MIDDLE EAST TECHNICAL UNIVERSITY
Electrical and Electronics Engineering Department

EE444 Introduction to Computer Networks
Practice Problems

## Question 1

Let *MSS*, *RTT*, *cwnd*, *rwnd* be the maximum segment size, round-trip time, congestion window size, receiver window size, respectively. Answer the following:

(a) The average initial transmission rate of a TCP connection is _____.

(b) The average transmission rate of a TCP connection is _____.

(c) The new values of TCP congestion window size and the threshold are _____and _____when a triple duplicate ACK is received.

(d) The new values of TCP congestion window size and the threshold are _____and _____when a timeout occurs.

(e) During congestion avoidance phase, the new value of TCP congestion window size is set to _____ every _____.

(f) The sender can send up to _____TCP segments in a period of one _____.

## Question 2

Fill in the blanks in the following statements.

1. The layers which are implemented in all of the network devices are _____.
2. _____ networks keep state information about the connections.
3. _____networks require full destination address to route the packets.
4. File transfer applications use _____protocol which opens two TCP connections on different ports for _____ and _____.
5. Email servers use _____ protocol to communicate with each other where the client applications access the servers using _____ and _____ protocols.
6. _____HTTP opens a TCP connection for each object while_____can transfer multiple objects over a single connection.
7. Web and email applications run over _____transport protocol while real time applications mostly run over _____ transport protocol.

**Question 3**

Consider a transmission where the rates of the access links of both sender and receiver us 0.5 Mbits/sec link and RTT is measured as 2 msec. An application running on Station A generates an image file of size 1000bits. This image is sent from Station A to Station B using a Selective Repeat data link layer protocol with packet size of 125bit length. There is clock in Station A that ticks periodically every 1 msec. If Station A has any packet to send it can only send it at the clock ticks. Similarly, Station B has a clock which ticks periodically every 2 msec. Station B sends 500 bit packets back to station A continuously at every clock tick.

The acknowledgements (ACK) are piggybacked on these packets. If a packet does not arrive on time following a successfully received packet, a single Negative Acknowledgement (NACK) is sent to Station A in piggybacked fashion. After the NACK, an ACK for the last successfully received packet is also transmitted until the missing packet arrives.

ACKs and NACKs are sent with the information of the expected packet by the receiver. The window sizes are selected to maximize the packet transmission efficiency with 3-bit sequence numbers. Ignore all headers. Time-out duration is very long.

Station A starts data transmission at t=0.5 msecs and Station B starts at t=2 msecs. Between t=5 msec and t=5.5 msec the underlying transmission facility breaks down and any transmission in this period is lost.

(a) Draw a time diagram that shows the events of this transmission for both stations A and B. Clearly indicate the sequence number of packets and the piggybacked acknowledgements.
(b) Indicate the sequence numbers contained in the sender and receiver windows whenever a window is updated.

*MIDDLE EAST TECHNICAL UNIVERSITY*
*Electrical and Electronics Engineering Department*

**EE 444 Introduction to Computer Networks**
**Midterm Exam**

**April 13, 2011**

**4 QUESTIONS**
**TIME ALLOTTED:** 110 minutes.

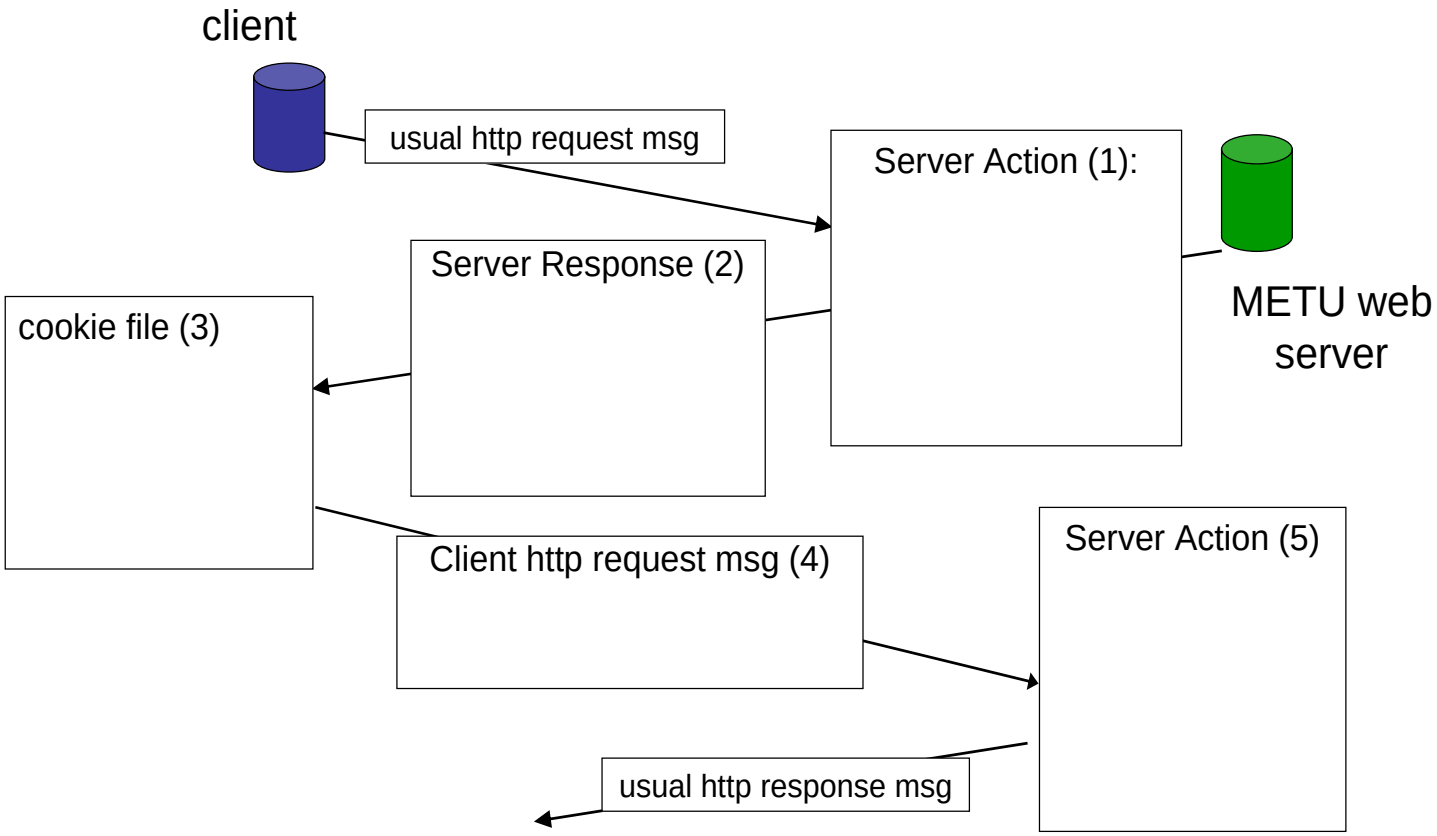
**PLEASE OBSERVE THE FOLLOWING:**
- No calculators, **no cell phones**, no electronic equipment is allowed.
- Show all your work, clearly state any assumptions you make.

STUDENT'S
NAME: .....
LASTNAME: .....
NUMBER: .....
SIGNATURE: .....

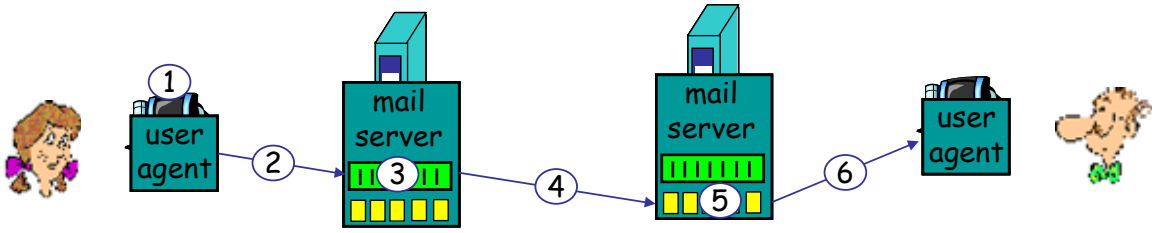
| **1** | **2** | **3** | **4** | **TOTAL** |
|---|---|---|---|---|
| 30 pts | 25 pts | 25 pts | 20 pts | 100 pts |
| | | | | |

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

**Q.2. (a)** Fill in the numbered boxes in the figure below to explain how http can keep state information using cookies. Cookie file is initially empty.

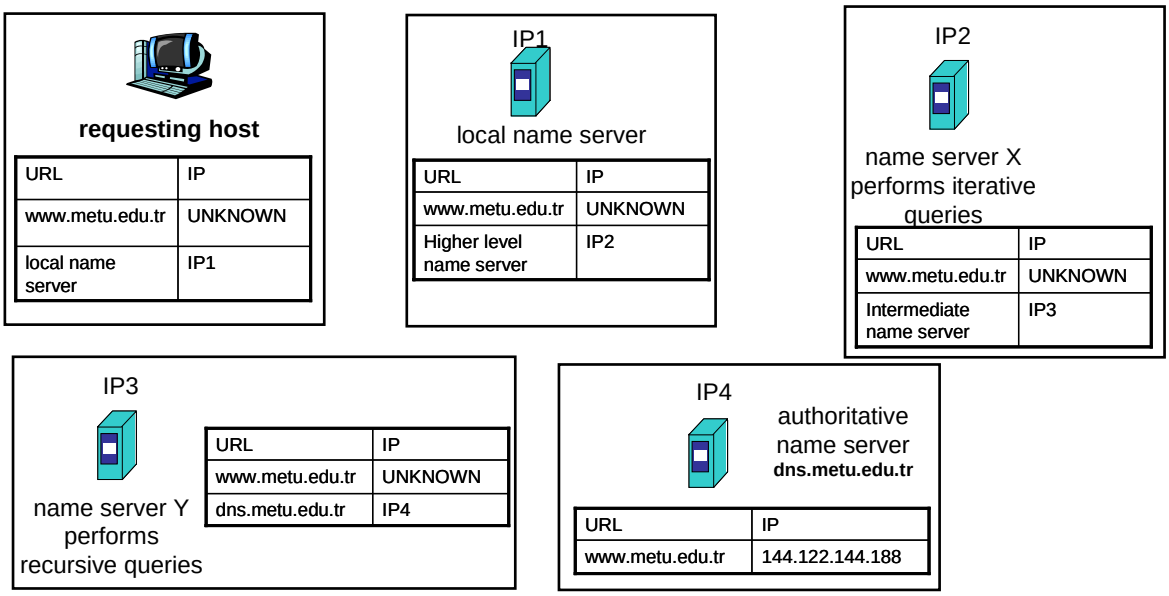


**Q2.(b)** Explain how Ayse sends an email to Bulent in the figure. Complete the steps in the procedure and the related application layer protocols when communication takes place as indicated in the table below.




| Step | Application Layer Protocol | Explanation |
|---|---|---|
| 1 | | Ayse uses User Agent to compose email and "to" bulent@metu.edu.tr |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

**Q2.(c)** The requesting host seen in the figure below wants to browse www.metu.edu.tr for the first time. The IP addresses and the table of URL-IP mappings of each involved networking device is provided in the figure. **Name server X only performs iterative queries and name server Y only performs recursive queries.** Complete the sequence of steps of the DNS query procedure in the provided table below. Each step corresponds to a DNS message transmission. Indicate the source and destination of the DNS message as shown in Step 1.




| Step | From | To | Explanation |
|---|---|---|---|
| 1 | Requesting host | Local name server | Requesting host asks for the IP address of www.metu.edu.tr |
| | | | |
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**Q.4** Complete the following table that shows the size of the TCP sender window for the first 17 transmission rounds. TCP segments are 1 Kbytes. The receiver has a very large buffer. Initial threshold is 16 Kbytes. There is a triple ACK and timeout event.

| **Transmission Round** | **Sender Window (Kbytes)** | **Algorithm Phase, Explanation** | **Event** | **Threshold (Kbytes)** |
|---|---|---|---|---|
| 0 | 1 | Slow Start | | 16 |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | **TRIPLE ACK RECEIVED** | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | **TIMEOUT** | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |

**MIDDLE EAST TECHNICAL UNIVERSITY**
**Electrical and Electronics Engineering Department**

# EE 444 Introduction to Computer Networks
# Midterm Exam

**April 11, 2012**

**7 QUESTIONS**
**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: .....

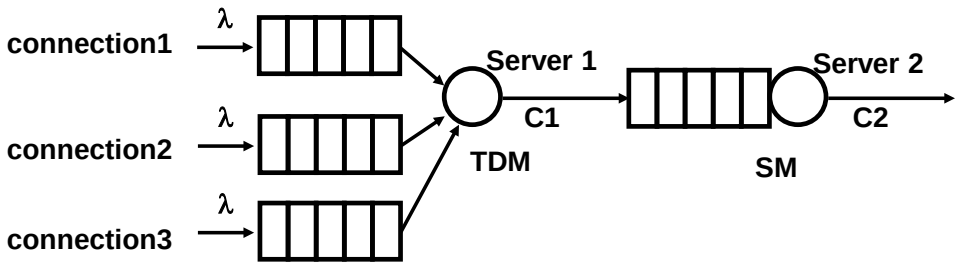
SIGNATURE: .....

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | TOTAL |
|---|---|---|---|---|---|---|---|
| 30 pts | 10 pts | 10 pts | 20 pts | 10 pts | 10 pts | 10 pts | 100 pts |
| | | | | | | | |

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

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

**Q.1.** Consider the queuing system shown below.



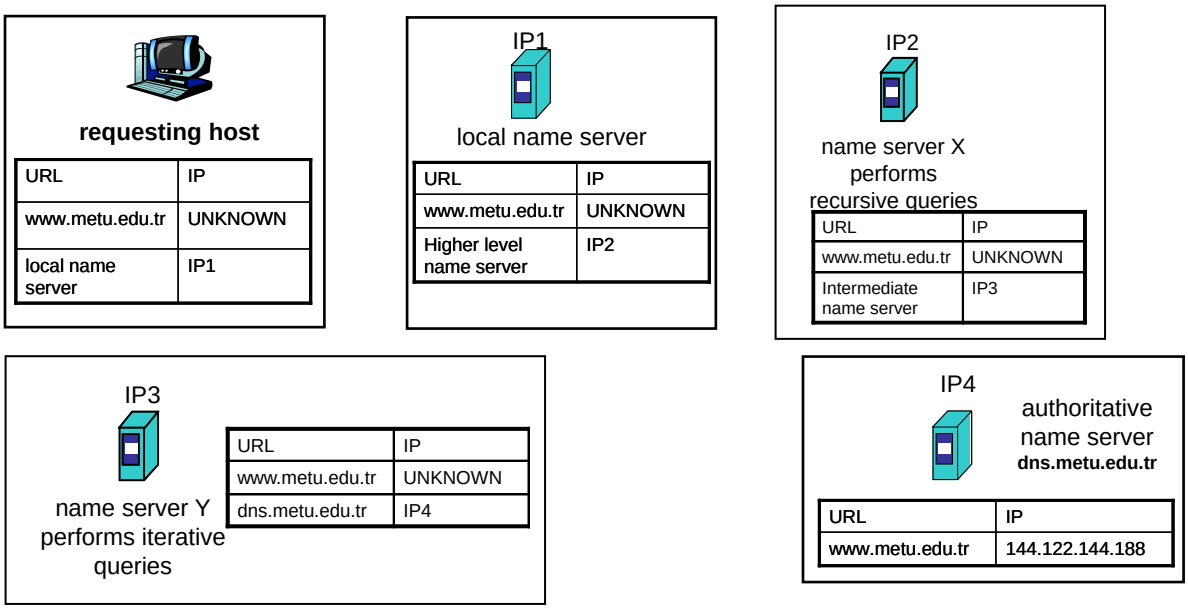

Server 1 has a capacity of C1=100bits/sec. It is applying static multiplexing (time-division multiplexing) with the following capacity shares:

| | | |
|---|---|---|
| connection1: 50bits/sec | connection2: 25bits/sec | connection3: 25bits/sec |

Server 2 has a capacity of C2=120bits/sec. It is applying statistical multiplexing.
The traffic arrivals for all three connections are Poisson processes where **each** connection has an arrival rate λ=1 packet/sec. The packet sizes are exponentially distributed with an average of 20bits/packet.

**a)** What is the expected number of packets in the total system (servers and queues)?
**b)** What is the expected end-to-end delay of a packet from connection1 in the total system (servers and queues)?

**Q.2.** The requesting host seen in the figure below wants to browse www.metu.edu.tr for the first time. The IP addresses and the table of URL-IP mappings of each involved networking device is provided in the figure. **Name server X only performs recursive queries and name server Y only performs iterative queries.** Complete the sequence of steps of the DNS query procedure in the provided table below. Each step corresponds to a DNS message transmission. Indicate the source and destination of each DNS message as shown in Step 1. Use as many rows as you need.




| Step | From | To | Explanation |
|---|---|---|---|
| 1 | Requesting host | Local name server | Requesting host asks for the IP address of www.metu.edu.tr |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Q.3.**Ahmet and Mehmet are two students in METU campus. They both want to access the same web page located on a server in the United States. The web page consists of a base html file and two jpeg pictures. The file sizes are negligible. The RTT between METU and the web server is 200msec. The HTTP protocol is persistent HTTP. First Ahmet accesses and displays the web page on his browser, a short time after Mehmet displays the same web page.

**a)** What is the total amount of time Ahmet needs to display the web page? What is the total amount of time Mehmet needs to display the web page?

**b)** Now assume a web proxy server is installed in ULAKBIM Ankara which caches and serves all web requests for the servers in the United States. The RTT between the proxy server and METU is 20msec. The RTT between the proxy server and the web server in the US is 200msec. Repeat part (a). Assume that the proxy does not have any files initially and the delays are symmetric in two directions.

**Q.4.** Fixed size messages of 100 bits are generated by an application and transmitted with a reliable transmission service. The sizes of headers and acknowledgements of the reliable transmission layer (RTL) are negligible. The data packets are generated only on the sender side. The transmission rate of the sender is 100Kbits/sec. The **round trip time** between sender and receiver is 19msec. Time out is selected to be 29msec.The time out period begins after the last bit of a data packet is transmitted. The receiver is a powerful machine with enough amount of buffer memory.

**(a)** Assume that the sender has a buffer of only 100bits. It is observed that the probability of a successful transmission of the data packet and the corresponding ACK is 0.75. What is the average data rate provided to the application?

**(b)** Assume that now the sender has a buffer of 3200 bits. The probability of a successful transmission of the data packet and the corresponding ACK is 0.75.

i. What is the ***maximum* possible** average data rate provided to the application? Justify your method for reliable transmission.

**ii.** How many bits of sequence numbers is required to support the correct operation?

**Q.7.** Complete the following table that shows the size of the TCP sender window for the first 13 transmission rounds. TCP segments are 1 Kbytes. Initial threshold is 16 Kbytes. The receiver buffer is window is assumed to be infinite.

Fill in all of the missing parts the Sender Window, Reason and Threshold columns in the following table.

| **Transmission Round** | **Sender Window (Kbytes)** | **Reason: Window management algorithm stage that causes the change of the Sender Window size and the Threshold value** | **Threshold (Kbytes)** |
|---|---|---|---|
| 0 | 1 | Slow Start | 16 |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | 1 | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | 4 | | |
| 12 | | | |
| 13 | | | |

**MIDDLE EAST TECHNICAL UNIVERSITY**
**Electrical and Electronics Engineering Department**

# EE 444 Introduction to Computer Networks
# Midterm Exam

**April 17, 2013**

**6 QUESTIONS**
**TIME ALLOTTED:** 110 minutes.

**PLEASE OBSERVE THE FOLLOWING:**

- Solve each question in the provided space below the question. If the space is not enough, indicate if you use any extra pages.
- Show all your work, clearly state any assumptions you make.
- No calculators, **no cell phones**, no electronic equipment is allowed.

STUDENT'S

NAME: .....

LASTNAME: .....

NUMBER: .....

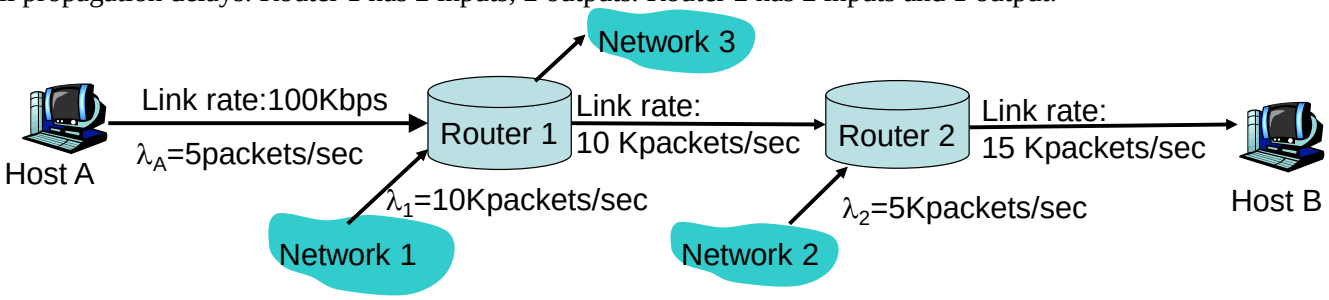
SIGNATURE: .....

| **1** | **2** | **3** | **4** | **5** | **6** | **TOTAL** |
|---|---|---|---|---|---|---|
| 20 pts | 20 pts | 15 pts | 15 pts | 15 pts | 15 pts | 100 pts |
| | | | | | | |

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

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

**Q.1.** Consider the network that is shown below. For all packets in this network, the packet sizes are exponentially distributed with an average size of 1000 bits/packet. All packet generation processes are Poisson processes. Ignore all propagation delays. Router 1 has 2 inputs, 2 outputs. Router 2 has 2 inputs and 1 output.




Host A generates packets with a rate of $\lambda_A$=5 packets/sec and sends them to Host B over Router 1 and Router 2. Traffic from Network 1 has a rate of $\lambda_1$=10Kpackets/sec. 10% of these arrivals are routed to Network 3 and the rest of them go on to Router 2. Traffic from Network 2 has a rate of $\lambda_2$=5Kpackets/sec.

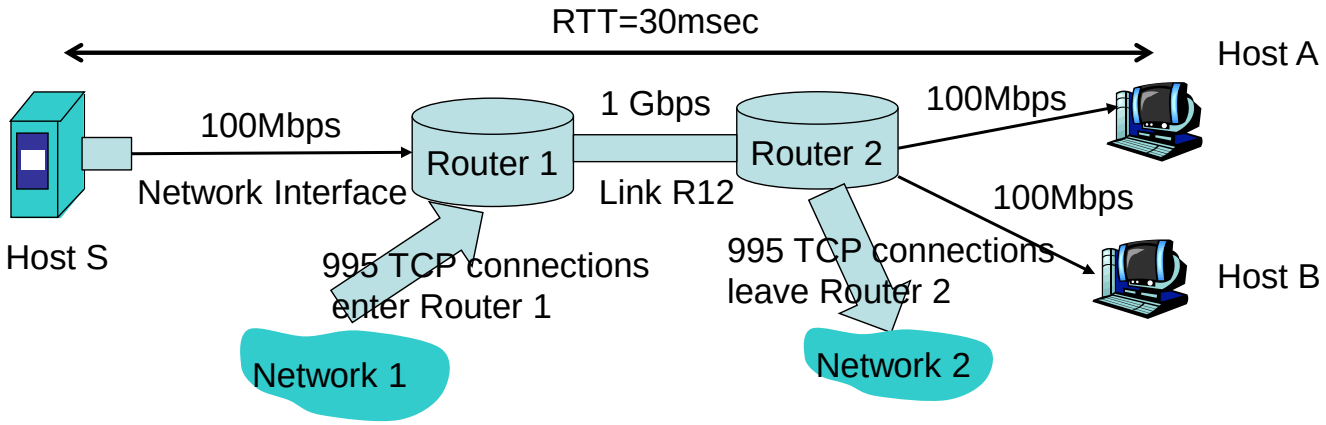
**a)** What are the components of the total average delay for a packet that is sent from Host A to Host B.

**b)** What is the total average delay for a packet that is sent from Host A to Host B. **Clearly specify all your assumptions and the properties that you use.**

**Q.4.** Complete the following table that shows the size of the TCP **sender window** for the first 15 transmission rounds. TCP segments are 1 Kbytes. The receiver buffer is 200Kbytes. Initial threshold is 32 Kbytes. The loss event for a given transmission round happens after the segments are sent in that round.

| **Transmission Round** | **Number of segments that are sent** | **Loss Event** | **Threshold (in Kbytes)** |
|---|---|---|---|
| 1 | 1 | | 32K |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | Triple ACK | |
| 9 | | | |
| 10 | | Timeout | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | Triple ACK | |
| 15 | | | |

**Q.6.** Consider the file transmissions carried out over TCP as shown in the figure.




Host A and Host B are downloading large files from Host S. The application on Host A opens a single TCP connection for this transfer. The application on Host B opens 4 parallel TCP connections. Assume that Host S does not send data to any other host. Both Host A and Host B download the files in 500Byte fixed size segments. The Round trip time (RTT) between either of these hosts and Host S is 30msec and it stays constant during the transfer. Assume that the time out values are long enough such that time out does not happen. In addition to the TCP connections between Host A-Host S and Host B-Host S there are 995 other TCP connections running on the link from R1 to R2 which has 1 Gbps capacity.

**a)** What is the average download rate achieved at Host A and Host B?

**b)** What is the utilization of the transmitter at the network interface of Host S?

**c)** What is the expected **maximum** number of segments in the sender window for any of the TCP connections on Host S?