Answer for EE3315 Test 2 2020-2021

Question 1. **[20 marks]**

Suppose that within your web browser you click on a link to obtain a web page. Suppose that web page associated with the link contains some HTML text. Let *RTT* denote the round trip time between the local host and the server containing the HTML file with size $2L$. Further suppose that the page references ten objects each with size $2L$ and the transmission rate R. Assuming the queueing time of each object is $2Q$, how much time is needed from when the client clicks on the link until the client receives all the ten referenced objects with

i) persistent HTTP with pipelining? [4 marks]
ii) persistent HTTP without pipelining? [4 marks]
iii) non-persistent HTTP with no parallel connections? [4 marks]
iv) non-persistent HTTP with parallel TCP connections but the maximum number of parallel connections is set to two? [4 marks]
v) non-persistent HTTP with parallel TCP connections but the maximum number of parallel connections is set to six? [4 marks]

i) $= 3RTT + 22L/R + 20Q$.
ii) $= \mathbf{12}\boldsymbol{RTT} + \mathbf{22}\boldsymbol{L/R} + \mathbf{20}\boldsymbol{Q}$.
iii) $= 22RTT + 22L/R + 20Q$.
iv) $= 12RTT + 12L/R + 10Q$.
v) $= 6RTT + 6L/R + 4Q$.

Question 2. **[24 marks]**

Consider Figure Q.2, in which there is an institutional network connected to the Internet. Suppose that the average object size is 37,500 bytes and that the average request rate from the institution's browsers to the origin servers is 120 requests per minute. Also suppose that the amount of time it takes for the signal traveling from the router on the Internet side of the access link to the origin servers is two seconds on average and it takes the same amount of time for the signal coming back. Model the total average response time as the sum of the average access delay (that is, the delay from the Internet router to the institution router), the LAN delay (that is, the delay spent in the LAN) and the average Internet delay. For the average access delay (or the LAN delay), use $T/(1-TB)$, where T is the average time required to send an object over the access link (or the LAN) and B is the arrival rate of objects to the access link (or the LAN). Note that the number of significant digits after the decimal point should be limited to four during the calculation.

i. Find the average total response time. **[8 marks]**
ii. Now suppose a cache is installed in the institutional LAN. Suppose that the hit rate is 0.6. Find the total average response time. **[8 marks]**
iii. What is the total average response time if we upgrade the access link with two parallel links, one with 5 Mbps and another with 10 Mbps, instead of installing a cache in the institutional LAN? Assume that the traffic is evenly distributed on the two links. **[8 marks]**

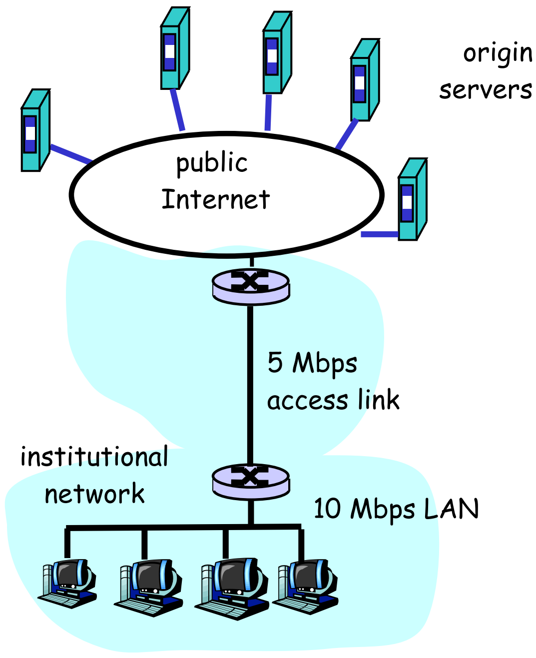


Figure Q.2

i. The time to transmit an object of size L over a link or rate R is L/R. The average time is the average size of the object divided by R:
For the access link,
T= (300,000 bits)/(5,000,000 bits/sec) = 0.06 sec
The traffic intensity on the link is TB = (120/60)(0.06) = 0.12. Thus, the average access delay is $T/(1–TB)$ = (0.06 sec)/(1– 0.12) = 0.0682 seconds.

For the LAN,
T= (300,000 bits)/(10,000,000 bits/sec) = 0.03 sec
The traffic intensity on the LAN is TB = (120/60)(0.03) = 0.06. Thus, the average access delay is $T/(1–TB)$ = (0.03 sec)/(1– 0.06) = 0.0319 seconds.

The total average response time is therefore 0.0682 sec + 0.0319 + 4 sec = 4.1001 sec.

ii. The traffic intensity on the access link is reduced by 60% since the 60% of the requests are satisfied within the institutional network. Thus the average access delay is $T/(1–TB)$=(0.06 sec)/[1 – (0.4)(0.12)] = 0.0630 seconds. The response time is the LAN delay if the request is satisfied by the cache (which happens with probability 0.6); the average response time is 0.0630 sec + 0.0319 sec + 4 sec = 4.0949 sec for cache misses (which happens 60% of the time). So the average response time is (0.6)(0.0319 sec) + (0.4)(4.0949 sec) = 1.6571 seconds. Thus the average response time is reduced from 4.1001 sec to 1.6571 sec.

iii. Now, the access link is updated with two parallel links, one with 5 Mbps and another with 10 Mbps, instead of installing a cache in the institutional LAN.
1) For the link with 5 Mbps:

T= (300,000 bits)/(5,000,000 bits/sec) = 0.06 sec

The traffic intensity on the link is TB = (60/60)(0.06) = 0.06. Thus, the average access delay is $T/(1-TB)$ = (0.06 sec)/(1– 0.06) = 0.0638 seconds.

2) For the link with 10 Mbps:

T= (300,000 bits)/(10,000,000 bits/sec) = 0.03 sec

The traffic intensity on the link is TB = (60/60)(0.03) = 0.03. Thus, the average access delay is $T/(1-TB)$ = (0.03 sec)/(1– 0.03) = 0.0309 seconds.

The total average response time is therefore (0.0638 sec + 0.0309 sec)/2 + 0.0319 + 4 sec = 4.0793 sec.

Question 3. **[20 marks]**

In this problem we consider the delay introduced by the TCP slow-start phase. Consider a client and a Web server directly connected by one link of rate $R/3$. Suppose the client wants to retrieve an object whose size is exactly equal to $13S$, where S is the maximum segment size (MSS). Denote the round-trip time between client and server as RTT (assume to be constant). Ignoring protocol headers, determine the time to retrieve the object (**excluding** TCP connection establishment) when 9 S/R > RTT > 3 S/R and RTT ≥ 9 S/R, respectively.

i) If 9 S/R > RTT > 3 S/R, the total delay is

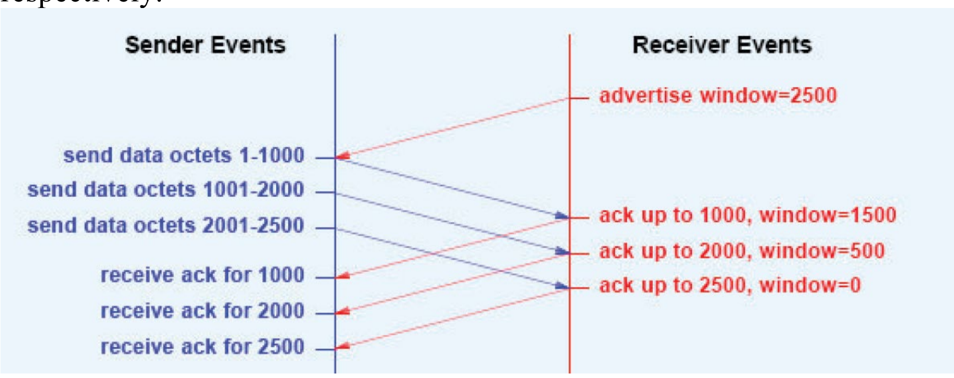
RTT + 3 S/R + RTT + 3 S/R + RTT + 12S/R + 18S/R = 3RTT + 36 S/R

ii) If RTT ≥ 9 S/R, the total delay is

RTT + 3 S/R + RTT + 3 S/R + RTT + 3 S/R + RTT + 18 S/R = 4RTT + 27 S/R

Question 4. TCP flow control: **[20 marks]**

(i) According to the figure below, if advertise window is changed from 2500 to 2000, list out in sequence the modified Sender Events and the modified Receiver Events, respectively.



(i)

Sender Events:

Send data octets 1-1000

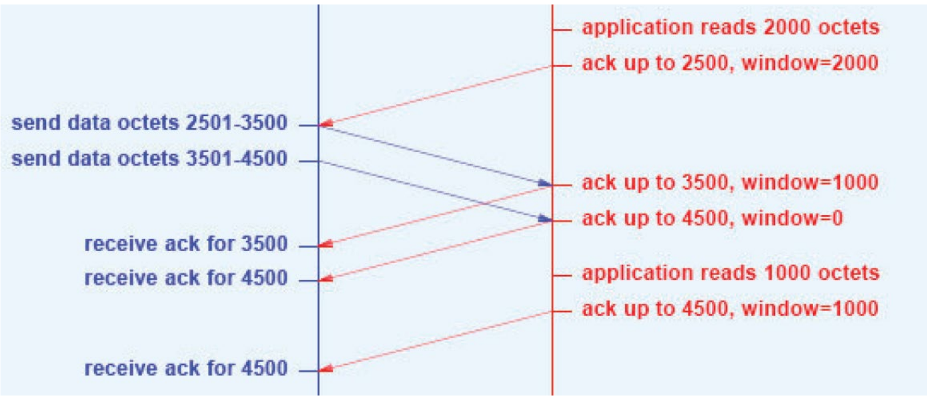
Send data octets 1001-2000

Receive ack for 1000

Receive ack for 2000

Receiver Events:
advertise window=2000
ack up to 1000, window=1000
ack up to 2000, window=0

(ii) According to the figure below, if the application reads 2500 octets instead of 2000 octets, list out in sequence the modified Sender Events and the modified Receiver Events, respectively.



(ii)
Sender Events:
Send data octets 2501-3500
Send data octets 3501-4500
Receive ack for 3500
Receive ack for 4500
Receive ack for 4500

Receiver Events:
application reads 2500 octets
ack up to 2500, window=2500
ack up to 3500, window=1500
ack up to 4500, window=500
application reads 1000 octets
ack up to 4500, window=1500

<u>Question 5</u>. **[16 marks]**

Assuming TCP Reno is the protocol experiencing the behavior shown in Table 1, answer the following questions. In all cases, you should provide a short explanation justifying your answer.

Table 1: TCP congestion control

NTR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CWS	20	21	22	23	24	12	13	14	15	16	1	2	4	8	4	5

NTR – number of transmission round
CWS – congestion window size

i. Identify the one/two interval(s) of time when TCP slow start is operating.
ii. Identify the one/two interval(s) of time when TCP congestion avoidance is operating.

iii. After the 5th transmission round, how segment loss is detected?
iv. After the 10th transmission round, how segment loss is detected?
v. What is the maximum possible initial value of Threshold at the first transmission round?
vi. What is the value of Threshold at the 6th transmission round?
vii. What is the value of Threshold at the 11th transmission round?
viii. What will be the congestion window size and the value of Threshold at the 17^{th} transmission round if a segment is lost after the 18^{th} transmission round due to a triple duplicate ACK?

i. TCP slowstart is operating in the interval [11,13]: double the previous window size
ii. TCP congestion avoidance is operating in the intervals [1,10] and [14,16]: linearly increase the window size
iii. After the 5th transmission round, segment loss is recognized by a triple duplicate ACK. If there was a timeout, the congestion window size would have dropped to 1.
iv. After the 10th transmission round, packet loss is detected due to timeout, and hence the congestion window size is set to 1.
v. The maximum possible initial value of the threshold at the first transmission round is 20 since when the congestion window size is 20, TCP congestion avoidance is operating.
vi. The threshold is set to half the value of the congestion window when packet loss is detected. When loss is detected during transmission round 5, the congestion windows size is 24. Hence the threshold is 12 during the 6th transmission round.
vii. The threshold is 8 during the 11th transmission round since packet loss is detected. When loss is detected during transmission round 10, the congestion windows size is 16. Hence the threshold is 8 during the 11th transmission round.
viii. The congestion window size is 6 and the threshold value is 4 since there is no loss at the 17th transmission round.