LEBANESE INTERNATIONAL UNIVERSITY

الجامعة اللبنانية الدولية

School of Engineering
Department of Computer and Communication Engineering
Semester: *Fall 2012 – 2013*
Course: CENG415 – Communication Networks

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Midterm Examination
Time: 90 minutes

Student Name: ______________________________ **Student ID:** ________________ **Section:** ____

There are **3 questions** in the booklet each has several parts, please answer all parts of the **3** questions to the best of your ability.

Marking Scheme:

Questions	Weight	Mark	Covered PC	Coverage %
Question 1	**30 points**		**PC-1, PC-3, PC-5**	**60, 30, 10**
Question 2	**35 points**		**PC-1, PC-2, PC-3**	**20, 70, 10**
Question 3	**35 points**		**PC-1, PC-2, PC-5,**	**20, 50, 30**
Total	**100 points**			

1. **This booklet contains 12 pages including this one. Make sure all these pages are attached.**
2. **Closed book examination.**
3. **Do not take the staple out. The exam booklet must remain intact.**
4. **Cheating penalty will be an "F" grade on the exam.**
5. **Programmable calculators are not allowed.**
6. **Mobile phones/devices are to be turned off and stowed away.**

Good luck

Question 1: Internet and delays (30 points)

Part A: General questions (14 points)

1. What is the difference between circuit-switching networks and packet-switching networks? Give an example for each type of networks. (4 points)

A circuit-switching network can guarantee a certain amount of end-to-end bandwidth for the duration of a call because it has a dedicated circuit per call. Packet-switching networks cannot make any end-to-end guarantees for bandwidth.
Internet uses packet switching. Telephony network is a circuit switching network.

2. List the 5 layers of the internet model from top to down. What are the layers implemented in the routers? Why it is not necessary to have all 5 layers in such type of devices? (4 points)

Application layer; Transport layer; Network layer; Link layer; Physical layer.
Network, link layer and physical layers are only implemented in a router because it is a core-network element.

3. Fill in the blanks using one of the following terms: *transmission; segment; protocols; P2P; message; propagation; datagram; transmission rate; processing; client-server; Tier-1; queuing*. (6 points)
   Each blank is worth 0.5 point.

   a. An application-layer packet is called a _______________________. A transport-layer packet is called a _______________________. A network-layer packet is called a _______________________.

   b. End systems, packet switches and other pieces of the Internet run _______________________ that control the sending and receiving of information within the Internet.

   c. _______________________ ISPs are also known as Internet backbone networks.

   d. The _______________________ of a link is measured in bits/second.

   e. The application architecture dictates how the application is structured over various end systems. There are two predominant architectural styles used in practice: _______________________ architecture and _______________________ architecture.

   f. The total nodal delay for a router is a sum of _______________________delay, _____________________ delay, ___________________ delay, and _______________________ delay.

   a: message, segment, datagram (in this order) *b: protocol*

c: Tier-1

d: transmission rate

e: client-server, P2P (any order is correct)

f: transmission, propagation, processing, queuing (any order is correct)

<u>Part B: Delay calculation</u> (16 points)

1. Suppose that two nodes A and B are connected by 2500 km optical fiber with a propagation speed of 2.5×10^8 m/sec.

   a. Calculate the propagation delay between A and B? What is the round trip time (RTT) in this case? (3 points)

      $T\_prop = 2500.10^3 / 2.5x10^8 = 10$ ms
      $RTT = 2 * T\_prop = 20$ ms

   b. Calculate the total time required to transmit a file of 10 Kbytes from A to B. Suppose that the file is transmitted continuously with a transmission rate of 1 Mbps. (3 points)

      $T\_trans = 8*10.10^3 / 1.10^6 = 80$ ms
      $T\_tot = T\_prop + T\_trans = 90$ ms

   c. Now suppose that data are transmitted between A and B using packets of size 1000 bytes with a transmission rate of 1 Mbps. Suppose that the source do not add any header to the packets but it should wait one RTT before sending the next packet. Each packet has a processing delay of 0.1 ms and a queuing delay of 2 ms. What is the total time required to transmit a file of 10 Kbytes from A to B? (3 points)

      *10 packets are needed to transmit the file. Each packet needs a transmission time of $8*1000/1.10^6 = 8$ ms, a propagation time of 10 ms, a processing delay of 0.1 ms and a queuing delay of 2 ms. Plus we need to wait 9 RTTs between the 10 packets. Total time= 10 *20.1 + 9* 20 = 381 ms*

2. Suppose two hosts, A and B, are separated by 1500 km and are connected by a direct link of rate R = 3 Mbps. Suppose the propagation speed over the link is 2.5×10^8 m/s. Consider sending a file of 700 Mbytes from A to B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time? (3 points)

   The maximum number of bits in the link is obtained when d_trans = d_prop → L_max = R.d/c = 18000 bits.

3. Consider the queuing delay in a router buffer with infinite size. Assume that each packet consists of L bits. Let R (bits/sec) denote the rate at which packets are pushed out of the queue.
    a. Suppose that the packets arrive periodically every L/R seconds. What is the average router queuing delay? (2 points)

    The average queuing delay is zero because by the time a packet arrives to the router, the previous packet would have left the queue.

    b. Suppose that N packets arrive simultaneously every (L/R).N seconds. What is the average router queuing delay? (2 points)

    The first packet will be sent directly → queuing delay=0
    The second packet will have to wait that the first packet is sent → queuing delay = L/R
    *The third packet will have to wait that the two first packets are sent → queuing delay = 2*L/R*
    *... The queuing delay of the Nth packet is (N-1)*L/R.*
    In average, the queuing delay is (1/N) (0+ L/R + 2L/R + ... +N)= (1/N)(L/R)*N*(N-1)/2 = (L/R)*(N-1)/2 seconds.*

<u>Question 2: Application layer</u> (35 points)

<u>Part A: Multiple choices</u> (10 points)

Choose the correct answer. Only one answer is correct in each question. (1 point for each question).

1. HTTP with persistent connections
    a. requires 2 RTTs per object
    b. requires the server to open a new TCP connection to send a response
    c. provides higher security
    d. none of the above CORRECT

2. Cookies enable a Web server to
    a. infect a user's machine with malware
    b. track a user's activity at its own Web site CORRECT
    c. know all previous Web pages visited by the user
    d. learn your full name, e-mail address and credit card information

3. IMAP
    a. is built on top of POP3
    b. is stateless across sessions
    c. allows users to create remote folders CORRECT
    d. is not compatible with SMTP

4. FTP
    a. uses TCP as transport layer protocol
    b. provides a reliable, connection-oriented service for transferring files
    c. uses port numbers 20 and 21
    d. all of the above CORRECT

5. In a DNS resource record RR (name, value, type, ttl), if the type = A that means, name and value represent respectively:
    a. Domain and hostname of authoritative name server
    b. Alias for a canonical name and the canonical name
    c. Hostname and IP address CORRECT
    d. Mail server and IP address

6. The method POST of HTTP is used by a browser to:
    a. request an object with empty entity body
    b. request an object with a fill out form CORRECT
    c. upload an object to a given path
    d. delete an object in a given path

7. To get an IP address for a given web page, local DNS server communicates first with the:
    a. Authoritative DNS server
    b. TLD DNS server
    c. Web server
    d. Root DNS server CORRECT

8. The response time of a web page with N objects for non persistent HTTP is equal to:
    a. N. RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$
    b. (2N). RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$ CORRECT
    c. 2. RTT + transmission time of the largest object
    d. (N+1). RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$

9. The response time of a web page with N objects for persistent HTTP without pipelining is equal to:
    a. N. RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$
    b. (2N). RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$
    c. 2. RTT + transmission time of the largest object
    d. (N+1). RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$ CORRECT

10. The response time of a web page with N objects for persistent HTTP with pipelining is equal to:
    a. N. RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$
    b. (2N). RTT + $\sum_{i=1}^{N} \text{transmissionTime}_i$
    c. 2. RTT + transmission time of the largest object CORRECT

d. (N+1). RTT + $\sum_{i=1}^{N}$ $\text{transmissionTime}_i$

Part B: Comprehensive questions (25 points)

1. The DNS service in the Internet is distributed by design. Alternatively, DNS could have a centralized design instead. List two disadvantages of the centralized design. (2 points)

   Single point of failure, capacity, latency etc.

2. List two advantages of deploying a Web cache (i.e. a proxy server) in an institutional network. (2 points)

   Low latency, outbound traffic, low connection cost etc.

3. Determine what transport layer protocol (TCP or UDP) you would use for each of the following applications and justify your choice. (5 points)

   a. File Transfer:

   b. Live video streaming:

   c. DNS server:

   d. Web browser:

   e. VoIP:

   TCP for a and d (these applications require reliable transmission), UDP for b,c,e (these applications require quick transmission)

4. A user in Beirut, connected to the internet via a 2 Mbps connection retrieves a 25 Kbytes web page from a web server in Paris, where the page references 3 images of 200 Kbytes each. Assume that the one way propagation delay is 20 ms.

   a. How long does it take for the page (including images) to appear on the user's screen, assuming non-persistent HTTP using a single connection at a time? (3 points)

   RTT= 2 one way propagation delay = 40 ms*
   *Time to download the web page with non-persistent HTTP = 8 RTT + time transmission of the base file (25 Kbytes) + time transmission of the 3 images (200 Kbytes each) = 8*40 ms +* $(8*25.10^3/2.10^6) + (3*8*200.10^3/2.10^6) = 322.5$ *ms*

b. What would become the time for the page (including images) to appear on the user's screen if he used persistent HTTP without pipelining in place of non-persistent HTTP? (2 points)

Time to download the web page with persistent HTTP without pipelining = 6 RTT + time transmission of the base file (25 Kbytes) + time transmission of the 3 images (200 Kbytes each) = $6*40\ ms + (8*25.10^3/2.10^6) + (3*8*200.10^3/2.10^6) = 242.5\ ms$

5. You send an e-mail message to your friend amir@gmail.com with a copy to your other friend marco@live.com. The subject of the message is "*Pizza*" and the text of the message is "*Let's go out for a pizza tonight*".

a. Assuming your e-mail address is student@liu.edu.lb and that your mail user-agent is configured to use the mail server liu.edu.lb, write the complete SMTP exchange between your user agent and the mail server of your friends, including the whole body of the message. (2 points)

From: student@liu.edu.lb
To: amir@gmail.com
CC: marco@live.com
Subject: Pizza

Let's go out for a pizza tonight.

b. Name 2 protocols that your friends can use to access their inbox and read the mail message. (2 points)

2 out of the 3 protocols: POP3, SMTP and HTTP.

c. What do you have to do in order to send a photo of the pizza attached to your mail message? (1 point)

I should use MIME (Multimedia Mail Extension).

6. You want to register your company "CENG" website (ceng.org with IP address "IP1") and mail server (mail.ceng.org with IP address "IP2") into the internet.

a. What type of DNS server contains the records for the IP addresses of the website and the mail server of your company? Give the two corresponding resource records. (3 points)

Authoritative DNS server.
(ceng.org, IP1, A)
(mail.ceng.org, IP2, MX)

b. If an internet user is searching for the company website's IP for the first time, what are in order, the DNS servers that the user's local DNS server need to query? (3 points)

Root DNS server, Top Level Domain (TLD) DNS server and authoritative DNS server.

<u>Question 3: Transport layer</u> (35 points)

<u>Part A: General questions</u> (14 points)

1. What is the need for the UDP? Would it not have been enough to just let user's processes send IP packets without using a transport protocol? Explain in a few sentences. (2 points)

UDP is used for multiplexing. In fact, IP packets contain IP addresses, which specify a destination device. UDP packets contain a destination port. This information is essential so they can be delivered to the correct process within the destination device.

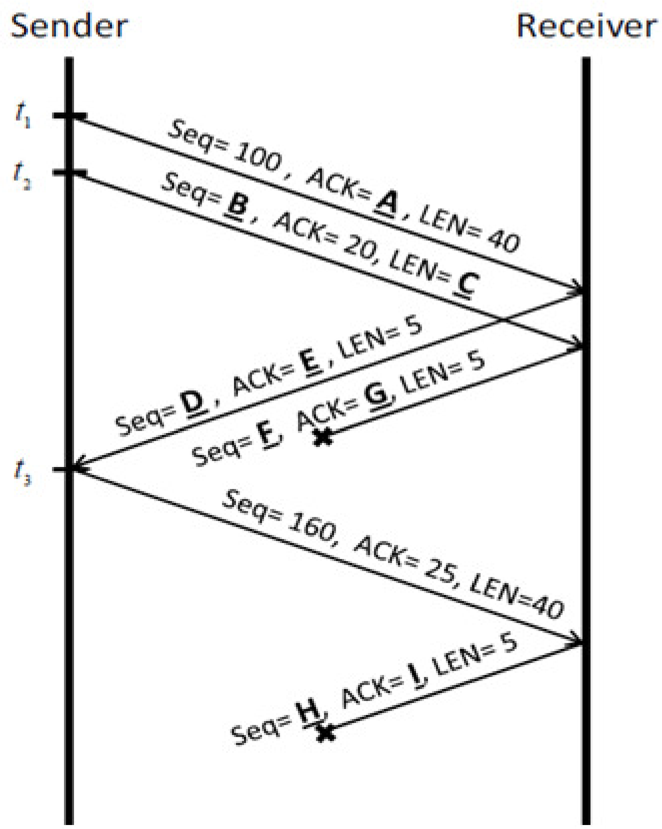
2. If at a certain time, an HTTP server is responding to N requests, how many sockets are open at the server? (2 points)

   N+1 sockets (N sockets for the N requests and 1 socket for listening).

3. TCP protocol maintains two key dynamic values per connection: a round-trip estimation and congestion window size. Why these 2 values are important for TCP protocol? Describe briefly how each value is computed and how is it used by TCP. (4 points)

   Round trip estimation is used by TCP to set the RTO (retransmission timeout) and the congestion window size to set the width of the segments to send (taking into consideration the congestion in the network).

4. Complete the missing sequence numbers (Seq), acknowledgment numbers (ACK), and segment length (LEN) in the following TCP connection. Each missing value is worth 1 point. (6 points)
   We assume that:
   - No timeouts occur at the receiver.
   - The sender starts the timer at t1.
   - The connection is full duplex (bi-directional data flow in same connection).
   - The sender and the receiver have always data to transmit.
   - There are no delayed acknowledgements at the sender or the receiver.



A	20
B	
C	20
D	
E	
F	
G	160
H	
I	

B = 140; D = 20; E = 140; F = 25; H = 30; I = 200

Part B: Sliding window protocols (12 points)

1. Consider the sliding window protocol in Figure 3-1 below. Does this figure indicate that Go-Back-N is being used, Selective Repeat is being used, or there is not enough information to tell? Explain your answer briefly. (2 points)

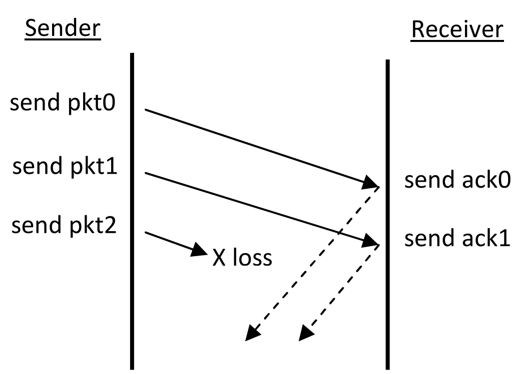


Figure 3-1

There is not enough information to tell, since both GBN and SR will individually acknowledge each of the first two messages as they are received correction.

2. Consider the sliding window protocol Figure 3-2 below. Does this figure indicate that Go-Back-N is being used, Selective Repeat is being used, or there is not enough information to tell? Explain your answer briefly. (2 points)

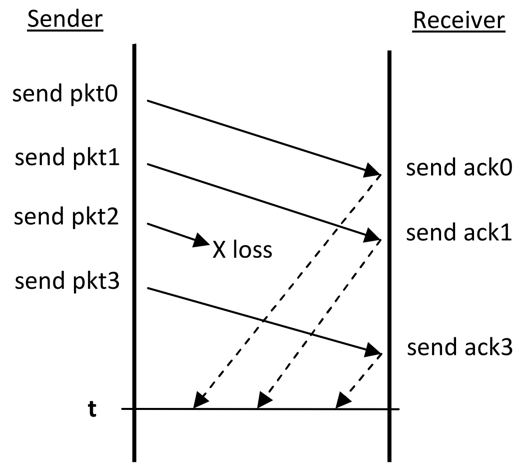


Figure 3-2

This must be the SR protocol since pkt3 is acknowledged even though pkt2 was lost. GBN uses cumulative acknowledgments and so would not generate an ACK 3 if pkt2 was missing.

3. Consider Figure 3-2 again. Suppose the sender and receiver windows are of size N = 4 and suppose the sequence number space goes from 0 to 9. Show the position of the sender and receiver windows over this sequence number space at time **t** (the horizontal line). (2 points)

Sender: $\boxed{0\ 1\ 2\ 3}$ 4 5 6 7 8 9

Receiver: 0 1 $\boxed{2\ 3\ 4\ 5}$ 6 7 8 9

4. Following is a list of all possible future events at the sender resulting from the acknowledgments currently propagating from receiver to sender at time **t** (Figure 3-2).
For each of these events, indicate the action take at the sender only (4 points).

- The next event is ack0 received:

- The next event is ack1 received (ack0 is lost):

- The next event is ack2 received (ack0 and ack1 are lost):

- The next event is a timeout (ack0, ack1, and ack3 are lost):

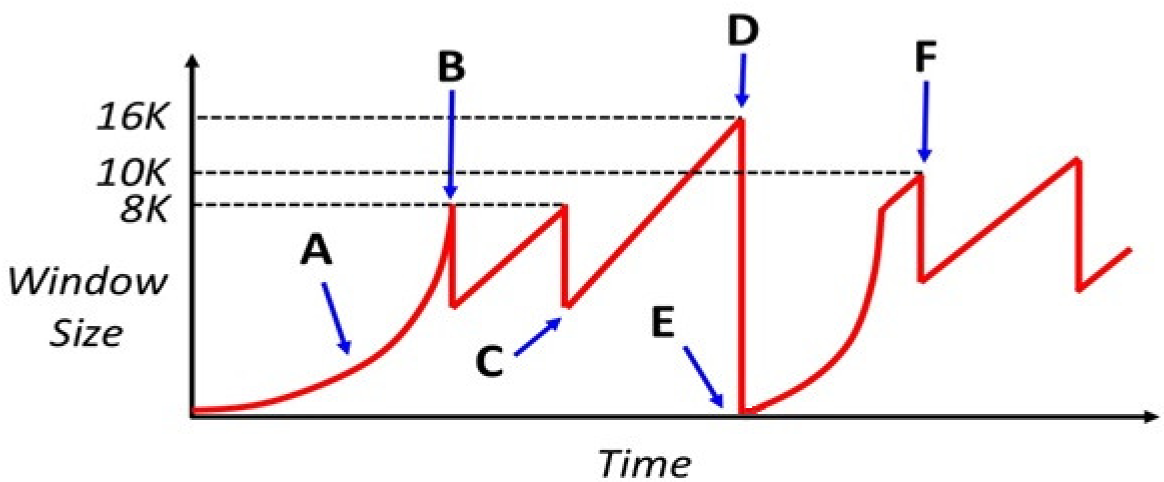
- *If the next event is ack0 received, then the sender will advance the window and send pkt4.*
- *If the next event is ack1 received (ack0 is lost), then the sender will note that pkt1 has been acknowledged but will not advance the window and will not send anything.*
- *If the next event is ack2 received (ack0 and ack1 are lost), then the sender will note that 2 has been acknowledged but will not advance the window and will not send anything.*
- *If ack0, ack1, and ack3 are lost the next event will be a timeout, and since no ACKs have been received the sender will resend pkt0, pkt1, pkt2 and pkt3.*

5. Suppose that it take 1 ms to send a packet, with a 10 ms one-way propagation delay between the sender and receiver. The sliding windows size is again $N = 4$. What is the channel utilization? (2 points)

   The utilization is 4/(1+20)= 0.19 or 19%

Part C: TCP congestion control (9 points)

Consider the following graph of TCP throughput (not drawn to scale), where the y-axis describes the TCP window size of the sender.



1. The window size of the TCP sender decreases at several points in the graph, including those marked by **B** and **D**.

   a. Name the event at **B** that occurs that causes the sender to decrease its window. (1 point)

      Triple duplicate ACK

   b. Does the event at **B** necessitate that the network discarded a packet? Explain your answer. (1 point)

      No. It could be due to reordering due to queuing or asymmetric paths.

   c. Name the event at **D** that occurs that causes the sender to decrease its window. (1 point)

Timeout

d. Does the event at **D** necessitate that the network discarded a packet? Explain your answer. (1 point)

No. Congestion in either direction could cause RTT > RTO (retrans. timeout).

e. For a lightly-loaded network, is the event at **D** more likely or less likely to occur? (1 point)

Less likely

2. Consider the curved slope labeled by point **A**. Why does the TCP window behave in such a manner, rather than have a linear slope? (1 point)

This "slow-start" period quickly discovers the maximum acceptable throughput that the path supports – otherwise, AI (additive increase) could take too long (each a full RTT).

3. Assume that the network has an MSS of 1000 bytes and the round trip time between sender and receiver of 100 milliseconds. Assume at time 0 the sender attempts to open the connection. Also assume that the sender can "write" a full window's worth of data instantaneously, so the only latency you need to worry about is the actual propagation delay of the network.

a. How much time has progressed by point **B**? (1 point)

1 RTT (TCP handshake) + 3 RTT in slow-start (1, 2, 4, 8 MSS) = 4 RTT = 400 ms

b. How much time has progressed between points **C** and **D**? (1 point)

Additive increase from 4 MSS to 16 MSS = 12 periods of RTT = 1.2 s

c. How much time has progressed between points **E** and **F**? (1 point)

First: slow start to 8K window size (1->2, 2->4, 4->8 MSS), then AI from 8 to 10 MSS window size (8->9->10 MSS). In total, we have 5 RTT = 500 ms.