Answer for EE3315 Test 2 2017-2018 Semester B

<u>Question 1.</u> **(18 marks)**

A TCP opens a connection and uses slow start. Assume that the maximum window size is 50 and the window threshold is 16.

i) Approximately how many round-trip times are required before TCP can send 16 and 30 segments, (i.e. window size = 16 and 30), respectively? [10 marks]

ii) What does TCP respond for congestion control if a segment is lost at the round-trip times equal to 20? [8 marks]

i) TCP initializes the congestion window to 1, sends an initial segment, and waits. When the ACK arrives, it increases the congestion window to 2, sends 2 segments, and waits. When the 2 ACKs arrive, they each increase the congestion window by one, so that it can send 4 segments. It takes $\log_2 16 = 4$ round trips before TCP can send 16 segments.

After the congestion window size reach 16, TCP enter congestion avoidance mode. TCP will increase its window size by one when all Acks for a full congestion window of packets are received. It takes 30–16=14 more round trips to reach window size equal to 30. Adding the number of round trips needed in slow start mode, it takes totally 4+14=18 round-trips before TCP can send 30 segments.

(ii) At round trip times equal to 20, TCP's window size has reached 32. When a segment is lost, the window threshold will be set to half of the current window size, i.e 32/2=16. If the lost is caused by time out, then the congestion window size will be set to one and TCP will enter the slow start mode. If the lost is caused by triple duplicate ACKs, then the congestion window size will be set to 16 and TCP will enter the congestion avoidance mode.

<u>Question 2.</u> **(24 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. [24 marks]

Table 1: TCP congestion control

NTR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CWS	8	9	10	11	12	6	7	8	9	10	1	2	4	5	6	3

NTR – number of transmission round (note that transmission round has been renumbered)

CWS – congestion window size

i. Identify the intervals of time when TCP slow start is operating.
ii. Identify the intervals of time when TCP congestion avoidance is operating.
iii. After the 5th transmission round, by which way is segment loss detected?
iv. After the 10th transmission round, by which way is segment loss 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 10th transmission round?

viii. What would be the congestion window size and the value of Threshold if the segment loss at the 16th transmission round is not due to timeout?

i. TCP slowstart is operating in the interval [11,13]: double the previous window size
ii. TCP congestion avoidance is operating in the intervals [1,5], [6,10] 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 8 since when the congestion window size is 8, 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 12. Hence the threshold is 6 during the 6th transmission round.
vii. The threshold is 6 during the 10th transmission round since there is no packet loss since transmission round 5 so the threshold remains the same as that during transmission round 5.
viii. The congestion window size and the threshold value are both reduced to 3 according to the procedure for segment loss due to a triple duplicate ACK.

Question 3. **(6 marks)**

Suppose Alice, with a Web-based e-mail account (such as Hotmail), sends a message to Bob, who accesses his mail from his mail server using POP3. And, suppose Bob, with an Outlook e-mail account, returns a message to Alice, who accesses her mail from her mail server using IMAP. Discuss how the message gets from Bob's host to Alice's host. Be sure to list the series of application-layer protocols that are used to move the message between the two hosts.

Message is sent from Bob's host to his mail server over SMTP.
Bob's mail server then sends the message to Alice's mail server over SMTP.
Alice then transfers the message from her mail server to his host over IMAP.

Question 4. **(24 marks)**

Consider Figure Q. 4, in which there is an institutional network connected to the Internet. Suppose that the average object size is 800,000 bits and that the average request rate from the institution's browsers to the origin servers is 5400 requests per hour. 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 and coming back is three seconds on average. 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) and the average Internet delay. For the average access delay, use $T/(1-TB)$, where T is the average time required to send an object over the access link and B is the arrival rate of objects to the access link.

i. Find the total average response time. [8 marks]

ii. Now suppose a cache is installed in the institutional LAN. Suppose that the hit rate is 0.3. 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, each with 5 Mbps, instead of installing a cache in the institutional LAN? Assume that the traffic is evenly distributed on the two links. If the speed of the access link can be further increased, what is the minimum possible value for the total average response time? [8 marks]

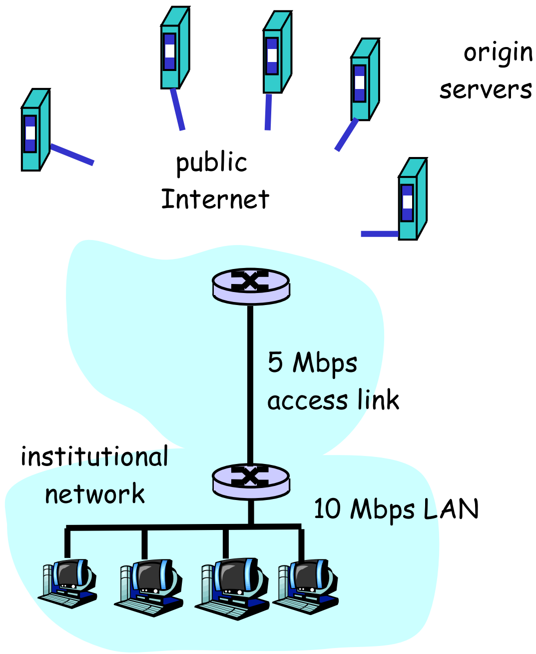

Figure Q.4

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:
T= (800,000 bits)/(5,000,000 bits/sec) = 0.16 sec
The traffic intensity on the link is $TB = (5400/60^2)(0.16) = 0.24$. Thus, the average access delay is $T/(1–TB) = (0.16 \text{ sec})/(1– 0.24) = 0.211$ seconds. The total average response time is therefore 0.211 sec + 3 sec = 3.211 sec.

ii. The traffic intensity on the access link is reduced by 30% since the 30% of the requests are satisfied within the institutional network. Thus the average access delay is $T/(1–TB)=(0.16 \text{ sec})/[1 – (0.7)(0.24)] = 0.192$ seconds. The response time is approximately zero if the request is satisfied by the cache (which happens with probability 0.7); the average response time is 0.192 sec + 3 sec = 3.192 sec for cache misses (which happens 70% of the time). So the average response time is (0.3)(0 sec) + (0.7)(3.192 sec) = 2.235 seconds. Thus the average response time is reduced from 3.211 sec to 2.235 sec.

iii. Now, the access link is updated with two parallel links, each with 5 Mbps, instead of installing a cache in the institutional LAN.

T= (800,000 bits)/(5,000,000 bits/sec) = 0.16 sec

The traffic intensity on the link is $TB = (2700/60^2)(0.16) = 0.12$. Thus, the average access delay is $T/(1-TB) = (0.16\text{ sec})/(1-0.12) = 0.182$ seconds. The total average response time is therefore 0.182 sec + 3 sec = 3.182 sec.

The minimum possible value for the total average response time is 3 sec.

Question 5. **(20 marks)**

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

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

i) $2RTT + L/R + 12 \times 2\,RTT + 12 \times 2L/R = 26RTT + 25L/R$.
ii) $2RTT + L/R + 3 \times 2\,RTT + 3 \times 2L/R = 8RTT + 7L/R$.
iii) $2RTT + L/R + 2 \times 2\,RTT + 2 \times 2L/R = 6RTT + 5L/R$.
iv) $2\text{RTT} + L/R + 12\text{RTT} + 12 \times 2L/R = 14\text{RTT} + 25L/R$.
v) $2\text{RTT} + L/R + \text{RTT} + 12 \times 2L/R = 3\text{RTT} + 25L/R$.

Question 6. **(8 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*. Suppose the client wants to retrieve an object whose size is exactly equal to 13*S*, 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

i) 3 S/R > RTT > S/R, [4 marks]
ii) 5 S/R > RTT > 3 S/R. [4 marks]

i) The total delay is

$$\text{RTT} + S/R + \text{RTT} + S/R + \text{RTT} + 4S/R + 6S/R = 3\text{RTT} + 12\ S/R$$

ii) The total delay is

$$\text{RTT} + S/R + \text{RTT} + S/R + \text{RTT} + S/R + \text{RTT} + 6S/R = 4\text{RTT} + 9\ S/R$$

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