EE3-17

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2016

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

COMMUNICATION NETWORKS

Corrected copy

Thursday, 8 December 9:00 am

Time allowed: 3:00 hours

Q 4 b (i)
before exam

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 [bit/packet]

C_i = Transmission speed link i [bits/s]

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

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

2. Optimal Routing Problem (ORP)

$Min\ D(F)$ with respect to $F = \{ F_i \}$

where, $D(F) = \sum_{i=1}^{L} \frac{F_i}{C_i - F_i}$

and,

C_i = Capacity of link l_i.

F_i = Flow carried by link l_i.

The Questions

1.

a) In the context of a CSMA/CD protocol the maximum length of the cable is $2.5\,km$ and the speed of propagation of this guided media is $2 \times 10^8\,m\,s^{-1}$.

The cable is assembled using five segments of equal length interconnected using repeaters. Note that each repeater introduces a $2.5\,\mu s$ delay.

Calculate the maximum waiting time that will allow any one station to detect a collision. [5]

b) Frames of a $1\,kbit$ size are transmitted through the following transmission media:

Transmission media	Media length	Propagation velocity
1) Twisted pair cable	$1\,km$	$2 \times 10^8\,m\,s^{-1}$
2) Leased line	$200\,km$	$2 \times 10^8\,m\,s^{-1}$
3) Satellite link	$30{,}000\,km$	$3 \times 10^8\,m\,s^{-1}$

Table 1.1: Characteristics of the transmission media.

Assuming that a Stop-and-Wait RQ protocol is in used:

i) Determine the utilisation of each media in Table 1.1 for the following transmission rates:

a) $1\,kbps$ and [3]

b) $1\,Mbps$. [3]

ii) Discuss your findings, using three (3) bullet points. [3, 3, 3]

2.

a) For a Selective Repeat ARQ protocol the effective transmission rate is given by the following expression:

$$R_{eff} = (1 - P_f)\left(1 - \frac{n_O}{n_f}\right)R$$

Where n_O is the number of bits of overhead in a frame (header plus CRC check bits), n_f is the number of bits in the information frame, and R is the bit rate of the transmission channel.

i) Derive an expression of P_f (the probability that a frame has errors), as a function of p (the probability that the transmission of a single bit is in error). [3]

ii) Discuss the impact on P_f for different values of p.
Use the range of $p = (10^{-6}, 10^{-4})$ for your discussion. [3]

2.

b) A network layer mechanism to prevent over-utilization of a node relies on monitoring its buffer occupancy.

i) Define the parameters on the x and y axis in Figure 2.1. [2]

ii) Describe the prevention mechanism shown in Figure 2.1. [3]

iii) Discuss the effect on access to the buffer, and on buffer utilization of the mechanisms described in ii). [4]

iv) Describe and explain, with the help of Figure 2.1., a Random early detection I/O (RIO) queue management scheme. [5]

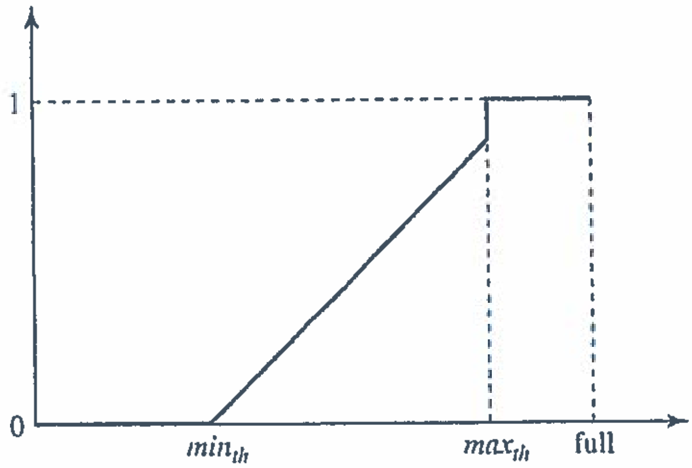

Figure 2.1: Queue management mechanism.

3.

a) Packets arriving at a router are to be forwarded to a layer 2 network that has a maximum transmission unit (MTU) of 576 bytes. The packets have an IP header of 20 bytes and a payload of 1484 bytes.

Show the results of packet fragmentation by deriving and completing the missing values in Table 3.1. [2, 2, 2]

	Total length	ID	MF	Fragment offset
Original packet	1504	x	0	0
Fragment 1				
Fragment 2				
...				

Table 3.1: Packet fragmentation mapping

3.

b) The maximum lifetime energy routing algorithm defines the link cost, $EC(i, j)$ as a function of node remaining energy $E(i)$ and the required transmission energy $e(i, j)$ between nodes i and j:

$$EC(i,j) = \frac{e(i,j)}{E(i)}$$

Using the graph representation of a wireless sensor network (WSN) in Figure 3.1 with the following information of $E(i) = (3,5,2,1,7,8,6)$:

i) Assign $EC(i, j)$ to all links in the network. [4]

ii) Using Dijkstra's algorithm, derive the shortest paths from all nodes in the WSN to the base station (BS). Assume that each message sent consumes $e(i, j) = 2$ units of energy for any (i, j) pair. [6]

iii) How many messages (all of them consuming the same amount of energy $e(i, j) = 2$) can node 6 send to node BS, before the communication between node 6 and node BS are no longer available. [4]

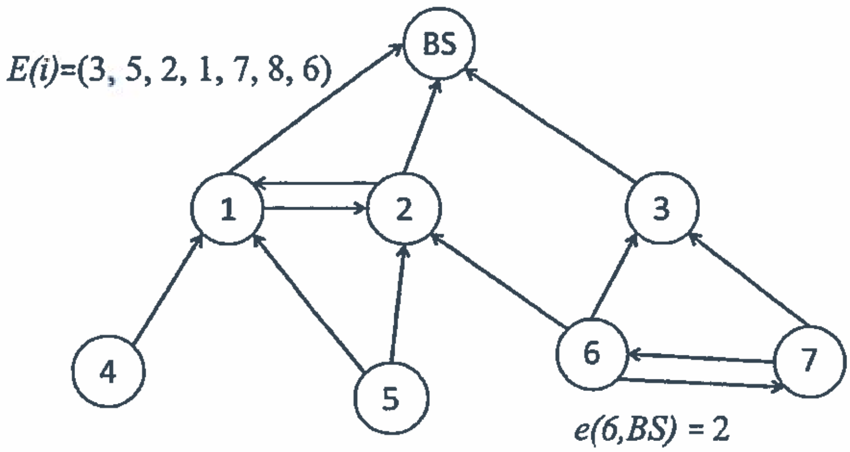

Figure 3.1: Wireless sensor network.

4.

a) Figure 4.1. shows a sample path of a dynamic TCP congestion window evolution.

i) Specify the parameters on the $x-$ and $y-$axis in Figure 4.1. [2]

ii) Clearly identify the different TCP protocol congestion control mechanism phases represented in the Figure 4.1. [2]

iii) Describe the rationale of each one of the identified phases in your answer to ii) above. [2]

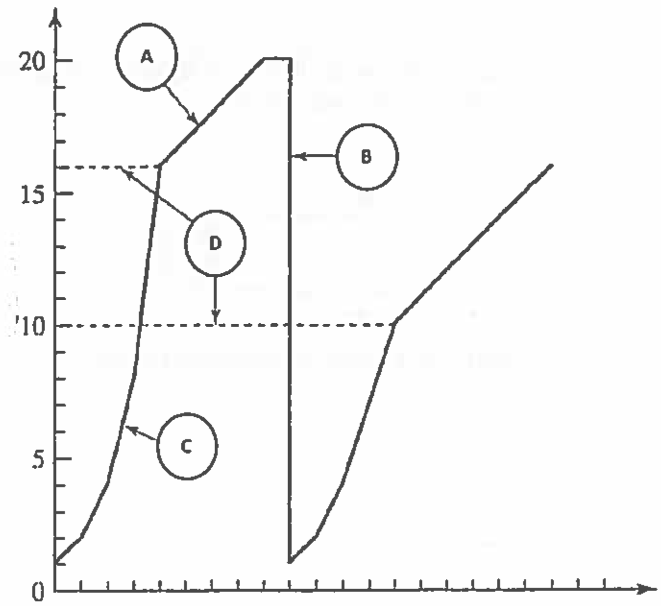

Figure 4.1: Dynamic TCP congestion widow evolution.

4.

b) Figure 4.2 represents a transportation network with two alternative paths, and their corresponding travel time probability density function $f_i(t)$, with mean μ_i and variance σ_i, are shown in Figure 4.3.

Let the cost function of using path p and arriving at the destination at time t be denoted by $C_p(t) = t^2$. Then, the expected cost of departing at time t and using path p is given by:

$$EC_p(t) = \int_0^{\infty} f_p(y)(t+y)^2 dy$$

i) Derive the departing time that minimises the expected cost of a path. [5]

ii) Choose the best route when the departure time gets closer to the target arrival time. Justify your answer. [5]

iii) Choose the best route when you can set the departure time of the two alternative paths independently. Justify your answer. [4]

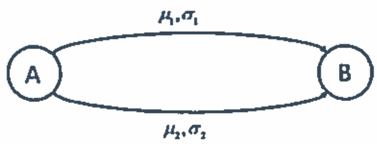

Figure 4.2: Two alternative paths trasportation network.

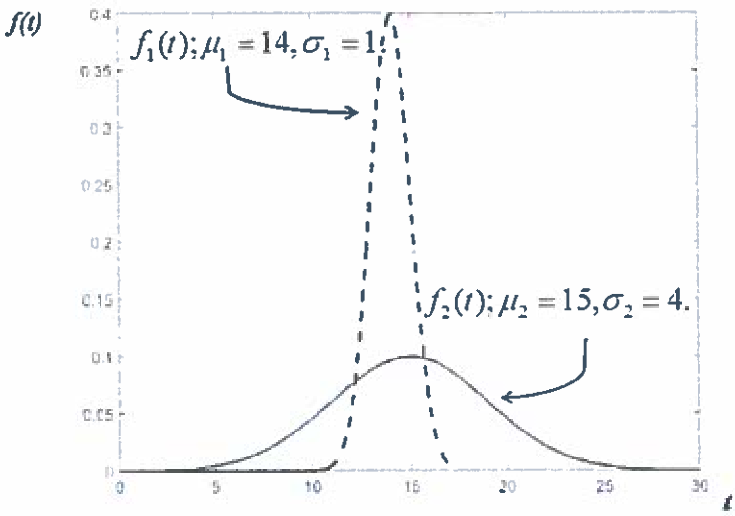

Figure 4.3: Travel time probability density function.