MIDDLE EAST TECHNICAL UNIVERSITY
Electrical and Electronics Engineering Department

EE 444 Introduction to Computer Networks
Midterm Exam

April 20, 2016

6 QUESTIONS + BONUS QUESTION
TIME ALLOTTED: 110 minutes.

PLEASE OBSERVE THE FOLLOWING:

- No calculators, **no cell phones**, no electronic equipment is allowed.
- Show all your work, clearly state any assumptions you make.

STUDENT'S

NAME: .....

LASTNAME: .....

NUMBER: .....

SIGNATURE: .....

1	2	3	4	5	6	BONUS	TOTAL
20 pts	20 pts	20 pts	10 pts	15 pts	15 pts	20 pts	120 pts

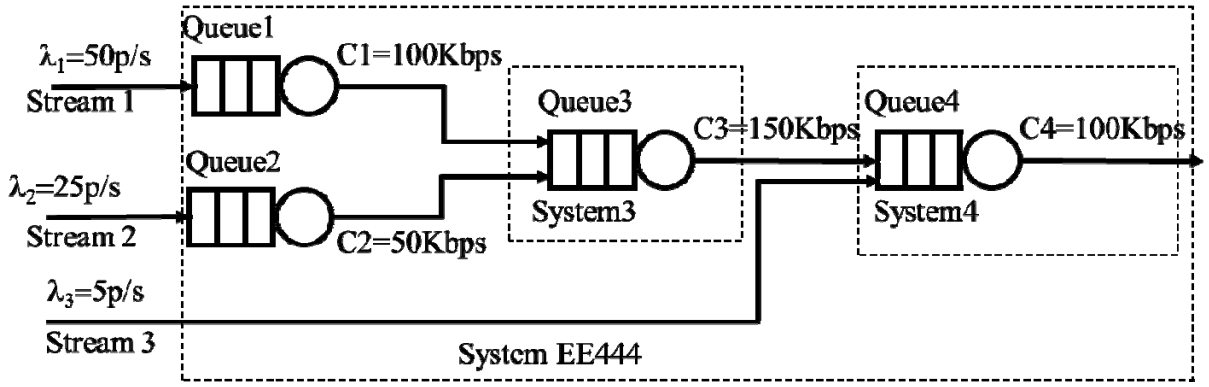
Note that:

For M/M/1 queues: E[Number of items in the system]=ρ/(1-ρ)
E[Time in the system]=1/(μ-λ)

Poisson expression with rate λ (events/unit time): $Pr\ [k\ events\ in\ interval\ of\ t] = \frac{e^{-\lambda t}(\lambda t)^k}{k!}$

$$\sum_{i=0}^{\infty} i(1-x)^{i-1} = \frac{1}{x^2}$$

Q.1 (20pts) Show all your work.
In the queuing system below, Stream 1, Stream 2 and Stream 3 are Poisson arrivals. The packet sizes for Stream 1 and Stream 2 are exponentially distributed with an average of 1000 bits/packet. Stream 3 has **fixed** size packets with a size of 1000bits. **Given information:** The average number of packets in System 4 is 4. All queues have infinite capacity. No packets are dropped.



a) What kind of queuing does System3 have in X/X/X notation? State all properties that you use.

b) What is the probability that System3 server is busy at a given time?

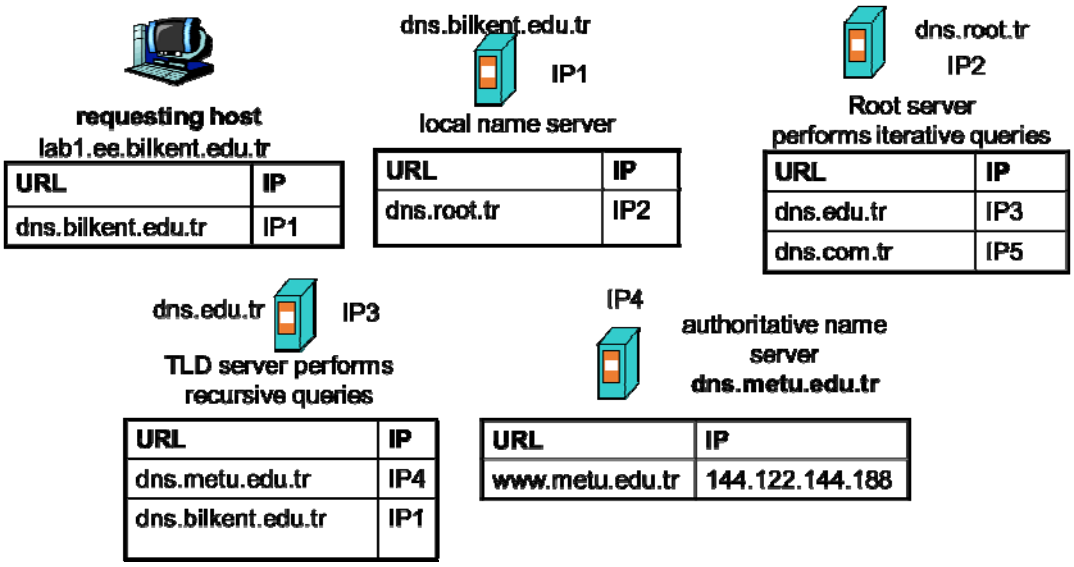
c) What is the average delay of any given packet in System3?

d) What kind of queuing does System 4 have in X/X/X notation? Explain.

e) What is the average delay of a packets on Stream 1 in SystemEE444?

Q.2 (20pts) Parts a) b) c) are independent.

a) Given the following host and DNS server configurations, the host lab1. ee.bilkent.edu.tr wants to browse www.metu.edu.tr. Show the sequence of DNS queries on the given picture below by putting arrows between the machines and clearly numbering the arrows. (TLD: Top Level Domain)



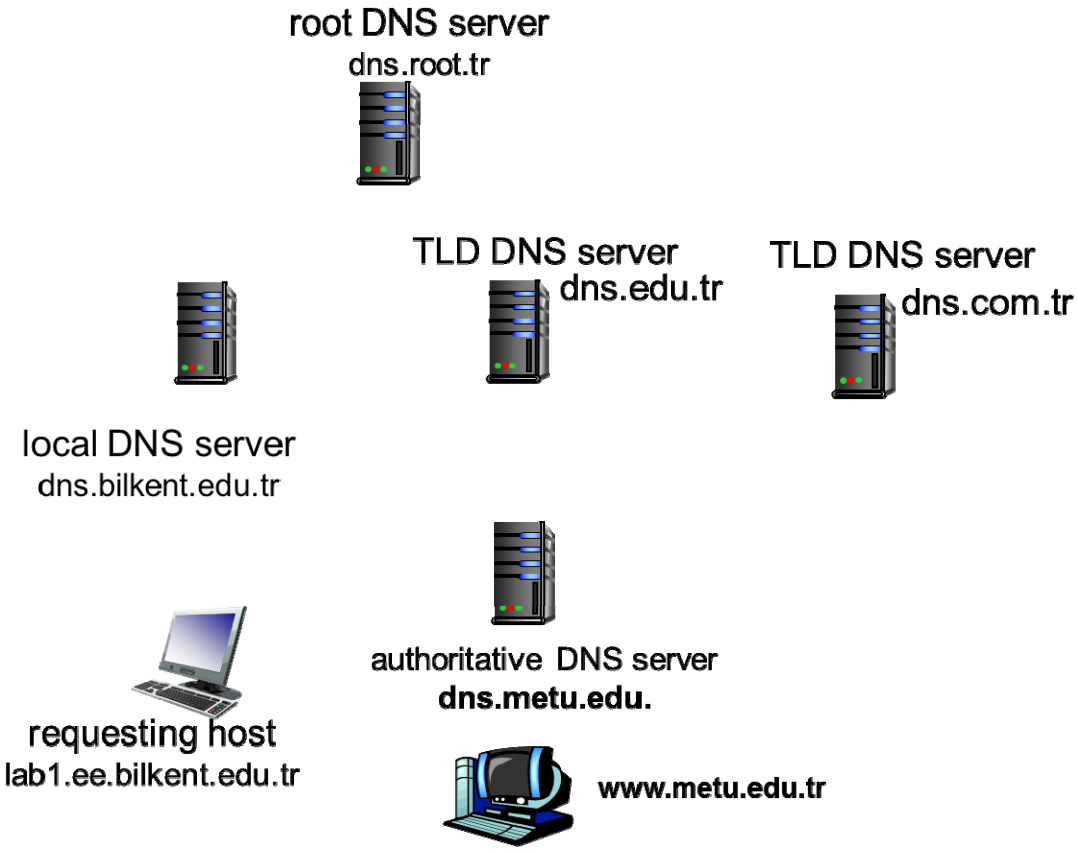
URL	IP
dns.bilkent.edu.tr	IP1

URL	IP
dns.root.tr	IP2

URL	IP
dns.edu.tr	IP3
dns.com.tr	IP5

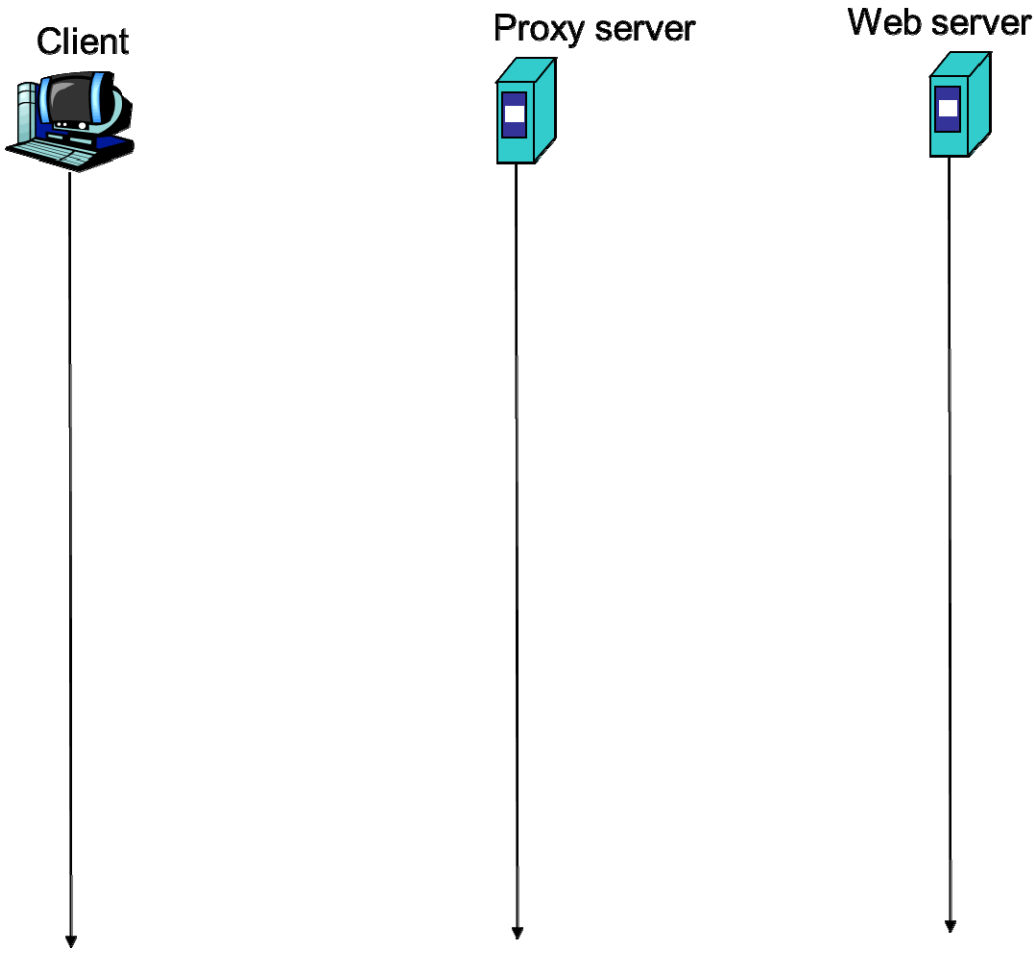
URL	IP
dns.metu.edu.tr	IP4
dns.bilkent.edu.tr	IP1

URL	IP
www.metu.edu.tr	144.122.144.188



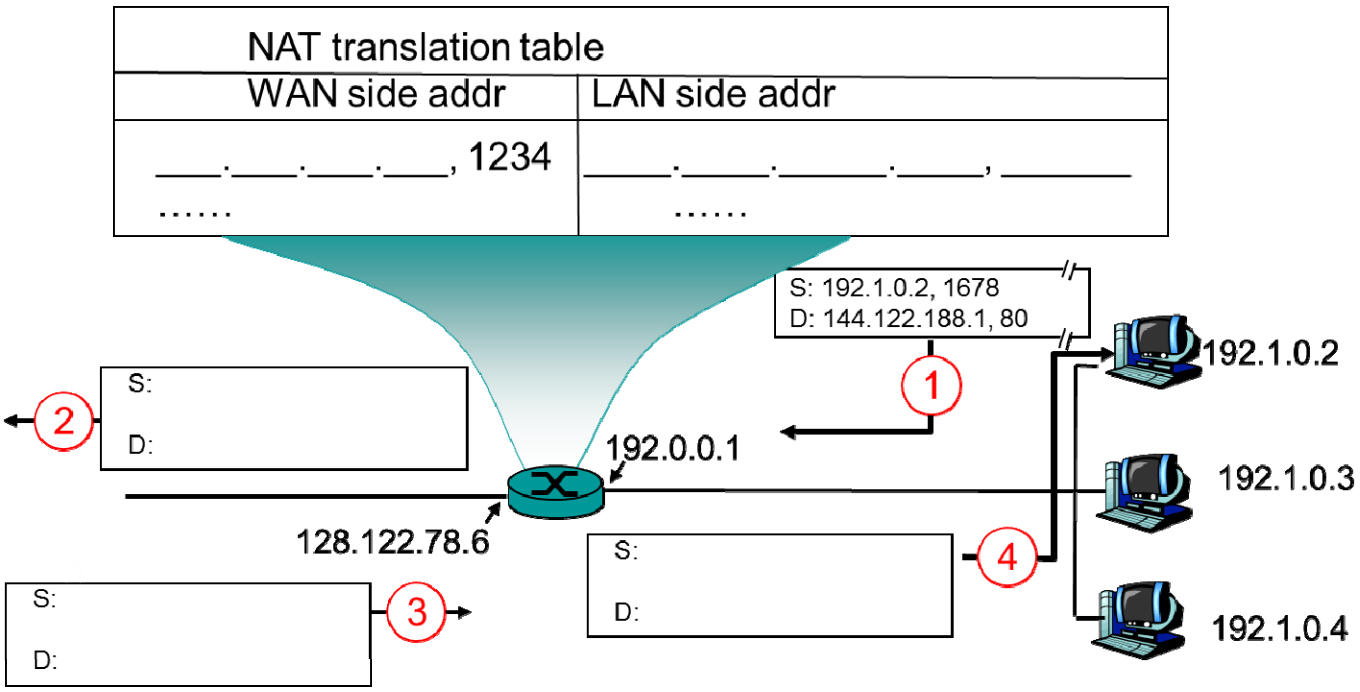
b) A web server hosts web pages that consist of a base html file only. The web service company employs a proxy server to give better service to the clients a campus network. The RTT between a given client and the proxy server is RTTCP=10msec. The RTT between the client and the web server is RTTCS=50msec. The RTT between the proxy server and the web server is RTTPS=90msec.

i) Draw the transmissions and compute the response time when the web page requested by a client is **not** found on the proxy server.



ii) What is the average response time for the client if the files are found on the proxy server with a probability of 0.9?

c) Fill in the blanks in the table and the sent and received packets for the following NAT scenario.



Q.3 (20pts) Consider the parameters and operation of EE444 Reliable Transmission Layer as described below:

- The **one-way** propagation delay from sender to receiver is 10msec, the **one-way** propagation delay from receiver to sender is 10msec.
- Sender sends fixed size packets with transmission time of 5msec/packet.
- Ignore all headers and ACK sizes.
- Both sender and receiver use 4 bit sequence numbers.
- The sender window size WS= 5 packets, the receiver window size WR=5 packets.
- **If there are no packet losses:** The receiver sends a cumulative ACK **for each 3 new packets** received and immediately delivers these 3 packets to upper layer.

The sender starts transmission at time t=0, with the first packet with sequence number=0. **There are no packet losses.**

a) Draw the transmission diagram for the first 11 packets sent (sequence numbers 0 to 10) Show all ACKS for your transmission diagram. Clearly show the timing for all sent packets and ACKs. Clearly show all sequence numbers. Clearly show the range of packets in the sender window and the receiver window whenever they are updated.

b) Assume that the sender goes on sending for a very long time sending a very large number of packets. What is the average efficiency for this transmission? *Hint:* Can you detect a periodic behavior in part a) ?

Q.4 (10pts)

a) For Stop and Wait the probability of failure of data transmission and/or ACK transmission is given as P. Derive the expected number of retransmissions.

b) Draw an example transmission diagram and derive the efficiency of Stop and Wait with the given parameters:

D: Time to transmit a data packet
A: Time to transmit an ACK packet
RTT: Round trip time
T: Time out
P: Probability of failure of data transmission and/or ack transmission (use your answer in part i directly)

Q.5 (15pts)

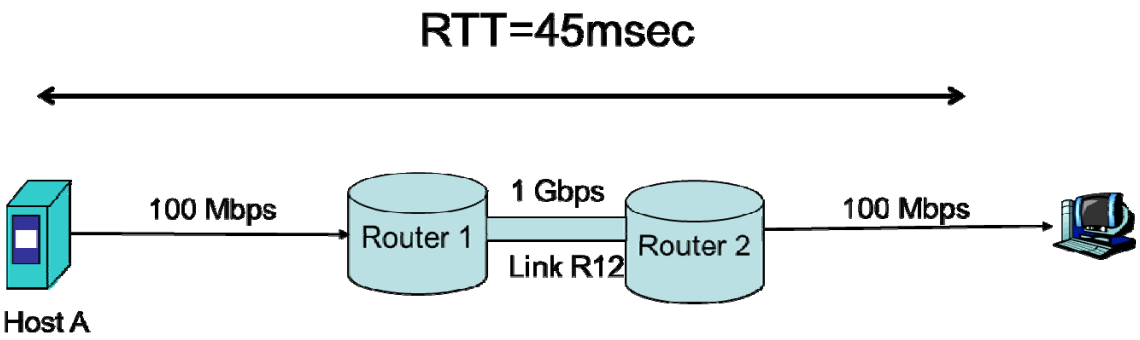
a) For TCP congestion control:
When cwnd is below threshold, which phase is the sender in? How does the cwnd grow?

When cwnd is above threshold, which phase is the sender in? How does the cwnd grow?

When a triple duplicate ACK occurs, describe what happens to the threshold and cwnd. How does the cwnd grow (TCP RENO)?

When a timeout occurs, describe what happens to the threshold and cwnd. How does the cwnd grow?

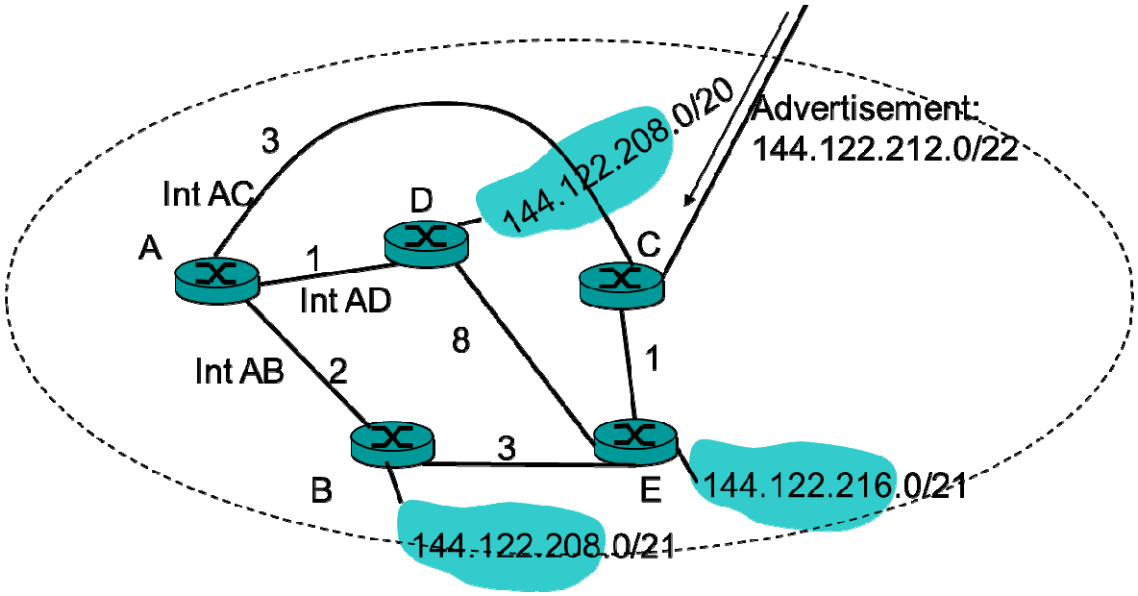
b) Consider the figure below which shows a TCP connection between application processes A and B on host A and Host B respectively. The RTT between A and B is 45 msec. There are a total of 1000 TCP connections on Link R12 including the connection between A and B.



i. What is the average rate of the TCP connection between A and B? State the TCP property that you use.

ii. Assuming no time out events at steady state, at which sending rate (in bps) a triple ACK event happens? What is the window size at this rate?

Q.6 (15pts) Build the routing table for Router A in the following table. Router C is a border gateway router which gets the advertisement of 144.122.212.0/22 from another A.S. The AS of Router A uses OSPF for intra-AS routing.



a) Complete the Logical Routing Table of Router A using the necessary algorithm in the table below. Indicate the routing protocol (s) that is used to construct each entry. Algorithm (Use as many rows as you need):

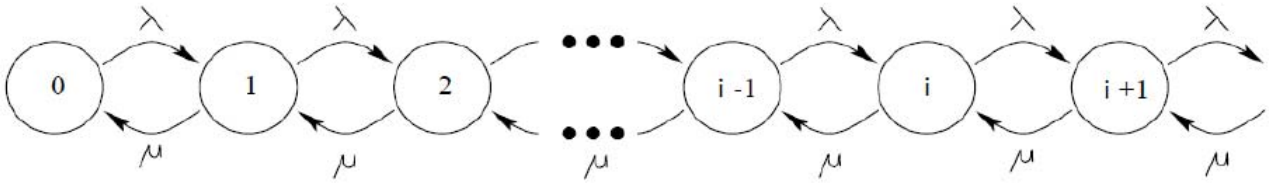
Current set	**D(B), p(B)**	**D(C), p(C)**	**D(D), p(D)**	**D(E), p(E)**

Logical Routing Table:

Subnet	Interface (AB, AC or AD)	Routing protocols (OSPF, BGP)
144.122.208.0./20		
144.122.208.0./21		
144.122.216.0/21		
144.122.212.0/22		

BONUS Question (20 pts)

Recall: π_i :The steady state probability that the system is in state i (has i packets).
Define: $\rho=\lambda/\mu$
For the following continuous time Markov Chain with infinite number of states:



a) Write the balance equations for the system with λ and μ to obtain π_2 interms of π_0 and ρ

b) Obtain a general formulation for π_i in terms of π_0 and ρ

c) Obtain a general formulation for π_i in terms of ρ only.

d) Obtain the formulation for the expected number of packets in the system (leave it as summation).

MIDDLE EAST TECHNICAL UNIVERSITY
Electrical and Electronics Engineering Department

EE 444 Introduction to Computer Networks
Midterm Exam

April 19, 2017

5 QUESTIONS
TIME ALLOTTED: 100 minutes.

PLEASE OBSERVE THE FOLLOWING:

- No calculators, **no cell phones**, no electronic equipment is allowed.
- Show all your work, clearly state any assumptions you make.

STUDENT'S

NAME: .....

LASTNAME: .....

NUMBER: .....

SIGNATURE: .....

1	**2**	**3**	**4**	**5**	**TOTAL**
25 pts	20 pts	20 pts	20 pts	15 pts	100 pts

Note that:

For M/M/1 queues: E[Number of items in the system]=ρ/(1-ρ)
E[Time in the system]=1/(μ-λ)

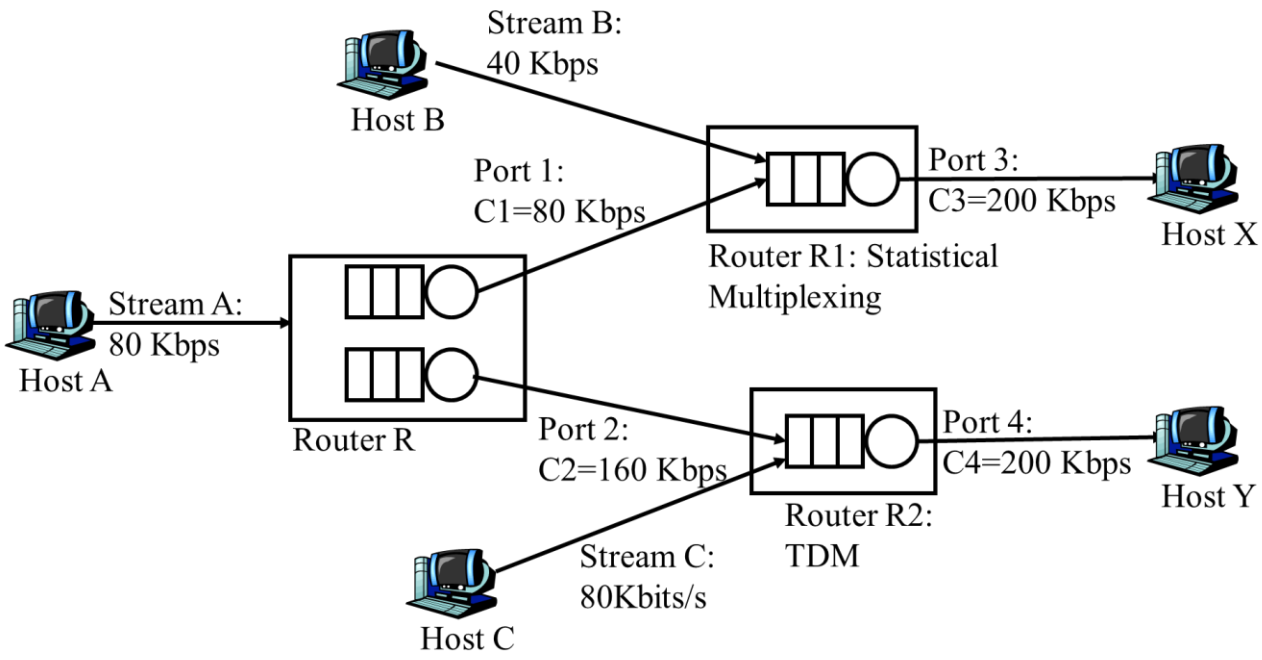
Poisson expression with rate λ (events/unit time): $Pr\ [k\ events\ in\ interval\ of\ t] = \frac{e^{-\lambda t}(\lambda t)^k}{k!}$

$$\sum_{i=0}^{\infty} i(1-x)^{i-1} = \frac{1}{x^2}$$

Q.1 (25pts) Show all your work.

In the network below average packet size is 1000 Bytes/packet (8000 bits/packet).

- Hosts A generates a Poisson packet stream (Stream A) with a rate of 80 Kbits/sec (Kbps). Packet sizes are exponentially distributed. Packets are sent to destination Host X with a probability of 0.4 and t destination Host Y with a probability of 0.6.
- Host B generates a Poisson packet stream (Stream B) with a rate of 40 Kbps. Packet sizes are from an unknown distribution. All packets are sent to Host X.
- Host C generates Poisson a packet stream (Stream C) with a rate of 80 Kbps. Packet sizes are exponentially distributed. All packets are sent to Host Y.
- Router R has 2 outgoing ports. Port 1 has a link capacity of C1=80Kbps. Port 2 has a link capacity of C2=160 Kbps.
- Router R1's outgoing port to Host X has C3=200Kbps link capacity. R1 applies statistical multiplexing. It is observed that the average of the total number of packets in R1 is 1.8 packets.
- Router R2's outgoing port to Host Y has C4=200Kbps link capacity. R2 applies static multiplexing on its outgoing link of 200Kbps. It allocates 2/5 of its capacity to Stream A and 3/5 of its capacity to Stream C.
- No packets are dropped.



a) **For the following questions clearly state which analytical properties you use to achieve the results. You can leave results as fractions with correct units.**

b) What is the average arrival rates of traffic from Host A (λ_A), Host B (λ_B) in packets/sec? What are the service rates of Port 1 (μ_1), Port 2 (μ_2), Port 3 (μ_3) in packets/sec?

c) What is the average delay of a packet from Host A to Host X?

d) What is the average delay of a packet from Host A to Host Y?

e) What is the fraction of time that R2 is serving a packet?

Q.2 (20pts)
Given the following host and DNS server configurations (TLD: Top Level Domain). The local DNS server has caching capability. The web server of cnn.com employs a proxy server with IP address of IP4. The proxy server knows the IP address of the original cnn.com server. Host A and Host B are two computers in the same room.

requesting host B

URL	IP
www.cnn.com	UNKNOWN
local name server	IP1

requesting host A

URL	IP
www.cnn.com	UNKNOWN
local name server	IP1

local name server

URL	IP
www.cnn.com	UNKNOWN
TLD name server	IP2

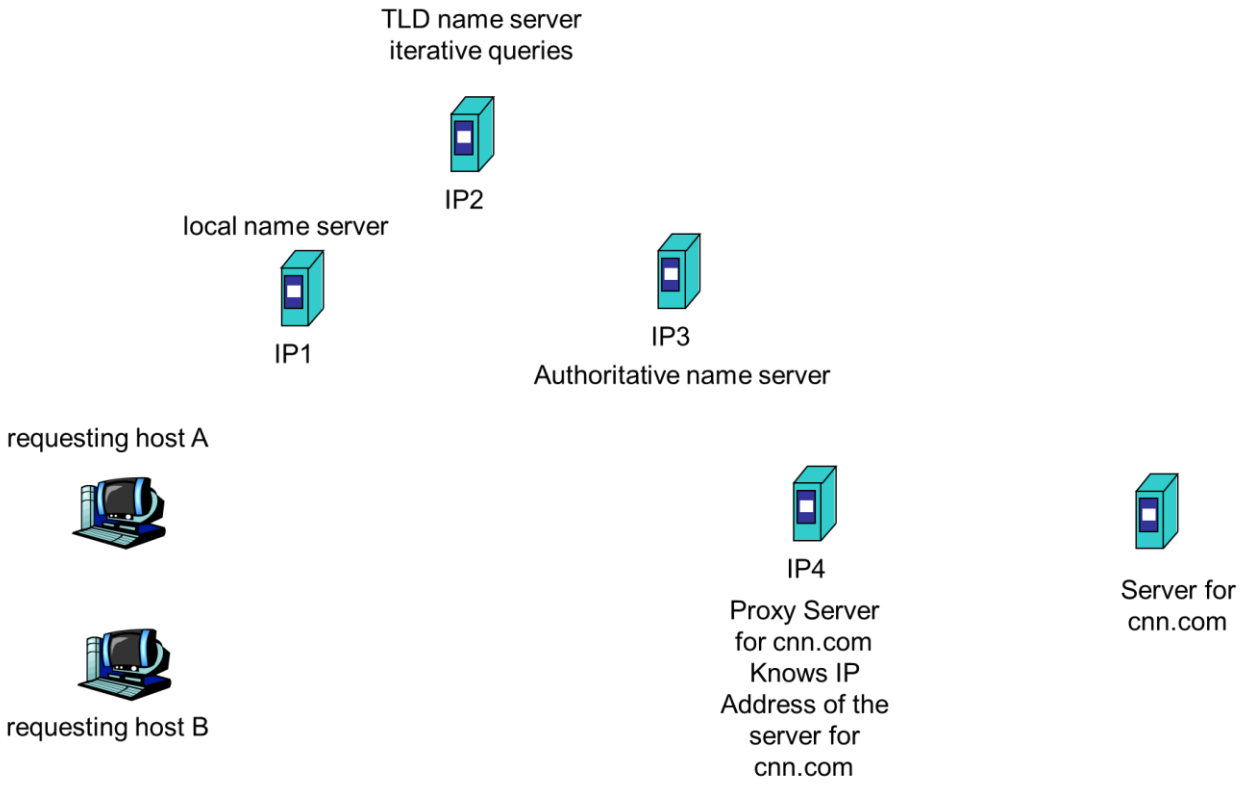
TLD name server iterative queries

URL	IP
www.cnn.com	UNKNOWN
authoritative name server	IP3

Authoritative name server

URL	IP
www.cnn.com	IP 4

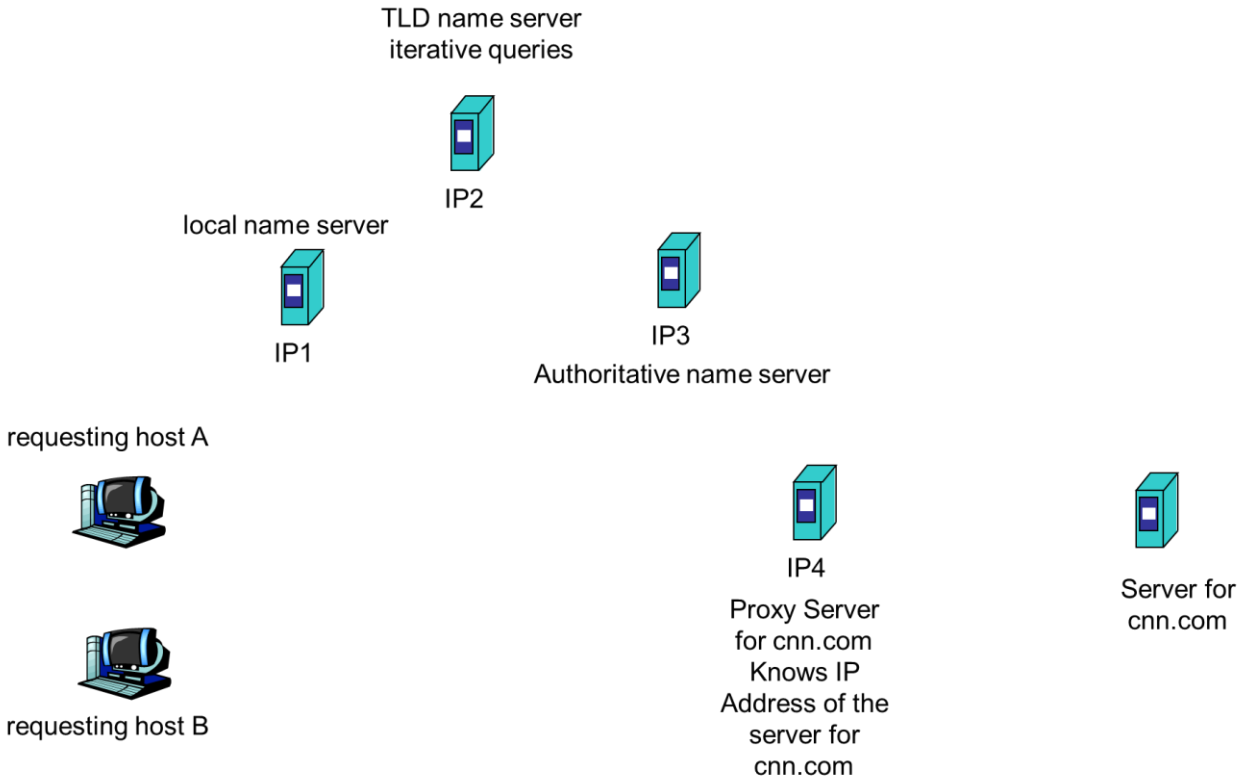
a) Host A wants to browse a web page on cnn.com that consists of a single small base html file. This page does not exist on the Proxy server. Show the sequence of all packet sending events until the page is displayed on the screen of Host A by drawing arrows on the following diagram and clearly numbering the arrows in sequence.



b) The RTTs (sum of two directions) between all pairs of hosts are given in the table below. Compute the total time spent in part a.

Host A/B-local name server:	10 ms	Host A/B - TLD name server:	50 ms	Host A/B- Proxy Server:	80ms
Local name server-TLD name server:	40 ms	Host A/B - Authoritative name server:	150 ms	Host A/B- cnn.com Server:	240ms
TLD name server- Authoritative Name server:	60 ms	Local name server- Authoritative Name server:	160 ms	Proxy Server- cnn.com server:	120ms

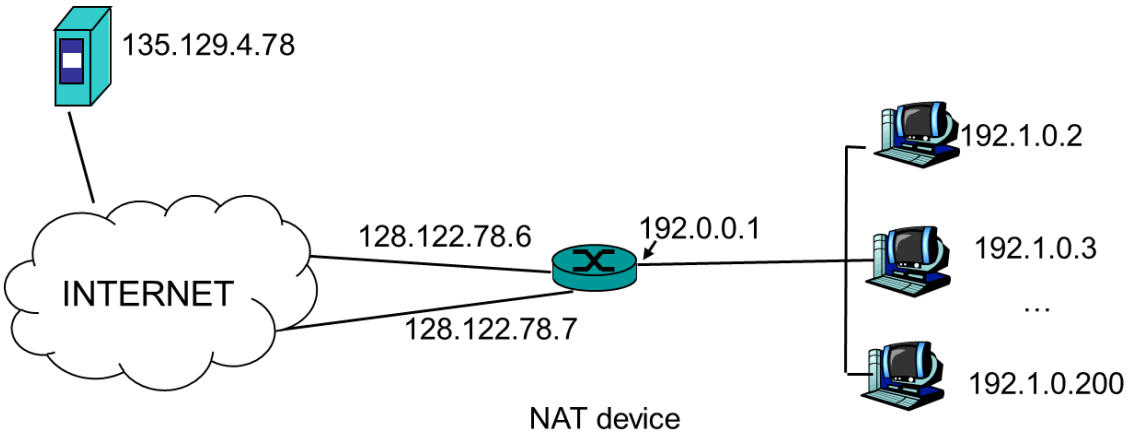
c) After the events in part a) Host B wants to browse the same web page on cnn.com. Show the sequence of all packet sending events until the page is displayed on the screen of Host B by drawing arrows on the following diagram and clearly numbering the arrows in sequence.



d) Compute the total time spent in part c).

Q.3 (20pts) Parts a, b and c are independent

a) The NAT device in the figure below is configured to forward the packets of the hosts with IP addresses 192.1.0.0 to 192.1.0.127 out of Interface with IP address of 128.122.78.6 and the packets of the hosts with IP addresses 192.1.0.128 to 192.1.0.255 out of Interface with IP address of 128.122.78.7.



Three hosts behind the NAT device are communicating with the web server with the IP address of 135.129.4.78.

Packet 1: Host 192.1.0.2 sends an IP packet to the web server on TCP port 1678.

Packet 2: Host 192.1.0.100 sends an IP packet to the web server on TCP port 3491.

Packet 3: Host 192.1.0.200 sends an IP packet to the web server on TCP port 5632.

Fill in all the blank information in the given NAT translation table and in the packet address translation table given below.

NAT Translation Table	
WAN side address	LAN side address
,1234	,1678
,1235	,3491
,1236	,5632

Sent IP packets by the NAT device to Internet	
Packet 1	Source IP, Port:
	Destination IP, Port:
Packet 2	Source IP, Port:
	Destination IP, Port:
Packet 3	Source IP, Port:
	Destination IP, Port:
Received IP packets by the NAT Device from the Internet	**Translated address by the NAT Device to send to the local network**
Source IP, Port:	Source IP, Port:
Destination IP, Port:	Destination IP, Port:
Source IP, Port:	Source IP, Port:
Destination IP, Port:	Destination IP, Port:
Source IP, Port:	Source IP, Port:
Destination IP, Port:	Destination IP, Port:

b) Divide the IP address block 128.130.10100000.0 in subnet blocks in the given order according to X.X.X.X/Y notation and fill in the table below with binary representation to clearly show your work when necessary. The underlined part is given in binary.

Subnet	**Subnet address in X.X.X.X/Y form**
Subnet 1 with 2^{10} hosts	
Subnet 2 with 2^{10} hosts	
Subnet 3 with 2^{9} hosts	
Subnet 4 with 2^{9} hosts	
Subnet 5 with 2^{8} hosts	
Subnet 6 with 2^{8} hosts	
Subnet 7 with 2^{8} hosts	
Subnet 8 with 2^{8} hosts	

c) Given the Routing table with the following logical subnets. Look up the given IP destination addresses showing all of the work of the router using binary representations when necessary. Underlined parts are in binary.

Subnet	**Interface**
145.78. 11100100.0/22	A
145.78. 11100110.0/23	B
145.78. 11100110.0/24	C

i) Packet with destination address : 145.78.11100101.56

ii) Packet with destination address : 145.78.11100110.135

Q.4 (20pts)

A reliable transmission layer has fixed size packets of 1000 bits with 100 bits header. ACK sizes are negligible. The transmission rate is 1Mbps. RTT=5msec. Time out=8msec. The retransmission timer starts when the first bit of the packet is transmitted. The retransmissions are triggered only by time out. The probability of an error in packet transmission or ACK transmission is 0.2. **You can leave your results as fractions with the correct units.**

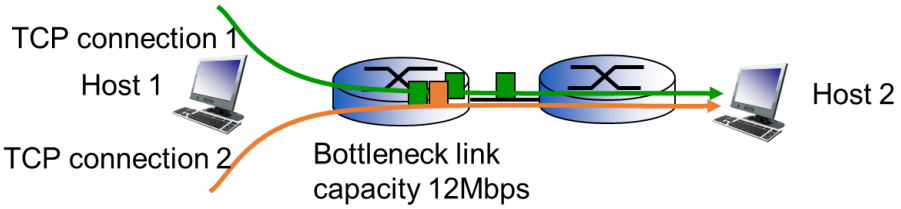
a) What is the data rate available to the upper layer if stop and wait is used?

b) Assume that we use sliding window with selective repeat. What should be the sender window size to maximize the data rate available to the upper layer that need the minimum amount of buffer on the sender size? At least how many bits of sequence number is necessary? What is the data rate available in this case?

c) Assume that we are using the protocol in part b) with a very large receiver window. The upper layer has 9000 bits to send. The transmission starts at t=0. The third packet (with sequence number 2) is in error. What is the required time to complete this transmission? What is the available data rate for the upper layer for this transmission? Complete the timing diagram below to clearly show the packets and acknowledgements with sequence numbers.

Q.4 (15pts) parts a and b are independent. Show all your reasoning and work.

a) Host 1 sets up two long duration TCP connections to Host 2 on a bottleneck link with total 12Mbps capacity as shown in the figure below.



i) What is the *average* throughput for TCP connection 1 in Mbps?

ii) Draw a simple figure that shows how this throughput changes over time after slow start is finished. Assume only triple ACKs occur and there are no packet losses. Indicate the minimum and maximum points in your throughput figure.

b) Assume that the TCP sender has `send_base`=100 Bytes at t=0. The last acknowledged byte at the TCP receiver side is 100. The receiver delays the acknowledgements for 100ms. The RTT is vert small.
Write the actions of the receiver for the following sequence of events. Indicate `send_base` if the action is affects the sender.

i) The receiver gets a 100 Byte segment [Byte 100, Byte 199] at t=0 msec.

ii) The receiver gets a 100 Byte segment [Byte 300, Byte 399] at t=50 msec.

iii) The receiver gets a 100 Byte segment [Byte 200, Byte 299] at t=100 msec.