start transmitting its frame to user 2? (4 marks)

$$T_{u1-start} = T_{u1-AP-data} + SIFS + d_{transmission-ACK} + SIFS$$

$$T_{u1-start} = 3502\mu + 10\mu + \frac{14 \times 8}{10^6} + 10\mu$$

$$T_{u1-start} = 3634\ \mu s$$

(e) When will user 2 completely receive the frame sent by user 1? (3 marks)

$$T_{u2-data} = T_{u1-start} + \ transmission\ delay\ of\ \ frame\ \ from\ user\ 1\ to\ user\ 2$$

$$T_{u2-data} = 3634 + \frac{(300 + 34) \times 8}{10^6}$$

$$T_{u2-data} = 3634 + 2672$$

$$T_{u2-data} = 6306\ \mu s$$

(f) When will user 1 finish the transmission cycle of its frame, i.e., finish all the steps necessary to transmit its frame and ensure that it has been received correctly? Assume that no errors occurred during transmission. (3 marks)

$$T_{u1-cycle} = T_{u2-data} + SIFS + d_{transmission-ACK}$$

$$T_{u1-cycle} = 6306 + 10 + 112$$

$$T_{u1-cycle} = 6428\ \mu s$$

(g) Assume that the router indicated in Figure 3 will send a frame to user 1. What will be the MAC addresses included in the Ethernet frame? What will be the MAC addresses included in the WiFi frame? The formats of the WiFi and Ethernet frames are shown in Figure 3. The MAC addresses of the all the nodes are indicated in Figure 3. (6 marks)

Ethernet Frame

Destination MAC: MAC_U1
Source MAC: MAC_R

WiFi Frame
A1: MAC_U1
A2: MAC_AP
A3: MAC_R
A4: Not used