Answer for EE3315 Test 2 2014-2015 Semester B

Question 1. **(50 marks)**

a. A TCP source opens a connection and uses slow start. Assume that the maximum window size is 50 and the window threshold is 4.

i) Approximately how many round-trip times are required before TCP can send 20 and 36 segments, (i.e. window size = 20 and 36), respectively? [8 marks]

ii) What does TCP respond for congestion control if a segment is lost at the round-trip times equal to 28? [6 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 $\log_2 4 = 2$ round trips before TCP can send 4 segments.

After the congestion window size reach 4, 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 20−4=16 more round trips to reach window size equal to 20. Adding the number of round trips needed in slow start mode, it takes totally 2+16= **18 round-trips** before TCP can send 20 segments.

In addition, it takes another 20 round trips or totally **34 round-trips** before TCP can send 36 segments.

(ii) At round trip times equal to 28, TCP's window size has reached 30. When a segment is lost, the window threshold will be set to half of the current window size, i.e 30/2=15. 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 15 and TCP will enter the congestion avoidance mode.

b. 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	28	29	30	31	32	16	17	18	19	20	1	2	4	8	1	2

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 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 [11,16]: double the previous window size
ii. TCP congestion avoidance is operating in the intervals [1,10]: 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 28 since when the congestion window size is 28, 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 32. Hence the threshold is 16 during the 6th transmission round.
vii. The threshold is 10 during the 11th transmission round since packet loss is detected. When loss is detected during transmission round 10, the congestion windows size is 20. Hence the threshold is 10 during the 11th transmission round.
viii. The congestion window size is 4 and the threshold value is 4 since there is no loss at the 17th transmission round.

c. 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 $14S$, 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 (**including** TCP connection establishment) when 6 S/R > S/R + RTT > 2 S/R. [12 marks]

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

2RTT + S/R + RTT + S/R + RTT + 4S/R + 7S/R = 4RTT + 13 S/R

ii) If 5 S/R > RTT ≥ 3 S/R, the total delay is

2RTT + S/R + RTT + S/R + RTT + S/R + RTT + 7S/R = 5RTT + 10 S/R

<u>Question 2.</u> **(50 marks)**

a. In Web caching, “conditional GET” is used to update the cached object. If the cache sends an HTTP request with “If-modified-since: 1 May 2014 10:00pm”, what is the condition that the cache gets the updated object. [6 marks]

The cached object has been modified/updated in the Web server since 1 May 2014 10:00pm.

b. 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 a small amount of HTML text. Let RTT denote the round trip time between the local host and the server containing the HTML file. Further suppose that the page references twelve objects each with size 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) 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 four? [4 marks]

b. i) $2RTT + RTT + 12L/R \quad = 3RTT + 12L/R$.
ii) $2RTT + 12RTT + 12L/R \quad = 14RTT + 12L/R$.
iii) $2RTT + 12 \cdot 2RTT + 12L/R \quad = 26RTT + 12L/R$.
iv) $2RTT + 6 \cdot 2RTT + 6L/R \quad = 14RTT + 6L/R$.
v) $2RTT + 3 \cdot 2RTT + 3L/R \quad = 8RTT + 3L/R$.

c. Consider Figure Q.2c, in which there is an institutional network connected to the Internet. Suppose that the average object size is 600,000 bits and that the average request rate from the institution's browsers to the origin servers is 2200 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 five 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 four parallel links, each with 10 Mbps, instead of installing a cache in the institutional LAN? Assume that the traffic is evenly distributed on the four links. [8 marks]

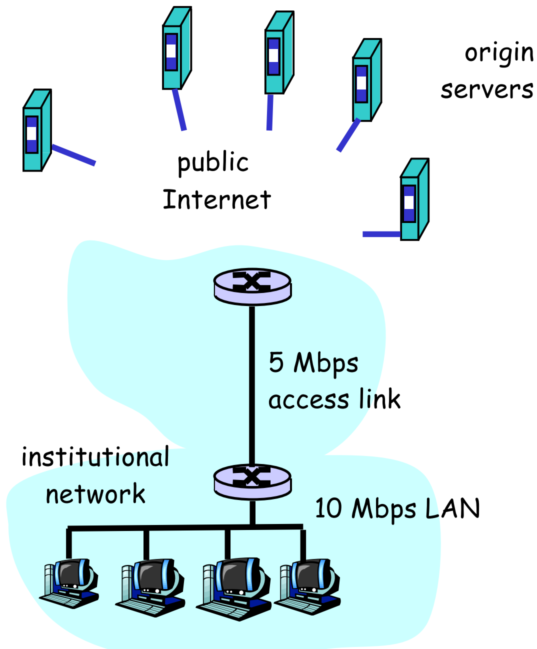

Figure Q.2c

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= (600,000 bits)/(5,000,000 bits/sec) = 0.12 sec

The traffic intensity on the link is TB = $(2200/60^2)(0.12)$ = 0.0733. Thus, the average access delay is $T/(1-TB)$ = (0.12 sec)/(1− 0.0733) = 0.1295 seconds. The total average response time is therefore 0.1295 sec + 5 sec = 5.1295 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 $T/(1-TB)$=(0.12 sec)/[1 – (0.7)(0.0733)] = 0.1265 seconds. The response time is approximately zero if the request is satisfied by the cache (which happens with probability 0.3); the average response time is 0.1265 sec + 5 sec = 5.1265 sec for cache misses (which happens 70% of the time). So the average response time is (0.3)(0 sec) + (0.7)(5.1265 sec) = 3.5886 seconds. Thus the average response time is reduced from 5.1295 sec to 3.5886 sec.

iii. Now, the access link is updated with four parallel links, each with 10 Mbps, instead of installing a cache in the institutional LAN.

T= (600,000 bits)/(10,000,000 bits/sec) = 0.06 sec

The traffic intensity on the link is TB = $(550/60^2)(0.06)$ = 0.009167. Thus, the average access delay is $T/(1-TB)$ = (0.06 sec)/(1− 0.009167) = 0.0606 seconds. The total average response time is therefore 0.0606 sec + 5 sec = 5.0606 sec.

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