University of Waterloo

ECE 358 Midterm Exam, F'2014

Dept. of Electrical and Computer Engineering
ECE 358 – Computer Networks
Instructor: Sagar Naik
Exam. Date and Time: Oct. 20, 2014, 1:30 PM—2:45 PM
Rooms: EIT 1015 and RCH 307

Instructions

- You have 75 minutes to complete the exam. This is a **closed book** exam.
- Should there be a need, **make reasonable assumptions** and proceed.
- "Mega" means 10^6 and "kilo" means 10^3. You may use a *basic calculator*.
- All acronyms have their standard expansions as explained in class.

UW ID | Your Name (**Last, First**) | Signature

Questions	Marks	Marked by
Q1	/18	
Q2	/16	
Q3	/21	
Q4	/20	
Total	**/75**	**xxxxxxxxxx**

Total number of pages: 11

Sample Solution

Q1. [18] (Introduction)

a) What is a communication protocol?

A communication protocol is a set of rules for transferring data from one communicating entity (e.g. computer/router/access point/) to another. A protocol defines message formats, sequences of messages to be transmitted and received, and actions to be taken upon sending/receiving messages.

b) Explain the concept of “store and forward” in packet switching networks.

When a router starts receiving bits from another router, it waits until the complete IP packet is received. If the IP packet is received without errors, it is stored in a local buffer. Next, the router determines the next-hop for the packet and forwards the packet to the corresponding 1-hop router.

c) Explain the concept of statistical multiplexing and its advantage(s).

Statistical multiplexing is a technique for sharing the bandwidth of communication links among many computers. In this technique, bandwidth is allocated to individual computers on a demand basis, instead of making static allocations. The advantages are: (i) the technique’s implementation is simpler than other multiplexing techniques (TDM/FDM); (ii) more number of users can be supported than what FDM/TDM would yield; and (iii) bandwidth is not wasted if there is an imbalance in demand from all the connected users.

d) What are three performance characteristics of a network link?

Speed (say, in Mbps), link delay (say, in milliseconds), and BER are three important performance characteristics of a network link.

e) Give two reasons for routers dropping IP packets.

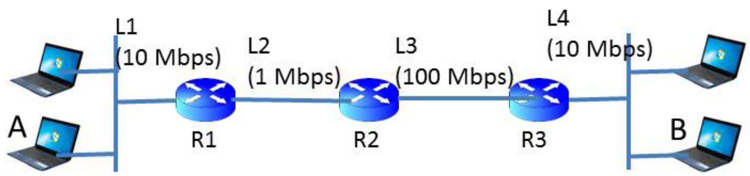
Routers drop packets if: (i) a received packet has bit errors; or (ii) if there is no space in its input/output buffers.

Sample Solution

f) Explain the concept of bottleneck bandwidth by means of an example.

Two computers A and B have been interconnected with three routers (R1—R3) and four links (L1 – L4). L2 has the minimum bandwidth among all the links between A and B, and this puts a limit on the data rate between A and B. Therefore, the end-to-end data transfer between A and B is at most 1 Mbps.

T



g) What is message encapsulation in a protocol stack? Explain its advantages and disadvantage.

In the Internet protocol stack, when Layer-N receives a message M from Layer-(N+1), it (Layer-N) creates a new message M' = <Header, M> and gives it to Layer-(N-1). The message M is said to have been encapsulated within M'.

Adv.: Protocols can be designed in a layered manner.

Disadv.: Encapsulation through a stack of protocols successively increase the length of the message to be eventually transmitted. In other words, encapsulation is done at the expense of increasing the length of messages.

h) Why are network protocols organized in a layered fashion on hosts and routers?

Layering supports independent design of different protocols. Therefore, if one protocol layer is modified, a faraway layer is not affected by the modifications.

i) Show the differences between the ISO/OSI protocol stack and the Internet protocol stack.

Refer to the lecture notes.
The Internet protocol stack does not have a separate Presentation Layer and a separate Session Layer. If needed, those functionalities are implemented in the application layer.

Sample Solution

Q2. [16] (Link Layer)

a) Identify four services provided by the link layer protocols on the Internet.

The services provided by Link Layer protocols are:
medium (link) access, error detection and correction, addressing, and flow control.

b) What are the three broad classes of MAC protocols?

The three broad classes of MAC protocols are: channel partitioning, random access, and taking-turns.

c) Explain the concept of Binary Exponential Backoff and its purpose in CSMA/CD.

Let i be the retransmit count and Tp be the propagation delay. Then, the wait period in the BEB box of CSMA/CD is computed as W = Tp x Random(0, 2^i-1). Statistically, the wait period is exponentially increased as (re)transmissions continue to fail.

The purpose of BEB is to dynamically adapt the wait period to the traffic intensity (or, the number of transmitting users) in order reduce the collision rate.

d) Why is there no concept of acknowledgment (ACK) in the CSMA/CD protocol?

The CSMA/CD protocol is run over copper or fiber physical media which have very low BER values (10^{-8} or 10^{-12}). On the other hand, the CSMA/CA protocol is run over free-space with a BER value of 10^{-5}, which is considered to be very high. To reduce retransmissions in upper-layer protocols, an ACK mechanism is built into the CSMA/CA protocol. However, the BER offered by copper or fiber is very low; hence, there is no ACK mechanism in CSMA/CD and the upper-layer protocols are asked to retransmit occasionally.

e) What is an ARP table? Why does a host computer need an ARP table?

ARP stands for Address Resolution Protocol. An ARP table has entries of the form: <IP address, MAC address, TTL>. Given an IP address of a 1-hop neighbor (host or router), the ARP protocol finds out the MAC address of the neighbor so that the neighbor can be reached with a 1-hop transmission of a frame. A host computer needs an ARP table because it must be able to transmit frames to its first-hop router without flooding its frames on the broadcast link. The TTL (Time To Live) value of an entry specifies the time duration for which the mapping between an IP address and a MAC address is valid.

Sample Solution

f) What kinds of communication errors can a completely reliable data transfer protocol withstand?

- Bit errors
- Packet loss
- Duplication of packets
- Reordering of packets

g) What is a MAC table? What networking entities create and manage MAC tables?

A MAC table comprises of entries of the form: <MAC address, port#, TTL>. The TTL value specifies the time duration for which the mapping between a MAC address and a port# is valid. Link layer switches create and manage MAC tables so MAC tables exist on link layer switches. An entry of the form <X, n1, t> in the MAC table means a device (host/router) with MAC address X is reachable via port# n1 of the switch, and this mapping is valid for t units of time.

h) How does an AP (access point) switch the modes of its WLAN between PCF and DCF?

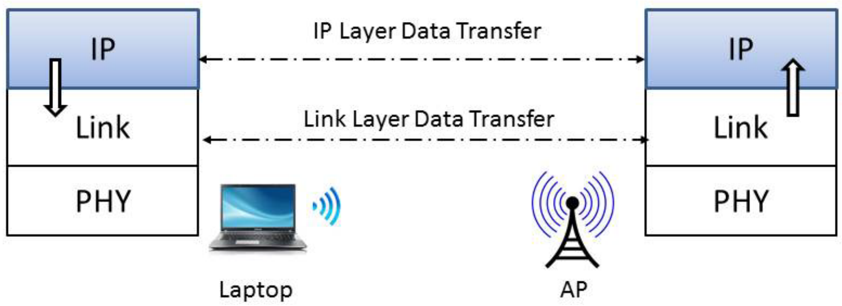
Put the WLAN in PCF mode: When an AP finds the medium to be idle for PIFS interval, it broadcasts a Beacon frame containing a time duration value in its CFPMaxDuration field. Upon receiving the Beacon frame, all nodes set their NAV to CFPMaxDuration and wait for control/data frame from the AP. Now the WLAN is operating in the PCF mode.

Put the WLAN in the DCF mode: Upon the expiry of the previously announced CFPMaxDuration period in a Beacon frame, the AP broadcasts a CF End frame . When nodes receive a CF End frame, they reset their NAV to 0, thereby entering into the DCF mode of operation.

Sample Solution

Q3. [21] (Link Layer)

A BSS (Basic Service Set) has only two nodes as shown in the figure below: an AP and one laptop with a WiFi interface with a physical-layer transmission rate of 1 Mbps.



Assume that the laptop is transmitting DATA frames containing 118 bytes of IP layer data.

The lengths of RTS, CTS, and ACK frames are 20, 14, and 14 bytes, respectively.
The total length of all the control information in the header of a DATA frame is 34 bytes.

Assume that the lengths of SIFS and aSlot intervals are 20 μs and 10 μs, respectively.

a) [2] Calculate the value of the DIFS interval?

DIFS = SIFS + aSlot + aSlot = (20 + 10 + 10) μs = 40 μs.

b) [3] What is the value of the **duration** field in the CTS frames transmitted by the ~~laptop~~? (It should have been AP instead of laptop. All assumptions will be accepted.)

Duration = Time to transmit (one DATA + one ACK) + 2*SIFS
= Time to transmit (152 (=34 + 118) bytes + 14 bytes) + 2*20 μs
= Time to transmit 166 bytes + 40 μs
= Time to transmit 1328 bits + 40 μs
= 1328 μs + 40 μs
= 1368 μs

c) [12] What is the maximum long-term data rate available to the IP layer, if the laptop is operating in the **handshake mode of DCF**? Show the details of your calculations.

As shown in the left-hand figure (DCF mode with handshake) below, duration in CTS = 1368 μs, as calculated before. The cycle time for repetitive transmission by the laptop, denoted by Tc, is as follows:
Tc = DIFS + Time to transmit (one RTS frame + one CTS frame) + one SIFS + duration in CTS
= DIFS + Time to transmit (20 x 8 bits + 14 x 8 bits) + 20 μs + 1368 μs
= 40 μs + 272 μs + 20 μs + 1368 μs = 1700 μs
In 1700 μs, the IP layer can send 118x8 bits of data.
In 1 second, the IP layer can send 118 x 8/1700 Mbits of data = 555294 bits.

Sample Solution

Max data rate of the IP layer = 555 Kbps (approximately)

Additional space for all calculations needed for Q3.

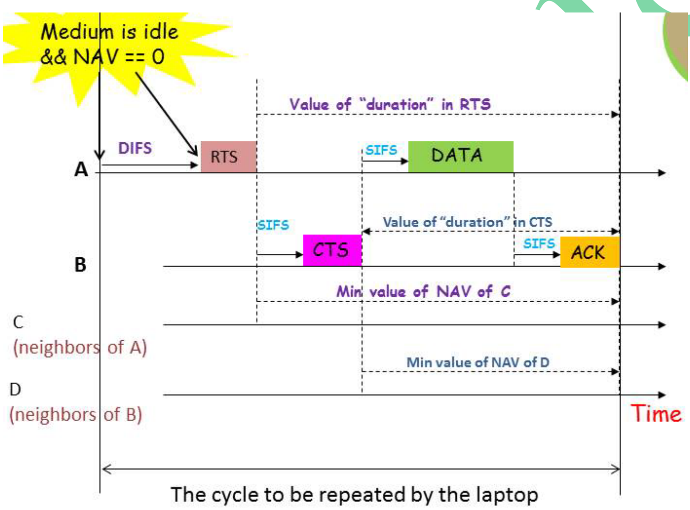
d) [4] What is the maximum long-term data rate available to the IP layer, if the laptop is operating in the **without-handshake mode of DCF**? Show the details of your calculations.

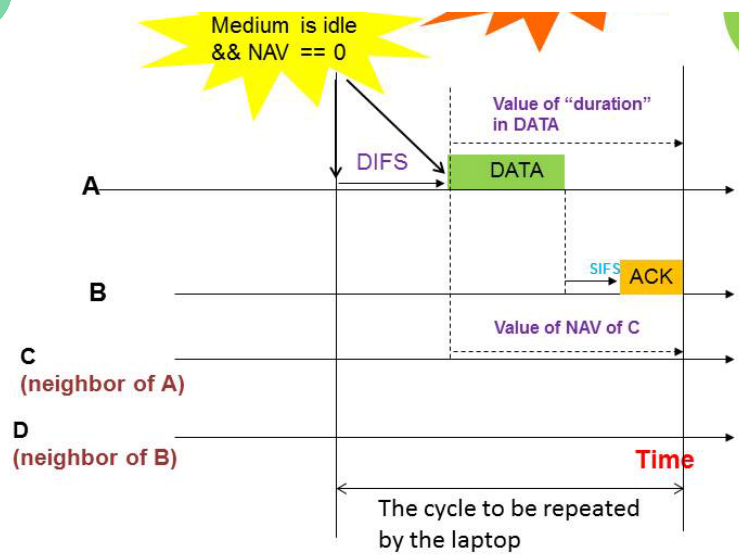
As shown in the right-hand (DCF mode without handshake) below, the cycle time for repetitive transmission by the laptop, denoted by Tc, is as follows:

Tc = DIFS + Time to transmit (one DATA + one ACK) + one SIFS
= DIFS + Time to transmit (152 x 8 bits + 14 x 8 bits) + one SIFS
= DIFS + Time to transmit (1328 bits) + one SIFS
= 40 μs + 1328 μs + 20 μs = 1388 μs

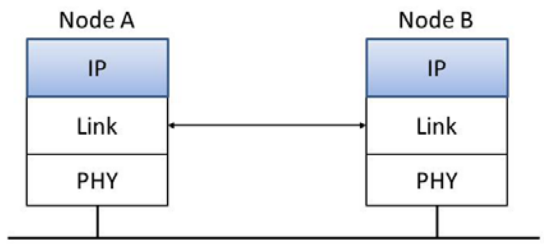
In 1388 μs, the IP layer can send 118x8 bits of data.
In 1 second, the IP layer can send 118 x 8/1388 Mbits of data = 680115 bits.
Max data rate of the IP layer = 680 Kbps (approximately)

Solution

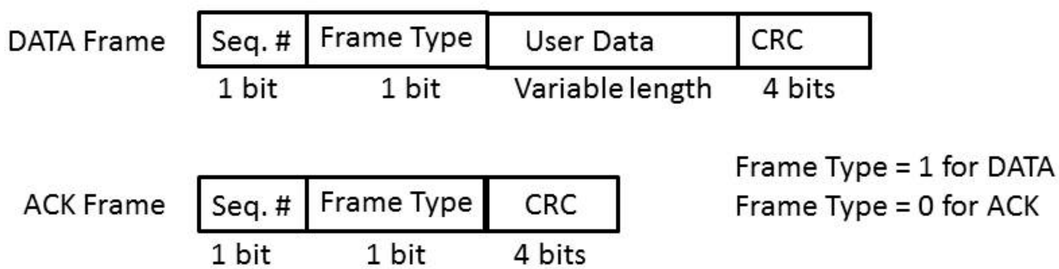




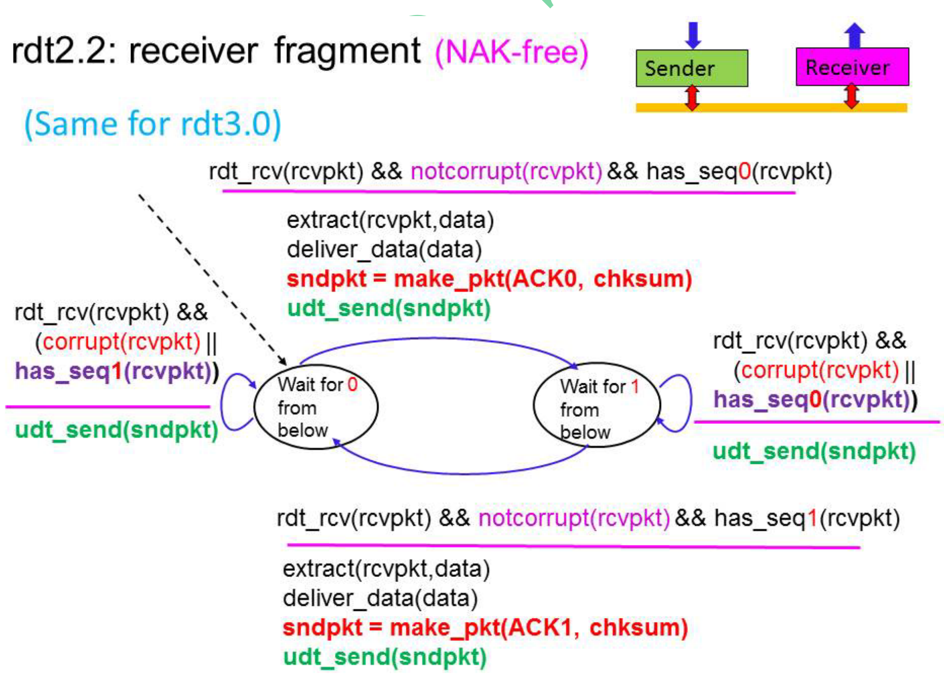
Q4. [20] (Link Layer)



In the above figure, the Link Layers use the **rdt 3.0** protocol to communicate. For simplicity, assume that node A is the sender and B the receiver. The formats of the DATA and ACK frames have been shown below. Bit errors are detected by means of CRC.



a) [5] Show the receiver's behavior in the form of a finite-state machine. You may use the following template. The level of details considered in class is good enough.



b) [15] Assume that the sender and the receiver use the generator pattern **10011** to compute CRC bits.

Note that CRC bits are computed from **<Seq. #, Frame Type, User Data>** -- and NOT just User Data -- because you want to know if the header as well is corrupted.

The receiver receives a frame given by the bit pattern 011010110111110 in the **"Wait for 0 from below"** state. Now answer the following questions.

- Did the receiver detect bit errors? Do the actual calculations on the following pages. Provide and justify your answer in the box given below.

  The result of dividing 011010110111110 by the generator 10011 produces 0000 remainder. Therefore, the receiver does not detect bit errors.

- If the receiver delivers data to the IP layer, what data is delivered to the IP layer? Provide and justify your answer in the box given below.

  Parse the frame 011010110111110 according to the format <Seq. #, Frame Type, User Data>. Since the receiver did not detect bit errors, the error-free data is 101011011, which is delivered to the IP layer.

- If the receiver sends a frame back to the sender, what bit pattern represents the frame? Provide and justify your answer in the box given below. Do all your calculations on the following pages.

  The receiver sends back an ACK frame with sequence number 0 and the corresponding CRC bits: <0, 0, CRC>. Essentially, generate four bits of CRC for 00, and the result is 0000. Therefore, the complete frame is 000000.

Sample Solution

Space for all calculations needed for 4(b)

Find the CRC bits by dividing the received frame (11010110111110) by the generator pattern 10011.

```
11010110111110
10011,,.,,....
-----,,.,,....
 10011,.,,....
 10011,.,,....
 -----,.,,....
  00001.,,....
  00000.,,....
  -----.,,....
   00010,,....
   00000,,....
   -----,,....
    00101,....
    00000,....
    -----,....
     01011....
     00000....
     -----....
      10111...
      10011...
      -----...
       01001..
       00000..
       -----..
        10011.
        10011.
        -----.
         00000
         00000
         -----
          0000 = Remainder
```

As an alternative to the procedure executed above, set the CRC bits in the received frame to all zeros, compute the new CRC bits, and evaluate if the computed CRC bits are equal to the CRC bits received in the frame.

Both the approaches are acceptable.

Sample Solution

Space for all calculations needed for 4(b)

Divide 000000 by 10011. Since no bit in 000000 is a 1, the input pattern will never be XOR-ed with the divisor (10011). Therefore, the remainder will be 0000.

Sample Solution