IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2014

MSc and EEE/EIE PART III/IV: MEng, Beng and ACGI

COMMUNICATION NETWORKS

Thursday, 23 January 10:00 am

Time allowed: 3:00 hours

Corrected Copy

There are FOUR questions on this paper.

Answer ALL questions.

All questions carry equal marks

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible First Marker(s) : J.A. Barria

Second Marker(s) : T-K. Kim

Special information for students

1. Mean delay for the M/M/1 system may be taken as

$$t_i = \frac{1}{\mu C_i - \lambda_i}$$

where,

$1/\mu$ = Average length of packet [bits / packet]

C_i = Transmission speed link i [bits / s]

μC_i = Service rate (link i) [packets / s]

λ_i = Arrival rate (link i) [packets / s]

2. Optimal Routing Problem (ORP)

$Min\ D(x)$ with respect to $x = \{ x_i \}$

where $D(x) = \sum_{i=1}^{L} \frac{x_i}{C(i) - x_i}$

$C(i)$ = capacity of link i,

x_i = flow carried by link i,

L = total number of links in the network.

The Questions

1.

a) For an N station token ring using the IEEE 802.5 LAN protocol. Assume normalised throughput to system capacity (i.e. packet *transmission delay* = 1).

Derive the utilisation of the token ring protocol for the complete range of values of a (= *propagation delay*/*trasmission delay*) assuming that the N stations are placed equidistant to each other. [5]

b) A summary of the TCP receiver's acknowledgment generation policy (RFC 1122 and RFC 2581) is shown in ***Table 1.1*** (with missing information).

Complete the missing information (blank boxes) in ***Table 1.1***. [8]

Table 1.1

Event at receiver	*TCP receiver action*
Arrival of in-order segment, with expect sequence number. All data up to expect sequence number have already been Acknowledged.	
	Immediately send single cumulative ACK: Acknowledging both in-order segments.
Arrival of out-of-order segment higher-than-expect sequence number (gap in sequence detected).	
	Immediately send ACK, provided that segment starts at the lower end of the gap in sequence detected.

ACK: acknowledgement

c)

i) Briefly describe two distinctive differences between the 802.11 and 802.3 MAC protocol mechanisms. [3]

ii) Explain and discuss the mechanism to manage collisions used by the protocol 802.11. [4]

2.

a) With the help of *Fig. 2.1.*

Explain how the TCP protocol could estimate:

i) the round trip time (RTT), and [4]

ii) the time out interval. [4]

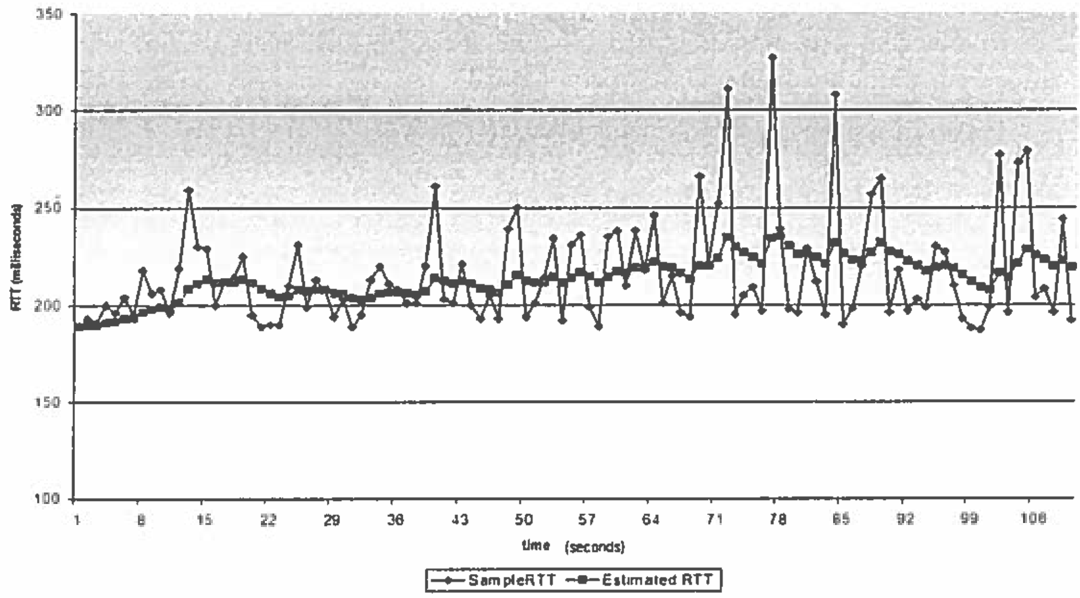


Figure 2.1 [Ref.: Computer Networking, J.F. Kurose and K.W. Ross]

Question 2 continues in the next page

Question 2

2.

b) The network shown in ***Fig. 2.2*** represents a packet network. A well known objective of network operators is to minimise the mean network delay given by:

$$\text{Min } D(x) = \sum_{i=1}^{L} \frac{x_i}{C(i) - x_i} \text{ with respect to } x = \{x_i\}$$

where $C(i)$ is the capacity of link i, x_i is the flow in link i, and the offered traffic is R(1, 4).

i) State clearly the optimality condition assuming that the three possible paths from Origin (node 1) to Destination (node 4) are actually carrying traffic. [6]

ii) If the link $C(5)$ needs to be replaced, what is the minimum capacity, under the current traffic conditions, for it to carry traffic?

In Part ii) assume in your calculations that $C(1) = C(2) = C(3) = C(4)$. [6]

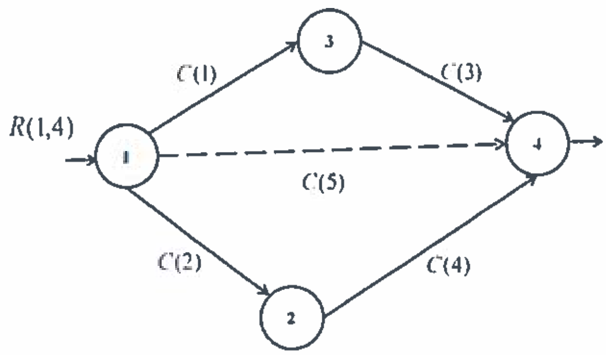


Figure 2.2

3.

a) The network in *Fig. 3.1* represents a communication network and the values next to its links represent the cost of carrying traffic in the link.

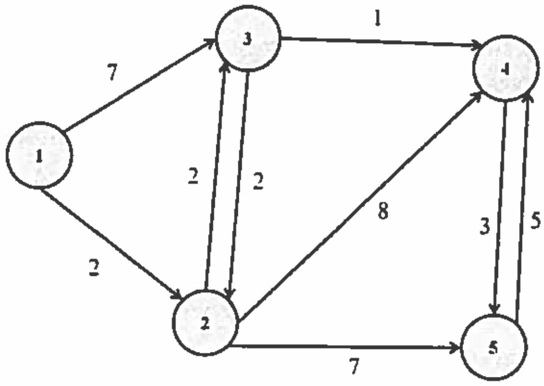


Figure 3.1

i) Solve the shortest path problem using Dijstra's shortest path algorithm.

Assuming that the Origin node is **node 1**: use the format shown in *Table 3.1* to clearly identify the outcome of each iteration. [8]

Table 3.1

Iteration Number	**N**	**D(x), p(x)**	**D(y), p(y)**	**D(z), p(z)**	**...**
0	1				
1					
...					

D(x) = current value of cost of path from source to destination x.

p(x) = predecessor node along path from source to destination x.

N = set of nodes whose least cost path are known.

Question 3 continues in the next page

Question 3

3.

b) ***Figure 3.2*** shows the time sequence of a TCP connection. Assume that the initial threshold has a large value (that is that the threshold is never attained by the congestion window) and consider the following information:

- O = size of the file to be transferred.
- W = the size of congestion window in segments,
- S = maximum segment size (MSS) in bits,
- R = the transmission rate (bps) of the link from the server to the client,
- RTT = round trip time, and

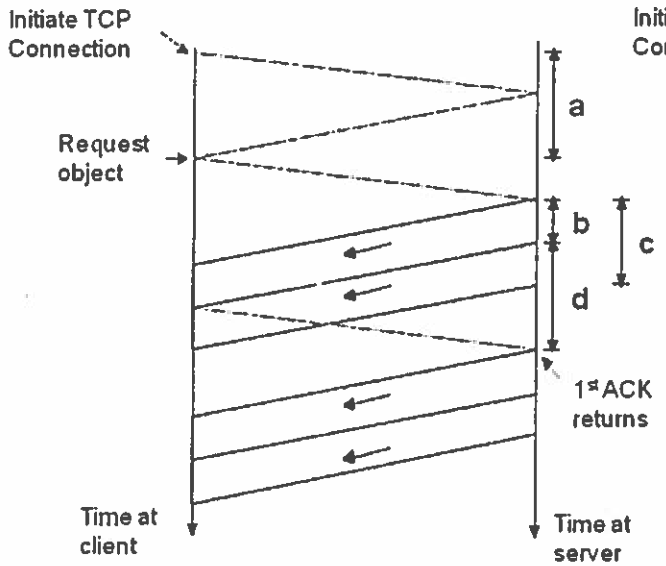
i) Complete the time sequence depicted in ***Fig 3.2 a)*** and ***Fig. 3.2 b)*** and clearly identify the value of labels a, b, c, d, e, f, g and h in each figure. [5]

ii) Clearly state if the figures represent the case in which $WS/R > RTT+S/R$ and/or $WS/R < RTT+S/R$, and explain what the physical interpretation of the sequences a) and b) are. [3]

iii) Derive an expression of the latency for the sequence in ***Fig 3.2 a)*** and the sequence in ***Fig 3.2 b)***. [4]

Figure 3.2. a) and Figure 3.2. b) in next page.

Question 3b) continues in the next page



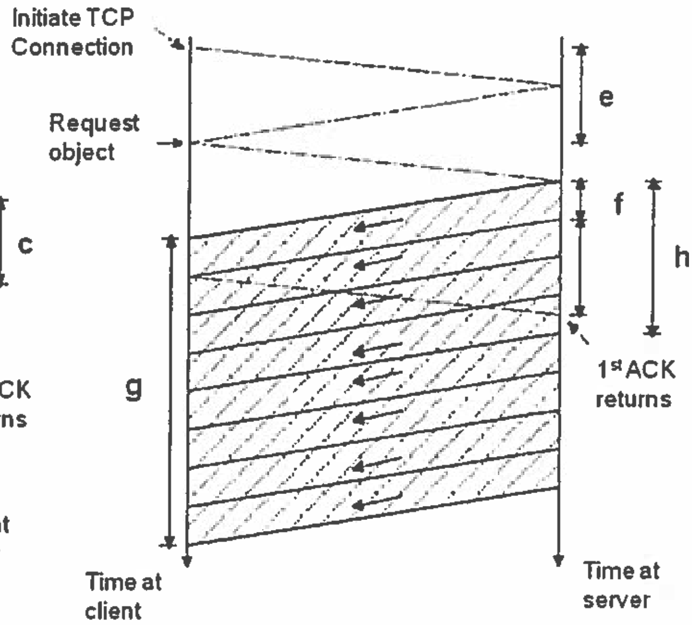


Figure 3.2. a) and *Figure 3.2. b)*

4.

a) Using as a reference the packet network representation shown in ***Fig. 4.1***:

i) State Littles's result and its relation to the mean network delay of a network of queues. [4]

ii) Assuming that all traffic offered and carried is Poisson traffic, and

-the mean packet arrival rate to each link C_i is λ_i (in ***Fig. 4.1***),

-the average packet length is $1/\mu$, and

-the total mean packet arrival rate to the network is γ.

Derive an expression of the total number of outstanding packets in the network. [4]

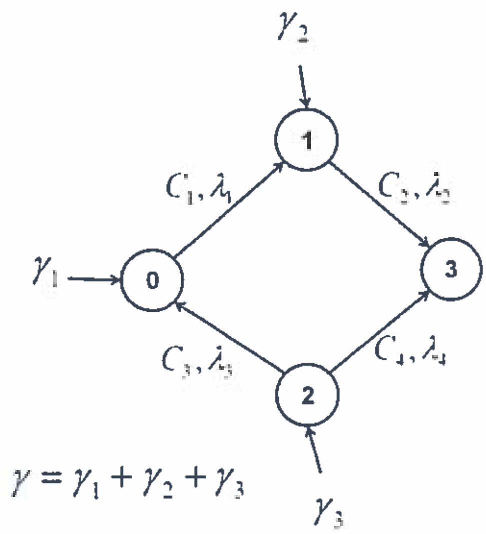


Figure 4.1

b) In the context of a connectionless network environment, like for example, the Internet:

i) Clearly explain and discuss the importance of the four basic principles:

- Marking packets,
- Protecting connections from each others,
- Efficient sharing of resources, and
- Call admission. [4]

ii) Explain how do the Intserv and the Diffserv peer models implement the four principles introduced in 4 b) i). [8]