City University of Hong Kong

Course code & title	:	EE3315 Internet Technology
Session	:	Semester B 2012/2013
Time allowed	:	Two hours

1. This paper consists of 4 questions.
2. Answer **ALL** four questions.

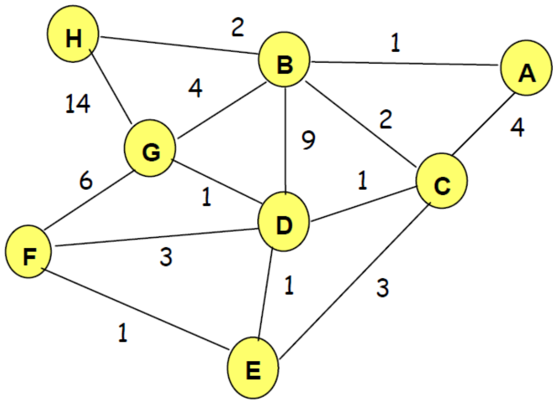
Materials, aids & instruments permitted to be used during examination:

1. Approved calculator

Do not take away the question paper after the examination!!

Question 1. **(25 marks)**

a. Consider the following network: [8 marks]



If **the cost between Node C and Node E becomes one**, using Dijkstra's algorithm, compute the shortest path from **Node E** to all network nodes. Use the table form below but work out the results in your answer book. If there is a tie, ***break it in favor of leftmost column***. List out all the shortest paths from Node E to all the other nodes.

N	A	B	C	D	F	G	H

b. Consider the Vector-Distance update shown in the Fig. Q.1b below. It shows an existing table (i) in a gateway K, and update message (ii) from another gateway J. Write down the changes in the table and give the reasons for those changes. Assume that the distance between gateway K and J is 3. [4 marks]

Destination	Distance	Route
Net 1	0	Direct
Net 2	0	Direct
Net 4	2	Gate L
Net 17	8	Gate M
Net 24	10	Gate J
Net 30	5	Gate J
Net 42	4	Gate Q

(i) An existing routing table for a gateway K

Destination	Distance
Net 1	2
Net 4	2
Net 17	1
Net 24	2
Net 30	3
Net 32	4
Net 42	2

(ii) An incoming routing update message from gateway J.

Figure Q.1b

c. In Figure Q.1c, assume that link AD has gone down for a long time. Assume B, C and D use split horizon with Poisoned Reverse. [13 marks]

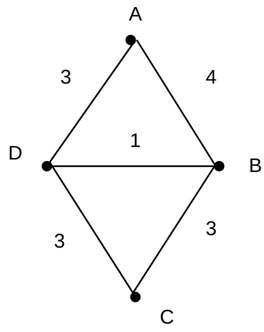


Figure Q.1c

i. What distance to A will D report to B?
ii. What distance to A will B report to D?
iii. What distance to A will D report to C?
iv. What distance to A will C report to D?

Now, suppose link AB goes down.
v. What distance to A will B report to C?
vi. At the same time, what distance to A will C report to B?
vii. At the same time, what is the distance to A that D reports to B?
viii. At the same time, what is the distance to A that D reports to C?
ix. What does C then think the shortest path to A is?
x. What does C then tell B about its distance to A?
xi. What does C then tell D about its distance to A?
xii. What is B's route to A now?
xiii. What does B then tell D the distance to A?

<u>Question 2.</u> **(25 marks)**

a. What is the advantage of TCP various-size sliding window scheme which decouples ACK and flow control? [3 marks]

b. How does the sender respond to an increased advertisement and a decreased window advertisement, respectively? [3 marks]

c. 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. [12marks]

Table 1: TCP congestion control

NTR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CWS	28	29	30	31	32	1	2	4	8	16	8	9	10	11	12

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 will be the congestion window size and the value of Threshold at the 16^{th} transmission round if a segment is lost after the 17^{th} transmission round due to a triple duplicate ACK?

d. Using TCP EA-RTT estimator (Exponential Average Round-Trip Time estimator), we have the following equation:

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

(i) Assume that all the RTT(K) are the same and equal to RTT. Write down the expression for EA-RTT(n) in terms of EA-RTT(2) and RTT. *Hint:* The equation for calculating EA-RTT can be rewritten to simplify the calculation, using the equation $(1 + \ldots + \beta^{n-2} + \beta^{n-1}) = (1 - \beta^n)/(1- \beta)$. [4 marks]

(ii) Choose $\alpha = 0.2$ and EA-RTT(2) = 2 seconds, and assume all measured RTT values = 5 second and no packet loss. What is EA-RTT(30) using the expression written in (i)? [3 marks]

Question 3. **(25 marks)**

a. Suppose Alice, with a Web-based Hotmail e-mail account, sends a message to Bob, who accesses his mail from his mail server using a Web-based Outlook e-mail account. And, suppose Bob, with a non-Web-based 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 Alice's host to Bob's host. Be sure to list the series of application-layer protocols that are used to move the message between the two hosts. [3 marks]

b. 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 2012 10:00pm", what is the condition that the cache does not get the updated object. [2 marks]

c. Suppose an HTTP client wants to download three objects from a server. The sizes of the three objects are all smaller than the MSS (maximum segment size). The transmission times for the three objects are T_1, T_2, and T_3, respectively, and those of the control packets are negligible. Assume that the transmission is error free and loss free, and pipelining is not used. Let *RTT* be the round-trip time. Assume that the client opens a new TCP connection only after the last ACK is transmitted. [8 marks]

i. Draw a transmission figure to show how the client opens a connection, downloads the first object from the server, and closes the connection, assuming that HTTP with non-persistent connection is used. Indicate the exchange of all packets (including control packets) in the figure.
ii. How much time is involved from the beginning of the download to the return of the last ACK, using HTTP with non-persistent connection to download the three objects?

iii. How much time is involved from the beginning of the download to the return of the last ACK, using HTTP with persistent connection to download the three objects? Draw a figure to justify your answer.

iv. How much time is involved from the beginning of the download to the return of the last ACK, using HTTP with persistent connection and pipelining to download the three objects?

d. Consider Figure Q.3, 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 6400 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. [4 marks]

ii. Now suppose a cache is installed in the institutional LAN. Suppose that the hit rate is 0.35. Find the total average response time. [4 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. [4 marks]

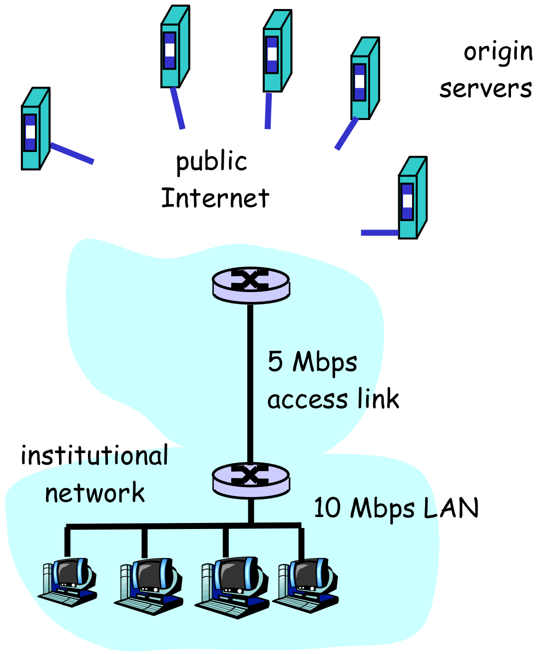


Figure Q.3

Question 4. **(25 marks)**

a. Consider Figure Q.4a. A sender begins sending packetized audio periodically at $t=1$. The first packet arrives at the receiver at $t = 6$.

a) What are the delays (from sender to receiver, ignoring any playout delays) of packets 1 through 8? Note that each vertical and horizontal line segment in the figure has a length of 1, 2, or 3 time units. [2 marks]
b) If audio playout begins at $t = 5$, which of the first eight packet sent will *not* arrive in time for playout? [2 marks]
c) If audio playout begins at $t = 6$, which of the first eight packets sent will not arrive in time for playout? [2 marks]
d) If audio playout begins at $t = 7$, which of the first eight packets sent will not arrive in time for playout? [1 marks]
e) What is the minimum playout delay at the receiver that results in all of the first eight packets arriving in time for their playout? [1 marks]

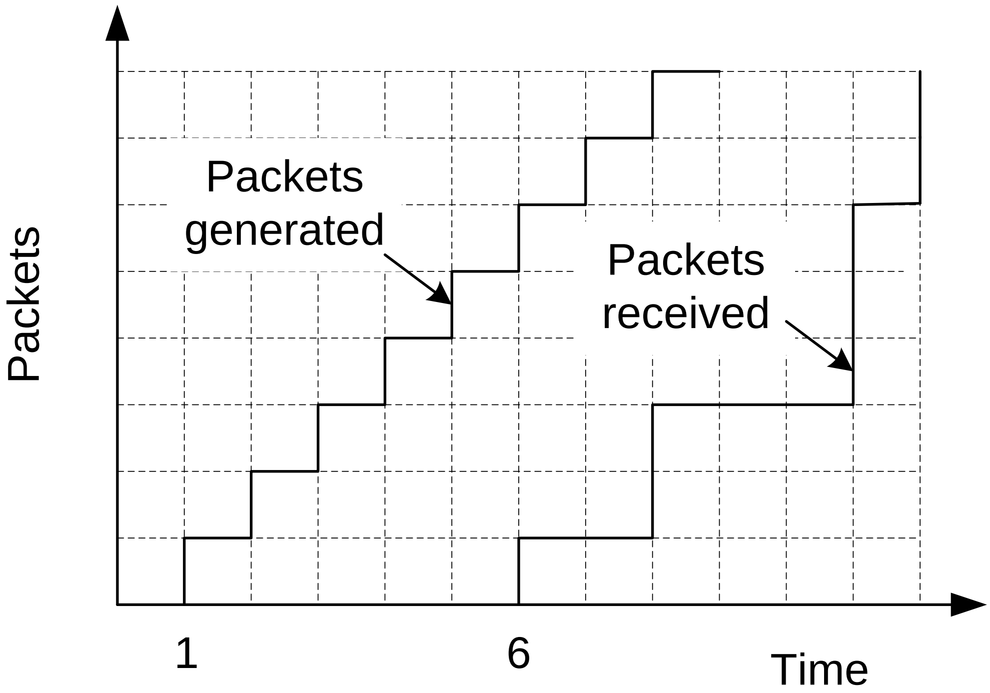


Figure Q.4a

b. How do you implement the token bucket policer such that we can limit the input traffic to specified burst size and average rate? [2 marks]

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 (**excluding** TCP connection establishment) when 6 S/R > S/R + RTT > 2 S/R. [6 marks]

d. Consider Figure Q.4d, which shows a token bucket policer being fed by a stream of packets. The token buffer can hold at most one token, and is initially full at t = 0. New tokens arrive at a rate of two tokens per slot. The output link speed is such that if two packets obtain tokens at the beginning of a time slot, they can both go to the output link in the same slot. The timing details of the system are as follows: [9 marks]

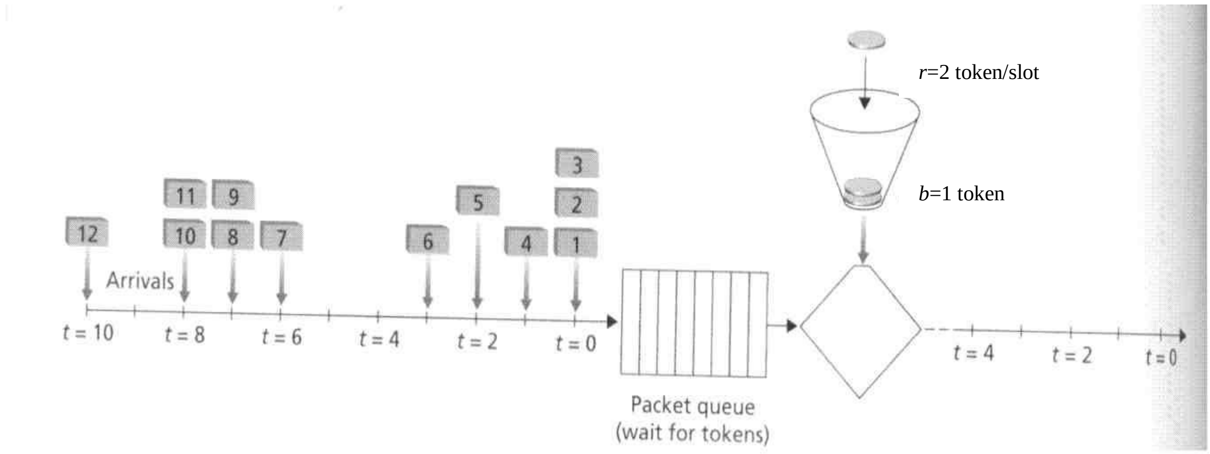


Figure Q.4d

1) Packets (if any) arrive at the beginning of the slot. Thus in the figure, packets 1, 2 and 3 arrive in slot 0. If there are already packets in the queue, then the arriving packets join the end of the queue. Packets proceed towards the front of the queue in a FIFO manner.
2) After the arrivals have been added to the queue, if there are any queued packets, one or two of those packets (depending on the number of available tokens) will each remove a token from the token buffer and go to the output link during that slot. Thus, packet 1 removes a token from the buffer (since there is initially one token) and go to the output link during slot 0.
3) One or two new tokens are added to the token buffer if it is not full until it is full, since the token generation rate is r = 2 token/slot.
4) Time then advances to the next time slot, and these steps are repeated.

Answer the following questions:

i. For each time slot, identify the packets that are in the queue and the number of tokens in the bucket, immediately after the arrivals have been processed (step 1 above) but before any of packets have passed through the queue and removed a token. Thus, for the t = 0 time-slot in the example above, packets 1, 2 and 3 are in the queue, and there is one token in the buffer.
ii. For each time slot, indicate which packets appear on the output after the token(s) have been removed from the queue. Thus, for the t = 0 time-slot in the example above, packet 1 appears on the output link from the token bucket during slot 0 (the t = 0 time-slot).

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