UNIVERSITY OF WATERLOO

Department of Electrical and Computer Engineering

ECE 358 – Computer Networks

Midterm Exam

Winter 2019

February 28, 2019
8:30 - 9:45 AM

Instructors: **Sagar Naik**, **Albert Wasef** — **Time Allowed: 75 Minutes**

First Name:	**Last Name:**
I.D. Number:	**Circle Your Section:**

Instructions:

1. This exam has 12 pages including this cover. Keep all sheets stapled.
2. The 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. 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	30 /30	AS/ JL/ AA/ MB/ KT	AW
2	17 /20	AS/ JL/ AA/ MB/ KT	AW
3	20 /20	AS/ JL/ AA/ MB/ KT	
4	24 /30	AS/ JL/ AA/ MB/ KT	
Total	91 /100		

Question 1 [30 Marks]: Concepts

30/30

Briefly answer the following questions.

(a) List the four broad kinds of delays encountered by IP packets while moving from router to router. Out of the four kinds of packet delays, what are mostly deterministic and what are highly variable for MTU (Max Transfer Unit) size packets? (4 marks)

The four kinds of delays are propagation delay, transmission delay, queueing delay, and processing delay. Propagation delay and transmission delay are mostly deterministic, and queueing delay and processing delay are highly variable.

(b) Why are correctly received data packets occasionally dropped by routers? (1 mark)

If the queue is full when a packet arrives, the packet will be dropped

(c) Why is collision detected *while* transmitting in the CSMA/CD protocol? (1 marks)

Collision is detected while transmitting so the transmission can be aborted and re-attempted sooner, saving time

(d) What are throughput, instantaneous throughput, and average throughput? (4 marks)

Throughput is the number of bits that can be transmitted in a unit of time. Instantaneous throughput is the number of bits being transmitted at a given time. Average throughput is the average number of bits that can be transmitted per unit time.

(e) What are the characteristics of an ideal MAC protocol? (5 marks)

An ideal MAC protocol should be efficient, should handle collisions effectively without wasting too much time, and should allow for multiple users to use it at once (depending on the context)

(f) What is message encapsulation? Explain its advantage(s) and disadvantage(s). (5 marks)

Application
Transport
Network
Link
Physical

Message encapsulation means that each layer in the IP Stack only looks at the part of the message intended for it (ex: the network layer only looks at the network header, not the transport header). This keeps the data safe from modification by layers that shouldn't have access to certain parts of the data, and increases efficiency because each layer only has to process information relevant to it. A disadvantage is that it adds overhead in the form of each layer's header.

(g) What are the basic services provided by Link Layer protocols? (5 marks)

Link layer protocols take care of transmitting frames from one node to another, within the same network. Each node in the network implements the link layer. It does not take care of determining the route by which to send packets (this is the network layer). The link layer provides store-and-forward capabilities, like in switches. It also provides error detection and correction.

(h) Compare ARP tables with switch tables. (5 marks)

ARP tables contain an IP address, a MAC address, and TTL (time to live) for that address combination, for each node that currently has an entry. Each IP node in a network has an ARP table.

Only switches have switch tables. These contain a node MAC address and the MAC address of the interface on the switch required to send a frame to that node. There is no TTL value.

Question 2 [20 marks]: Error detection

17/20

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 10110100.

(a) Determine the frame, F, transmitted by A. (7 marks)

$G = \underbrace{10011}_{r+1 \text{ bits}}$ $r+1=5$, so $r=4$

$D = 10110100$

$D \cdot 2^r = 101101000000$

```
           10101011
      ______________
10011 ) 101101000000
        10011
        0010110
          10011
          0010100
            10011
            0011100
              10011
              011110
               10011
               01101
                1101
                EDC
```

$F = \langle D, EDC \rangle$

$= 101101001101$

(b) Let B receive a frame F' = 101010101001. Show all the calculations done by computer B to make a decision after it receives F'. (7 marks)

G=10011

```
               10110111
       ____________________
10011 ) 101010101001
        10011
        0011001
          10011
          010100
           10011
           0011110
             10011
             011010
              10011
              010011
               10011
               00000
```

Since the remainder is 0, the frame was received correctly.

(c) Based on the calculations done in part (b), does B's link layer drop F' or does it deliver the received data D' to its upper layer? (2 marks)

The remainder of $\frac{F'}{G}$ was 0, so B's link layer delivers the received data D' to its upper layer.

(d) In part (c), in case B's link layer delivered the received data D' to its upper layer, is D' = D? If D' was delivered and D' ≠ D, where did things go wrong? (4 marks)

D' = D if nothing went wrong. If D' ≠ D, something went wrong while B was transmitting to its upper layer (on the connection between those layers).

-3

Question 3 [20 marks]: Hop-by-hop communication

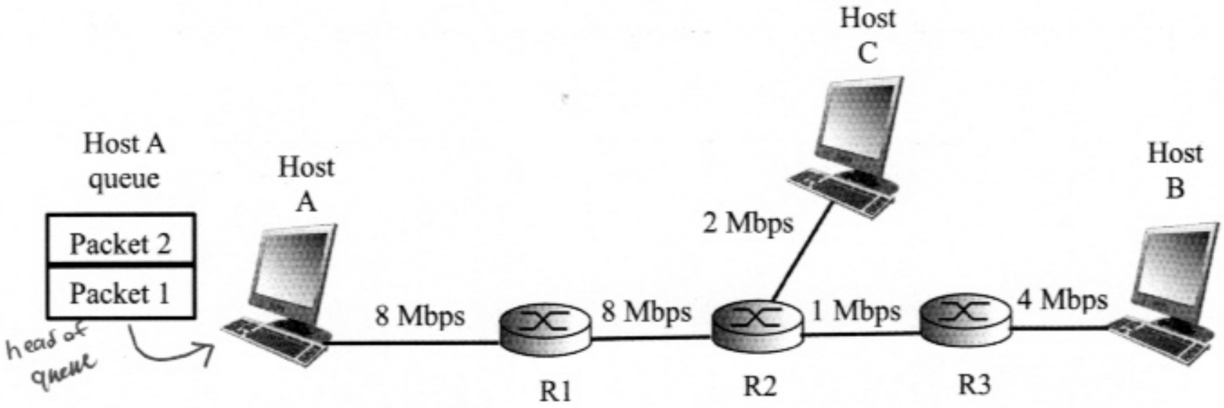


Figure 1. Question 3.

In the packet-switched network shown in Figure 1, the **propagation speed** in all the links is $2 \times 10^8\ m/s$, all the links are **100 meters** each, and each link has its speed as shown in Figure 1. Ignore the processing and queuing delays at all the routers.

Host A has **two** packets in its queue as shown in Figure 1: packet 1, which is destined to host B, and packet 2, which is destined to host C.
Packet 1 and packet 2 are of equal lengths of 800 Bytes each.
Consider that the transmission of packet 1 will start at **time 0**.

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

(a) When will router R2 completely receive packet 1? (4 marks)

$$T_{total} = t_{trans\,A-R_1} + t_{trans\,R_1-R_2} + t_{prop\,A-R_1} + t_{prop\,R_1-R_2}$$

$$= \frac{800B \cdot 8\frac{bits}{byte}}{8Mbps} + \frac{800B \cdot 8\frac{b}{B}}{8Mbps} + \frac{100m}{2\times10^8 m/s} + \frac{100m}{2\times10^8 m/s}$$

$$= 800\mu s + 800\mu s + 0.5\mu s + 0.5\mu s$$

$$= 1601\mu s$$

$$= 1.601 ms$$

(b) When exactly will Host B completely receive packet 1? (4 marks)

$$T_{total} = \text{time to } R_2 + t_{trans\,R_2-R_3} + t_{trans\,R_3-B} + t_{prop\,R_2-R_3} + t_{prop\,R_3-B}$$

$$= 1601\mu s + \frac{800B \cdot 8^{b}/_{B}}{1\,Mbps} + \frac{800B \cdot 8^{b}/_{B}}{4\,Mbps} + \frac{100m}{2\times10^8 m/s} + \frac{100m}{2\times10^8 m/s}$$

$$= 1601\mu s + 6400\mu s + 1600\mu s + 0.5\mu s + 0.5\mu s$$

$$= 9602\mu s$$

$$= 9.602ms$$

(c) How long will packet 2 wait in Host A's queue before its transmission starts? Assume that packet 2 has arrived at the link layer right after packet 1. (1 mark)

Packet 2 will wait for the amount of time it takes to put packet 1 on the medium (its transmission time). This is:

$$t_{trans} = \frac{800B \cdot 8\frac{bits}{byte}}{8\,Mbps} = 800\mu s$$

(d) When will router R2 completely receive packet 2? (3 marks)

$$T_{total} = 800\mu s + \underbrace{\frac{800B\cdot 8}{8Mbps}}_{t_{trans\,A-R1}} + \underbrace{\frac{800B\cdot 8}{8Mbps}}_{t_{trans\,R_1-R_2}} + 2\times\frac{100m}{2\times10^8 m/s}$$

$$= 2401\mu s$$

(e) When will host C completely receive packet 2? (3 marks)

$$T_{total} = \underbrace{\text{time to } R_2}_{\text{answer to part d}} + T_{trans_{R_2-C}} + t_{prop_{R_2-C}}$$

$$= 2401\mu s + \frac{800B \times \frac{8 bits}{B}}{2 Mbps} + \frac{100m}{2\times10^8 m/s}$$

$$= 2401\mu s + 3200\mu s + 0.5\mu s$$

$$= 5601.5\mu s$$

(f) Consider that Host A has an 80 Megabyte file to transmit to Host C, use the **bottleneck link** concept to calculate the approximate time required for moving this file from A to C. Consider that transmission delay is the only delay that the packets experience. Also, consider that the Maximum Transmission Unit (MTU) is 1000 Bytes for the network shown in Figure 1. (5 marks)

$$\frac{80 MB}{1000 \text{ bytes}} = 80,000 \text{ packets} = C$$

Slowest link between A and C is 2 Mbps → this is the bottleneck

$$T_{total} = \text{time to transmit 1 packet} + (C-1) \times \text{time to transmit on bottleneck link}$$

$$= t_{trans_{A-R_1}} + t_{trans_{A-R_2}} + (80,000-1) \times t_{trans_{R_2-C}}$$

$$= \frac{1000B\times8^{b}/_{B}}{8Mbps} + \frac{1000B\times8^{b}/_{B}}{8Mbps} + (79,999)\times\frac{1000B\times8^{b}/_{B}}{2Mbps}$$

$$= 1000\mu s + 1000\mu s + 319.996s$$

$$\doteq 320s$$

Question 4 [30 marks]: Ethernet and WiFi protocols

In the network shown in Figure 2, a client is connected through a WiFi link to the Access Point (AP). The AP in turn is connected through Ethernet links to a router and then to a server.

(Note that part (e) is independent from parts (a)-(d) and the two paragraphs following Fig. 2.)

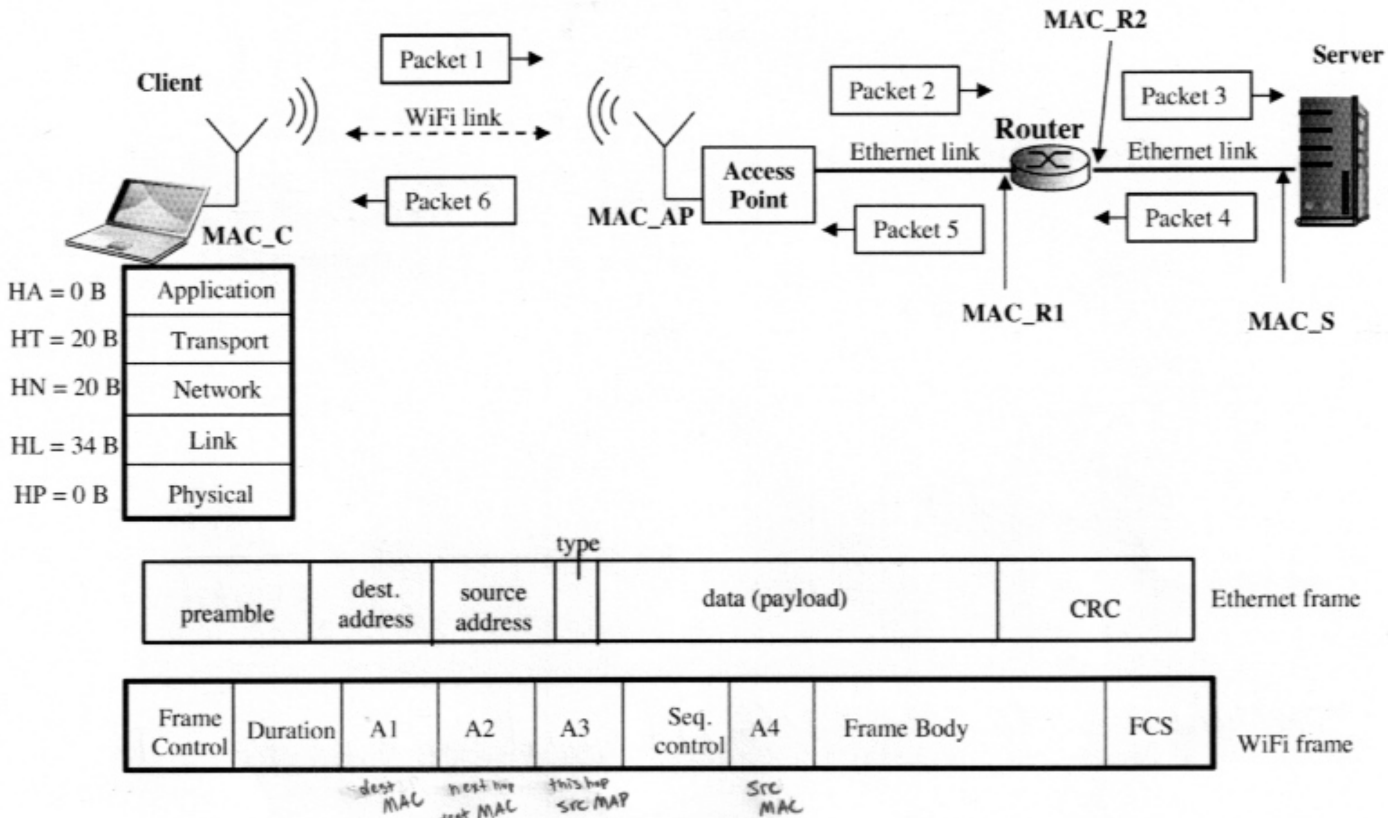


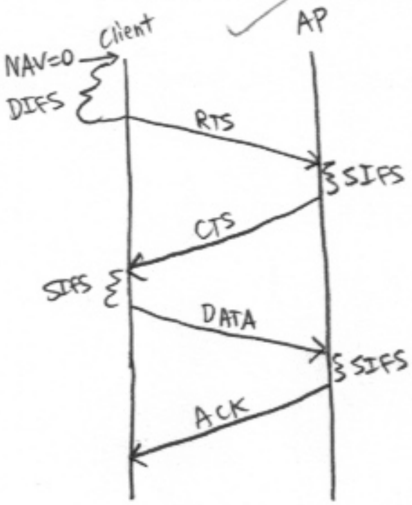
Figure 2. Question 4.

The WiFi link speed is **1 Mbps**.
The AP is operating in the **DCF** mode. The client has **dotRTSThreshold** = 350 Bytes.
The WiFi has DIFS = 50 μs and PIFS= 30 μs.
RTS, CTS, and ACK frames are 20, 14, and 14 Bytes, respectively.

The client is running an application that generates variable length data segments. Assume that the client application generated **data1** of size 250 bytes then **data2** of size 300 bytes. Assume that the other clients in the same Basic Service Set (BSS) are silent for a long time. Ignore the processing and propagation delays. The protocol stack of the client with corresponding **header size** (HA, HT, HN, HL, and HP) of each layer in bytes is shown in Figure 2. Assume that the client will transmit data frame 1 containing **data1**, at time 0. After data frame 1 is successfully transmitted, the client will transmit data frame 2 containing **data2**.

(a) When will the client start transmitting data frame 1 assuming that all the other nodes in the BSS do not have frames to transmit and that the client has its NAV = 0 at time 0? (7 marks)

DCF (with handshake)



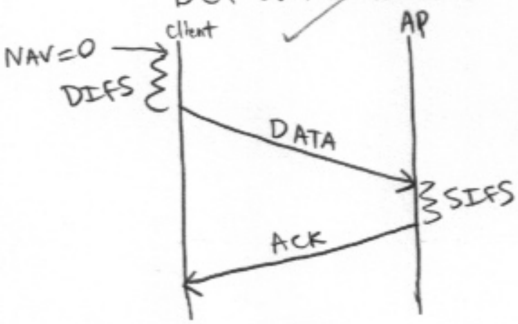
data1's total size is: 250B+20B+20B+34B=324B

324B<350B=dotRTSThreshold, so don't use handshaking

Therefore, the client will start transmitting data1 after waiting for DIFS, which is 50μs.

7

DCF (without handshake)



Answer: 50μs

(b) When will the AP receive the last bit of data frame 1? (2 marks)

Time of last bit $= DIFS + t_{trans\ DATA}$

$$= 50\mu s + \frac{324B \cdot 8 b/B}{1Mbps}$$

$$= 2642\mu s$$

2

(c) When will the client finish the transmission cycle of data frame 1, i.e., finish all the steps necessary to transmit data frame 1 and ensure that it has been received correctly? (4 marks)

$$T_{total} = \underbrace{DIFS + t_{trans\,DATA}}_{\text{answer to part b}} + SIFS + t_{trans\,ACK}$$

$$= 2642\,\mu s + 10\,\mu s + \frac{14B \cdot 8^{b}/_{B}}{1\,Mbps}$$

$$= 2764\,\mu s$$

$\boxed{4}$

$DIFS = 50\,\mu s$

$PIFS = 30\,\mu s$

$DIFS = PIFS + a$

$50\,\mu s = 30\,\mu s + a$

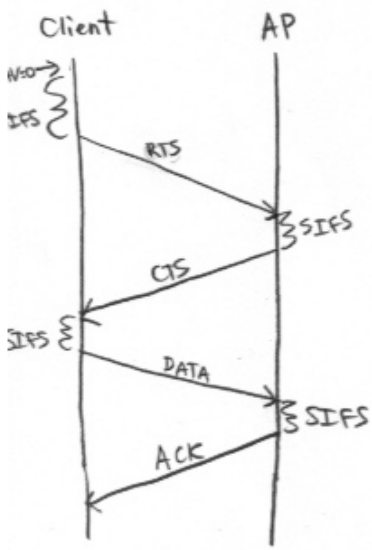
$a = 20\,\mu s$

$PIFS = SIFS + a$

$30\,\mu s = SIFS + 20\,\mu s$

$SIFS = 10\,\mu s$

(d) When will the client start transmitting data frame 2 assuming that all the other nodes in the BSS do not have data frames to transmit and that the client has its NAV = 0? (7 marks)



DCF with handshake

Size of data2 = 300B + 20B + 20B + 34B = 374B

374B > dotRTSThreshold, so use handshaking

$$T_{total} = T_{total\,data1} + DIFS + t_{trans\,RTS} + SIFS + t_{trans\,CTS} + SIFS$$

$$= 2764\,\mu s + 50\,\mu s + \frac{20B \times 8}{1\,Mbps} + 10\,\mu s + \frac{14B \times 8}{1\,Mbps} + 10\,\mu s$$

$$= 2764\,\mu s + 50\,\mu s + 160\,\mu s + 10\,\mu s + 112\,\mu s + 10\,\mu s$$

$$= 3106\,\mu s$$

$\boxed{7}$

(e) Assume that the client sent a request to the server via packets 1, 2 and 3 and the server replied to the client via packets 4, 5 and 6 as shown in Figure 2. The MAC addresses of the client (MAC_C), AP (MAC_AP), router (MAC_R1 and MAC_R2), and the server (MAC_S) are indicated in Figure 2. Assume that all the ARP tables for all the nodes are updated with all the possible entries. Also, assume that the client and the server knows each other's IP address.

I. What will be the MAC addresses in the WiFi packets 1 and 6? Use the table below to answer this question. Note that the format of the WiFi frame is indicated in Figure 2. (6 marks)

src IP dest IP dest. MAC

1

MAC addresses	**A1**	**A2**	**A3**	**A4**
Packet 1	MAC-S	MAC-AP	MAC-C	MAC-C
Packet 6	MAC-C	MAC-C	MAC-AP	MAC-S

II. What will be the MAC addresses in the Ethernet packets 2, 3, 4 and 5? Use the table below to answer this question. Note that the format of the Ethernet frame is indicated in Figure 2. (4 marks)

3

MAC addresses	**Destination address**	**Source address**
Packet 2	MAC-R1	MAC-AP
Packet 3	MAC-S	MAC-R2
Packet 4	MAC-R2	MAC-S
Packet 5	MAC-AP	MAC-R1