IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2017

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

COMMUNICATION NETWORKS

Corrected copy

Tuesday, 12 December 9:00 am

Time allowed: 3:00 hours

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) : C. Ling

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 link layer *Go back N ARQ* protocol each frame in error generates K retransmissions.

Assume that you know the probability P of a single frame in error, and that the expected number of transmissions, N_r, of a frame can be approximated by:

$$N_r = \sum_{i=1}^{\infty} f(i) P^{i-1}(1-P)$$

where $f(i) = 1 + (i-1)K$

i) Propose a suitable approximation of K for the case in which $W > 2a+1$ and for $W < 2a+1$. Discuss any assumption made. [5]

ii) Derive the utilisation of the medium for the case in which $W > 2a+1$ and for $W < 2a+1$. [5]

Note: W, is the normalised window size and, a, is the propagation delay / transmission delay ratio.

b)

i)

Describe the main characteristics of mobile ad hoc networks, ensuring that you discuss their main technical issues and the distinct characteristics of their routing algorithms.

[5]

Describe a potential application of a mobile ad hoc network, explaining the specific benefits of using such a network in this application.

[2]

ii) In the context of Intelligent Transportation Systems an intelligent vehicle will be endowed with specialised sensors networks. Briefly discuss three applications that will improve safety and drivers experience.

[3]

2.

a) For the network shown in Fig. 2.1.

i) The social optimal routing problem can be characterised by the cost function:

$$T_1 = \sum_{i \in E} x_i l_i(x_i)$$

Where x_i is the flow in link i and $l_i(x_i)$ is the cost (delay) function of link i.

Discuss what is being optimised when minimising the function T_1. [2]

Solve the social optimal routing, that is, obtain x_1^* and x_2^* that minimise T_1. [2]

ii) The user equilibrium routing problem is characterised by the cost function:

$$T_2 = \sum_{i \in E} \int_0^{x_i} l_i(x_i)$$

Where x_i is the flow in link i and $l_i(x_i)$ is the cost (delay) function of link i.

Discuss why this optimisation problem is also referred as "selfish routing". [2]

Solve the user equilibrium routing problem, that is, obtain x_1^* and x_2^* that minimise T_2. [2]

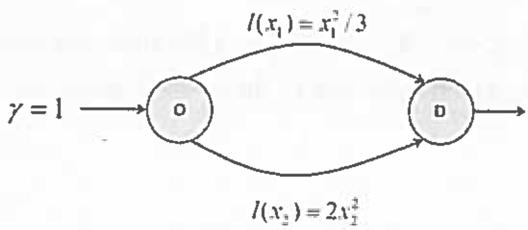

Figure 2.1

iii) Discuss and contrast the physical interpretation of these two solutions. [2]

b)

i) Define and discuss four principles to support quality of service (QoS) guarantees in a TCP/IP network environment. [8]

ii) For each one of the principles identified in i) discuss at least one mechanism that could be implemented in the differentiated service (DS) model. [2]

3.

a)

i) The TCP congestion control algorithm has three major components. Introduce and describe how the three components operate.

[4]

ii) In the context of TCP latency estimation:

Calculate the time it takes the TCP protocol to send an object of size O when $WS/R < RTT + S/R$, stating clearly any assumption made.

Here, W is the size of the window; S is the size of the maximum segment size; R is the transmission rate of the link from server to client; and RTT is the round trip time.

[6]

b) Fig. 1.1 represents a network of M/M/1 queues (links). This network is being fed with a stream of γ_{13} packets/s.

If the aim is to minimise the mean network delay:

i) Find the condition for path 1 (via $C(1)$ and $C(3)$) to start carrying traffic. Assume that initially all the traffic is being carried by path 2 (via $C(2)$).

[5]

ii) If $C(2) = 2\gamma_{13}$ and $C(3) = 2C(2)$ find the minimum capacity $C(1)$ of link 1 to start carrying traffic if initially all the traffic is being carried via link $C(2)$.

[5]

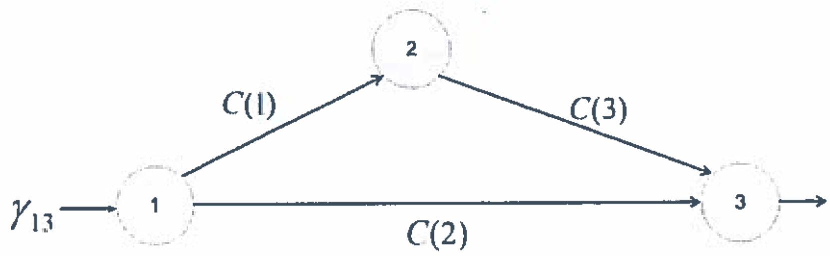

Figure 1.1.

4.

a) The fairness metric in a system that needs to share resources is a measure of how the resources are distributed among the users.

i) The Jain's fairness index is defined as: $\Gamma = \left(\sum_{i=1}^{n} x_i\right)^2 \Big/ \left(n\sum_{i=1}^{n} x_i^2\right)$

Discuss the characteristics of this index. Derive the value of the function Γ in the best and worst case scenario and discuss its physical interpretation. [3]

ii) Define and discuss *max-min fairness* and describe a simple procedure to implement it. [3]

iii) In Fig. 2.2. two applications are represented with their bandwidth utility functions: one elastic traffic application and one adaptive real-time traffic application.

- Identify and sketch the *utility max-min fairness* allocation, [2]
- Identify and sketch the *bandwidth max-min fairness* allocation, [2]
- Discuss the allocation impact on the two contending applications. [2]

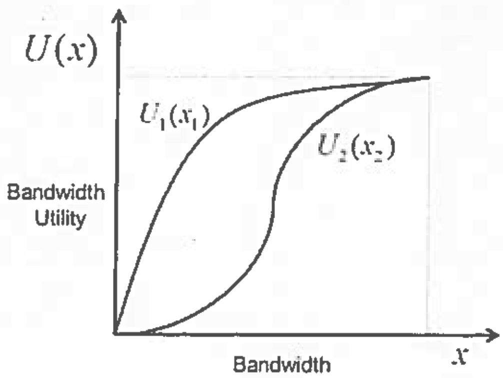

Figure 2.2

b) In the context of a differentiated service (DS) model:

i) Identify and discus the role of the functions that can be deployed at the Edge routers. [4]

ii) Identify and discuss the role of the functions that can be deployed at the Core routers. [4]