**Answer for EE3315 Test 2 (2022-2023B)**

**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 $STT$ denote the single trip time between the local host and the server containing the HTML file with size $2L$. Further suppose that the page references eleventh objects each with size $2L$ and the transmission rate $R$. Assuming the queueing time of each object is $3Q$, how much time is needed from when the client clicks on the link until the client receives all the eleventh 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 three? [4 marks]
v) non-persistent HTTP with parallel TCP connections but the maximum number of parallel connections is set to five? [4 marks]

i) $4STT + 2L/R + 2STT + 11 \cdot 2L/R + 11 \cdot 3Q = 6STT + 24L/R + 33Q.$
ii) $4\boldsymbol{STT} + \boldsymbol{2L/R} + 22STT + 11 \cdot 2L/R + 11 \cdot 3Q = 26STT + 24L/R + 33\boldsymbol{Q}.$
iii) $4STT + 2L/R + 11 \cdot 4STT + 11 \cdot 2L/R + 11 \cdot 3Q = 48STT+24L/R+33Q$
iv) $4STT + 2L/R + 4 \cdot 4STT + 4 \cdot 2L/R + 4 \cdot 3Q = 20STT + 10L/R + 12Q.$
v) $4STT + 2L/R + 3 \cdot 4STT + 3 \cdot 2L/R + 3 \cdot 3Q = 16STT + 8L/R + 9Q.$

**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 27,500 bytes and that the average request rate from the institution's browsers to the origin servers is 12 requests per second. 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 miss 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]**

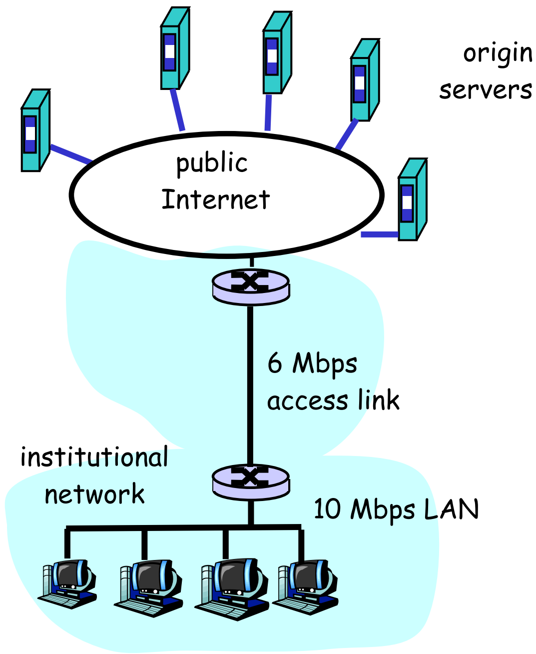



Figure Q.2

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= (220,000 bits)/(6,000,000 bits/sec) = 0.0367 sec
The traffic intensity on the link is $TB$ = (12)(0.0367) = 0.4404. Thus, the average access delay is $T/(1-TB)$ = (0.0367 sec)/(1– 0.4404) = 0.0656 seconds.

For the LAN,
T= (220,000 bits)/(10,000,000 bits/sec) = 0.022 sec
The traffic intensity on the LAN is $TB$ = (12)(0.022) = 0.264. Thus, the average access delay is $T/(1-TB)$ = (0.022 sec)/(1– 0.264) = 0.0299 seconds.

The total average response time is therefore 0.0656 sec + 0.0299 + 4 sec = 4.0955 sec.

ii. The traffic intensity on the access link is reduced by 40% since the 40% of the requests are satisfied within the institutional network. Thus the average access delay is $T/(1-TB)$=(0.0367 sec)/[1 – (0.6)(0.4404)] = 0.0499 seconds. The response time is the LAN delay if the request is satisfied by the cache (which happens with probability 0.4); the average response time is 0.0499 sec + 0.0299 sec + 4 sec = 4.0798 sec for cache misses (which happens 60% of the time). So the average response time is (0.4)(0.0299 sec) + (0.6)(4.0798 sec) = 2.4598 seconds. Thus the average response time is reduced from 4.0955 sec to 2.4598 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= (220,000 bits)/(5,000,000 bits/sec) = 0.044 sec

The traffic intensity on the link is $TB$ = (6)(0.044) = 0.264. Thus, the average access delay is $T/(1-TB)$ = (0.044 sec)/(1– 0.264) = 0.0598 seconds.

2) For the link with 10 Mbps:

T= (220,000 bits)/(10,000,000 bits/sec) = 0.022 sec

The traffic intensity on the link is $TB$ = (6)(0.022) = 0.132. Thus, the average access delay is $T/(1-TB)$ = (0.022 sec)/(1– 0.132) = 0.0253 seconds.

The total average response time is therefore (0.0598 sec + 0.0253 sec)/2 + 0.0299 + 4 sec = 4.0725 sec.

**Question 3**. **[20 marks]**

Please use the TCP EA-RTT estimator, which is given by

$$\text{EA-RTT}(K + 1) = \alpha \times \text{EA-RTT}(K) + (1 - \alpha) \times \text{RTT}(K + 1),$$

to obtain the estimated round-trip time RTT for the following cases. Please list out all the calculation steps.

a) Choose $\alpha$ = 0.90 and EA-RTT(0) = 1 second and assume the measured RTT values are RTT(n) = n second where n = 1,2,… and no packet loss. What is EA-RTT(4)? **[10 marks]**

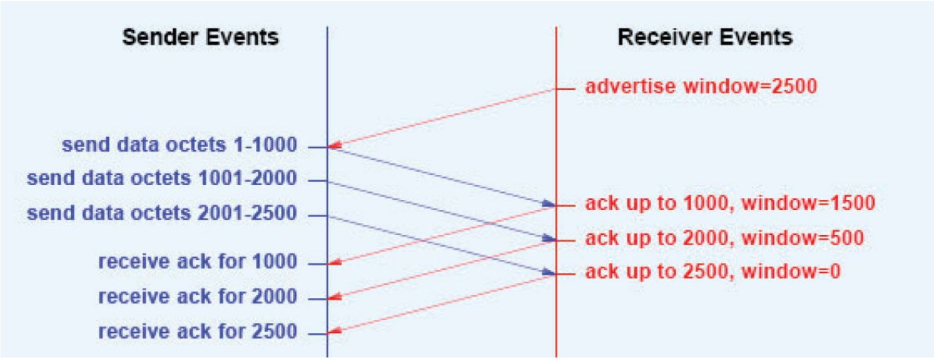
Recall that EA-RTT(K + 1) = $\alpha$ × EA-RTT(K) + (1 – $\alpha$) × RTT(K + 1)
EA-RTT(1) = $\alpha$ × EA-RTT(0) + (1 – $\alpha$) × RTT(1) = 0.9×1+0.1×1 = 1
EA-RTT(2) = $\alpha$ × EA-RTT(1) + (1 – $\alpha$) × RTT(2) = 0.9×1+0.1×2 = 1.1
EA-RTT(3) = $\alpha$ × EA-RTT(2) + (1 – $\alpha$) × RTT(3) = 0.9×1.1+0.1×3 = 1.29
EA-RTT(4) = $\alpha$ × EA-RTT(3) + (1 – $\alpha$) × RTT(4) = 0.9×1.29+0.1×4 = 1.56

b) Now let $\alpha$ = 0.25 and EA-RTT(0) = 4 second and assume the measured RTT values are RTT(n) = n+3 second and no packet loss. What is EA-RTT(4)? )? **[10 marks]**

EA-RTT(1) = $\alpha$ × EA-RTT(0) + (1 – $\alpha$) × RTT(1) = 0.25×4+0.75×4 = 4
EA-RTT(2) = $\alpha$ × EA-RTT(1) + (1 – $\alpha$) × RTT(2) = 0.25×4+0.75×5 = 4.75
EA-RTT(3) = $\alpha$ × EA-RTT(2) + (1 – $\alpha$) × RTT(3) = 0.25×4.75+0.75×6 = 5.69
EA-RTT(4) = $\alpha$ × EA-RTT(3) + (1 – $\alpha$) × RTT(4) = 0.25×5.69+0.75×7 = 6.67

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

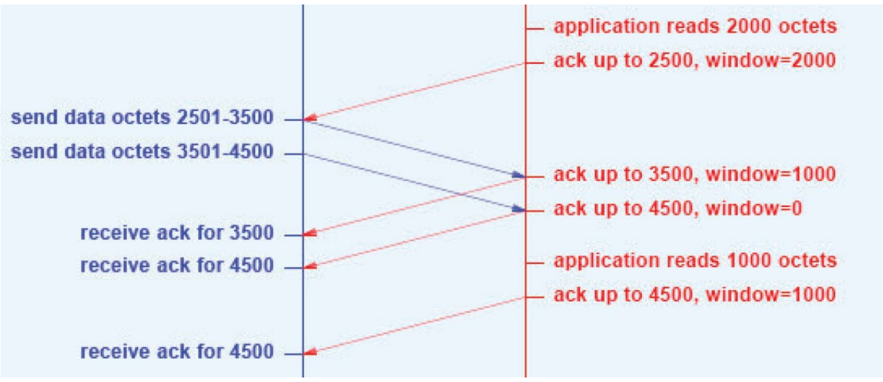
(i) According to the figure below, if advertise window is changed from 2500 to 1800, list out in sequence the modified Sender Events and the modified Receiver Events, respectively.




(i)
**Sender Events:**
Send data octets 1-1000
Send data octets 1001-1800
Receive ack for 1000
Receive ack for 1800

**Receiver Events:**
advertise window=1800
ack up to 1000, window=800
ack up to 1800, window=0

(ii) According to the figure below, if the application reads 1600 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 3501-4100
Receive ack for 3500
Receive ack for 4100
Receive ack for 4100

**Receiver Events:**
application reads 1600 octets
ack up to 2500, window=1600
ack up to 3500, window=600
ack up to 4100, window=0
application reads 1000 octets
ack up to 4100, window=1000

**Question 5**. **[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 | 14 | 15 | 16 | 1 | 2 | 4 | 8 | 9 | 10 | 11 | 12 | 6 | 7 | 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 3th transmission round, how segment loss is detected?
iv. After the 11th 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 4th transmission round?
vii. What is the value of Threshold at the 12th transmission round?
viii. What will be the congestion window size and the value of Threshold at the $16^{th}$ transmission round if a segment is lost after the $15^{th}$ transmission round due to a timeout?

Answer:

i. TCP slowstart is operating in the interval [4,6]: double the previous window size
ii. TCP congestion avoidance is operating in the intervals [1,3] and [7,16]: linearly increase the window size
iii. After the 3th transmission round, packet loss is detected due to timeout, and hence the congestion window size is set to 1.
iv. After the 11th 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.
v. The maximum possible initial value of the threshold at the first transmission round is 14 since when the congestion window size is 14, 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 3, the congestion windows size is 16. Hence the threshold is 8 during the 4th transmission round.
vii. The threshold is 6 during the 12th transmission round since packet loss is detected. When loss is detected during transmission round 11, the congestion windows size is 12. Hence the threshold is 6 during the 12th transmission round.
viii. The congestion window size is 1 and the threshold value are 2, which is half of the previous congestion window size (i.e. 4) due to a timeout.