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ISE3.31

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2009

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

Corrected Copy

COMMUNICATION NETWORKS

Friday, 15 May 10:00 am

Time allowed: 3:00 hours

There are SIX questions on this paper.

Answer FOUR 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 instructions for students

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

$$T = \frac{1}{\mu - \lambda}$$

where

λ = arrival rate at M/M/1 system [packets / s], and

μ = service rate of M/M/1 system [packets / s].

1.

a) The utilisation of a 1-persistent CSMA/CD protocol is given by:

$$U = \frac{1/2a}{1/2a + (1-A)/A} = \frac{1}{1+2a(1-A)/A}$$

i) Define and describe the significance of parameters "a" and "A".

[6]

ii) Derive A as a function of the number of stations N and any other statistics that you may think appropriate.

Explain clearly your derivations.

[6]

b) Several requirements have been identified when developing mobile IP standards.

Describe and discuss four (4) generic underlying requirements for the development of mobile IP standards.

[8]

2.

a) The allocation of resources, in a market oriented framework, is made taking into account users' preferences and network capacity. Within this framework:

i) Explain how users' preference can be represented. [3]

ii) If you are able to use two prices (p_1, p_2) explain how you segment the users into two subsets of demands. [3]

iii) Assuming that you are a centralised network planner, how do you maximise your benefits ? [3]

iv) Assuming that you are a centralised network planner, how do you characterise the optimal prices ? [3]

b) For the network represented in Figure 2.1, using the Dijstra shortest path algorithm:

Obtain the shortest path from node **1** to the rest of the nodes in the network.

Clearly explain step-by-step the progression of the algorithm. [8]

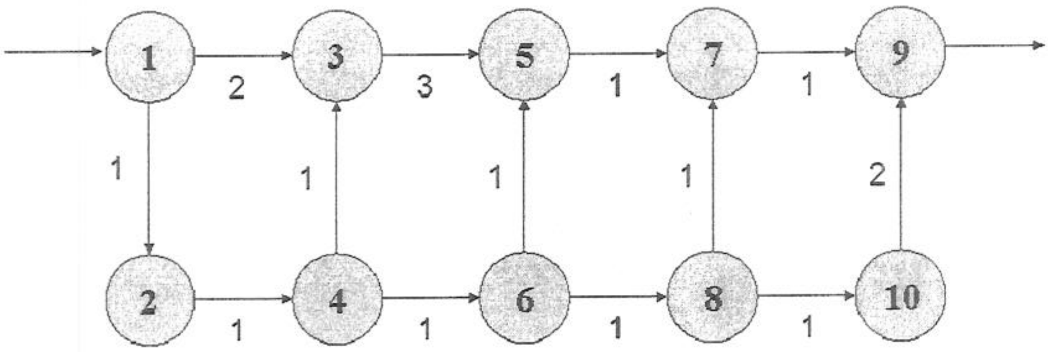

Figure 2.1

3.

a)

i) Describe and discuss the assumptions made in Burke's theorem and its applicability to communications networks.

[5]

ii) Describe and discuss the assumptions made in Jackson's theorem and its applicability to communications networks.

[5]

b) For the combined OR and flow control problem for the two-node one-link network shown in Figure 3.1:

- There is only one Origin-Destination demand pair R12 = 15 kbits/s
- The capacity of the link is C(1,2) = 9 kbits/s.
- Take the cost function to be:

$$D = \frac{r}{C(1,2) - r} + \frac{a}{r}$$

i) If it is required that the network operates at a maximum Average Network Delay = T, obtain the value of the parameter a of the flow control penalty function.

[10]

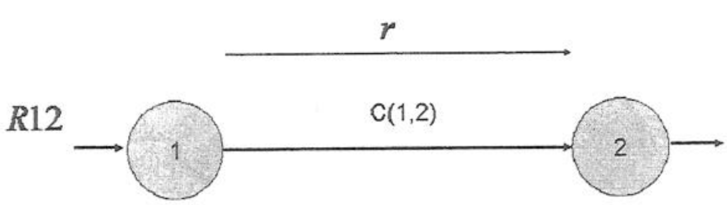

Figure 3.1

4.

a) Routing algorithms

i) Explain and describe the basic features of a global routing algorithm. Give one example of this type of algorithm.

[5]

ii) Explain and describe the basic features of a decentralised routing algorithm. Give one example of this type of algorithm.

[5]

b) ATM traffic management.

i) Using Figure 4.1, identify the location of the following ATM traffic management functions: TS, CAC and GCRA.

[3]

ii) Using Figure 4.1, explain the functionality and features of the ATM traffic management functions: TS, CAC and GCRA.

[7]

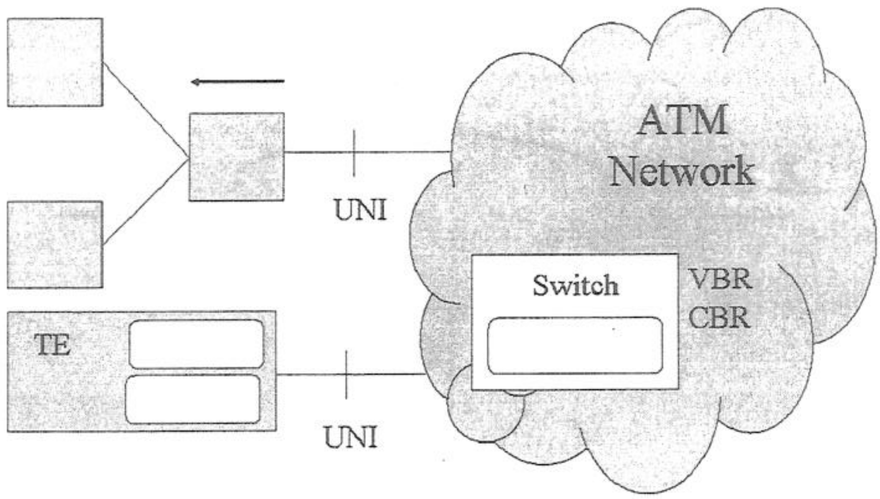

Figure 4.1

5. Given the following measurement of congestion for the network in Figure 5.1.

$$T = \sum_{i=1}^{L} P(i)T(i)$$

where

$$T(i) = \frac{1}{C(i) - \lambda P(i)}$$

$C(i)$ = capacity of link i.
$P(i)$ = routing probability to link i.
λ = packet arrival rate [packets/s].

Assuming also that $C(1) > C(2)$

i) Obtain the conditions such that a single link would carry all the traffic. [10]

ii) Obtain the optimal value of $P(i)$ such that T is minimised. [10]

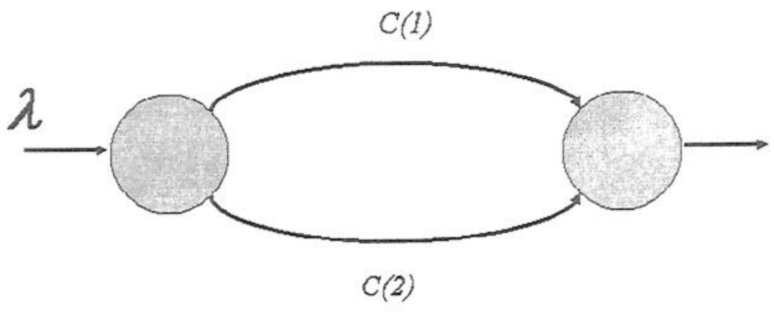

Figure 5.1

6.

a) Leaky Bucket Scheme.

i) With the help of Figure 6.1. and the assigned capital letters (A) – (F), explain the associated processes and/or components of the Leaky bucket scheme.

[5]

ii) With help of Figure 6.1:

- Describe and discuss the relevant features of the Leaky bucket scheme,

[3]

- Identify which of the letters (A)-(F) are associated to the features you have described.

[2]

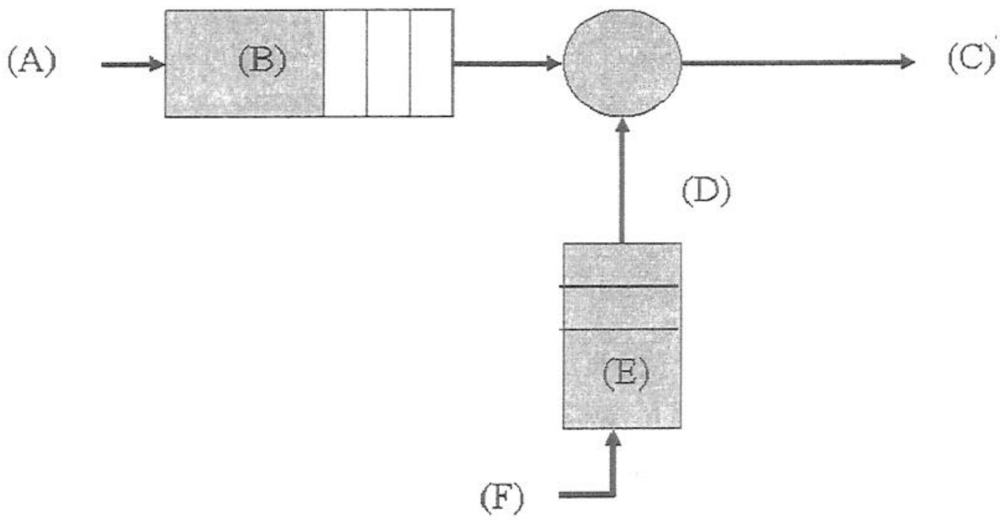

Figure 6.1

Question 6(b) continues next page

6.

b) In the context of emerging technologies for network survivability, and using Figure 6.2 as a reference:

Explain and discuss the four relevant phases highlighted in Figure 6.2.

[10]

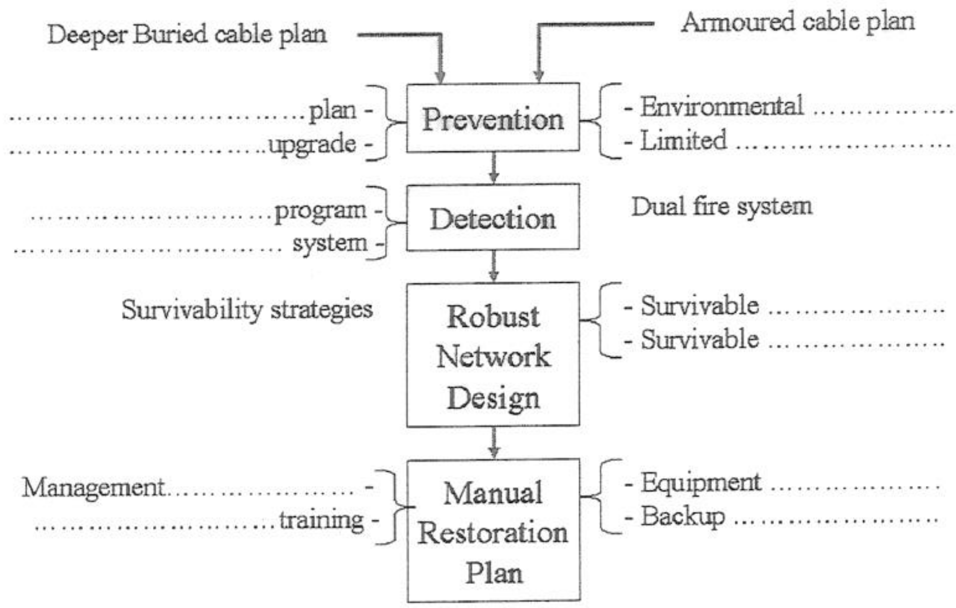

Figure 6.2

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Q1 a) i)

$$U = \frac{1}{1+2a(1-A)/A}$$

$$a = \frac{\text{propagation time}}{\text{transmission time}} = \frac{Rd}{LV}$$

A = Probability that exactly one station attempts transmission in a slot

ii) N = Number of stations

P = probability that a station transmit during an available time slot

$$A = \binom{N}{1} P^1 (1-P)^{N-1} = NP(1-P)^{N-1}$$

Q1 b) Compatibility: discussion on e.g. backward compatibility, No effect on MAC/LLC protocols. Accessibility to established servers and services. Also mention the implications on address format and routing mechanism

Transparency: should remain invisible for many higher layer protocols. Many application have not been designed for use in mobile environments. Some new applications it is better to be "mobility aware". give examples

Scalability & efficiency: Any new mechanism must not jeopardize its efficiency. Eg. must not generate too many new messages. Mention the growth and number of participants already connected

Security: mobility poses many security problems. The minimum is that messages are authenticated. Also need to be sure that the target host receive the correct packets (the IP layer only guarantee that the IP address of the receiver is correct.

2/

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Q2 a) i) Users' preference can be represented by their utility functions.

Example: $u_t(x) = u(x) - d_t x \qquad x \geq 0,\ t = 1, 2$

x = amount of traffic

u_t = benefit of sending data (e.g. e-mail)

$d_t x$ = loss or benefit reduction

ii) Assume that p_t is the incremental cost of sending information and that $d_1 < d_2$.

Then the users will transmit a message that will maximise her net benefit

$$\max\left[u_t(x) - p_t x\right] = \max\left[u(x) - d_t x - p_t x\right]$$

$$\frac{\partial}{\partial x}\left[u(x) - d_t x - p_t x\right] = 0$$

so users will transmit in period 1 if $p_1 + d_1 < p_2 + d_2$

iii) Users i will segment themselves into two subsets

$$I_1 = \{i \mid p_1 - p_2 < d_2^i - d_1^i\}\ ;\ I_2 = \{i \mid p_1 - p_2 \geq d_2^i - d_1^i\}$$

central planner

$$\max \sum_{i \in I_1}\left[u^i(x_1^i) - d_1^i x_1^i\right] + \sum_{i \in I_2}\left[u^i(x_2^i) - d_2^i x_2^i\right]$$

subject to $\displaystyle\sum_{i \in I_1} x_1^i \leq c_1 \quad ; \quad \sum_{i \in I_2} x_2^i \leq c_2$

iv) The optimal prices are characterised by p_1 & p_2 such that for each period

$$\frac{\partial u^i}{\partial x_t^i} = p_t + d_t^i \qquad \forall i \in I_t$$

$$I_1 = \{i \mid p_1 - p_2 < d_2^i - d_1^i\}\ ;\ I_2 = \{i \mid p_1 - p_2 \geq d_2^i - d_1^i\}$$

$$\sum_{i \in I_t} x_t^i \leq c_t$$

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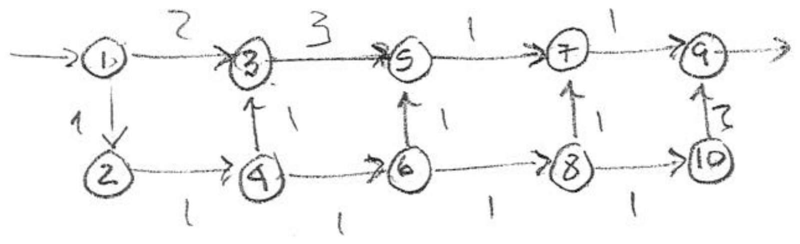
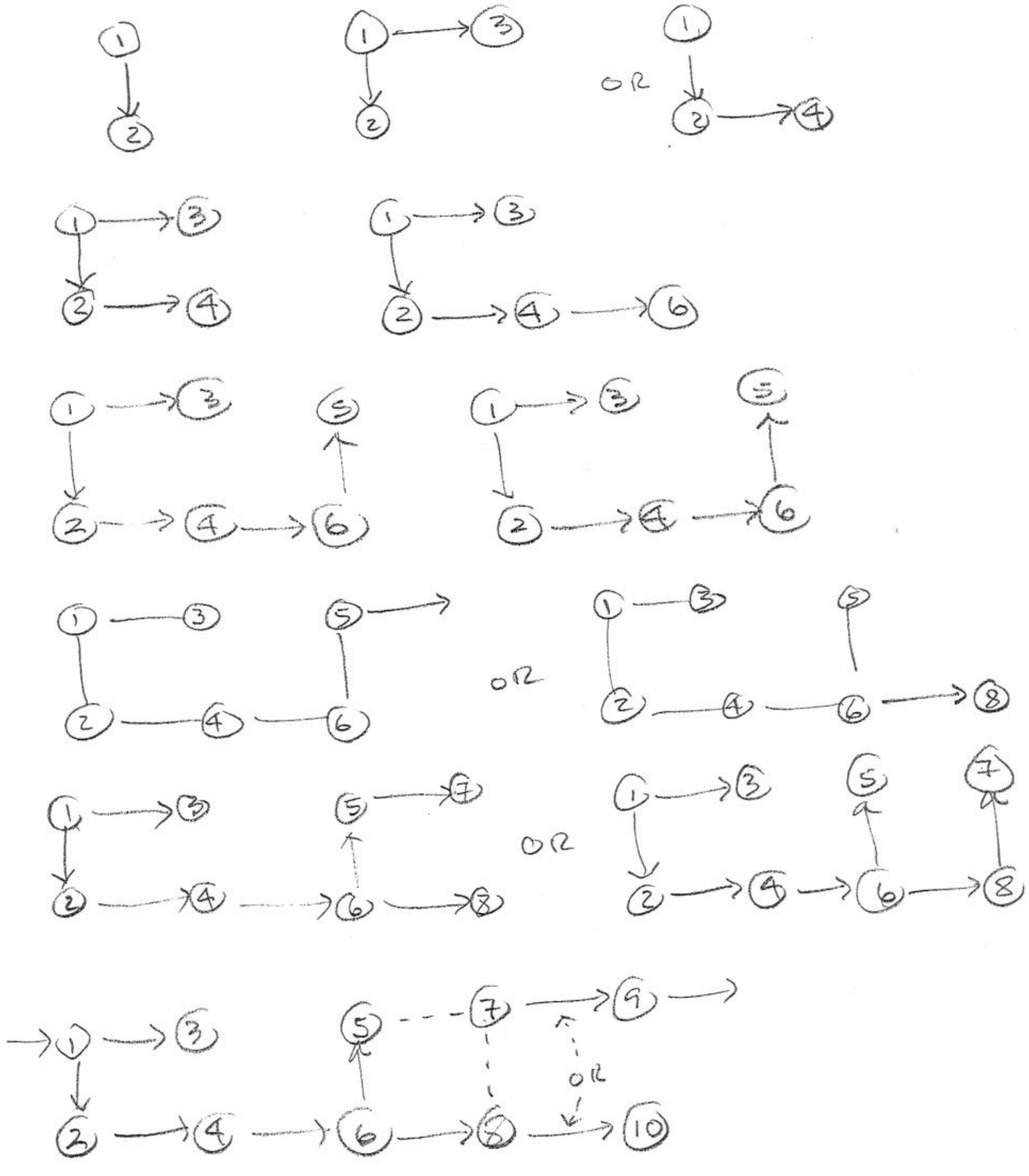
Q2

a)





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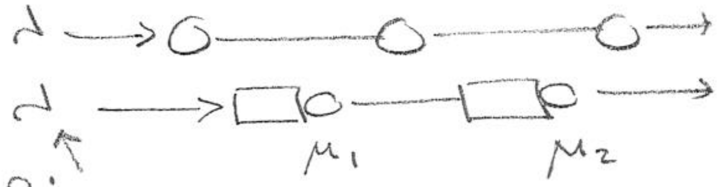
Q3 a) i) Burke's



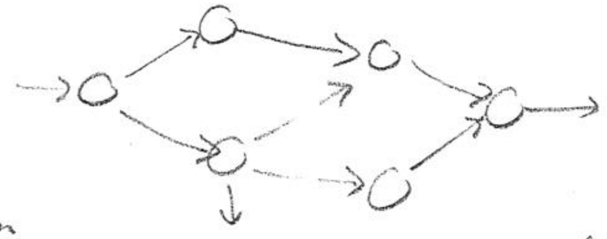
Assumptions

- Arrival stream is Poisson
- service time is exponential (μ_1, μ_2)
- service time in Q_1 and Q_2 independent random variable

→ Q_1 & Q_2 behaves like two independent M/M/1 system in series"

- Discussion on its applicability to communication Networks

ii)



Assumption

- Queueing network consists of l links each having an independent exponential service time distribution
- packets arriving from outside system to any one node is a Poisson stream.
- once served a packet goes to another node with fixed probability or leave the system.

In such network of queues each link behaves as an independent M/M/1 or M/M/K with Poisson flows determined by i) Partitioning ii) merging and iii) Tandem

- Discussion on its applicability to communication networks

5

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Q3 h) $R12 = 15$ Kbits/s $C(1,2) = 9$ Kbits/s

$$D = \frac{R}{C-R} + \frac{a}{R} \qquad T = \frac{R}{C-R} \Rightarrow R = \frac{Tc}{1+T}$$

Flow inside network

$$R = \frac{c\sqrt{a}}{\sqrt{a}+\sqrt{c}} = \frac{Tc}{1+T}$$

$$Tc(\sqrt{a}+\sqrt{c}) = c\sqrt{a}(1+T)$$

$$\cancel{Tc\sqrt{a}} + T\cancel{c}\sqrt{c} = \cancel{c}\sqrt{a} + \cancel{c\sqrt{a}T}$$

$$T\sqrt{c} = \sqrt{a} \Rightarrow a = T^2 c$$

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Q4 a) i) Global Routing algorithm

- Calculate least-cost path using complete, global knowledge about the network
- Need mechanism to obtain this information before calculations
- The calculations can be performed in one site or can be replicated at multiple sites

Example: Dijkstra's algorithm

ii) Decentralised routing algorithm

- Calculate the least cost path is done in an iterative, distributed manner
- Each node begins with only the knowledge of the costs of his attached links
- Then by exchanging information with neighbours nodes a node gradually calculates the least cost path.

Example: Bellman-Ford's algorithm

b)

CAC: Call admission control: determines whether a request for a new connection should be accepted or rejected. Contract and agreements.

T.S: Traffic shaping and rate control strategies discussion

GCRA: Generic cell rate Algorithm. Monitor the calls that are established. User parameter control (UPC) in the process of enforcing the traffic agreement at the UNI. Leaky bucket algorithm is a possible candidate to perform GCRA function.

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Q5 i)

$$T = \frac{R(i)}{C(i) - \lambda P(i)}$$

$C(1) > C(2)$

$P(2) = 0 \Rightarrow$

obtained optimal relationship $\left(\frac{\partial P(1)\,T(1)}{\partial P(1)} \overset{?}{(=)} \frac{\partial P(2)\,T(2)}{\partial P(2)} \right)$

$$\frac{C(1)}{\left(C(1) - \lambda P(1)\right)^2} = \frac{C(2)}{\left(C(2) - \lambda P(2)\right)^2}$$

$P(2) = 0 \Rightarrow$

$$\frac{C(1)}{\left(C(1) - \lambda\right)^2} \leq \frac{C(2)}{\left(C(2)\right)^2} \Rightarrow$$

$$\sqrt{C(1) \cdot C(2)} \leq C(1) - \lambda \qquad l = 2$$

$$0 \leq \lambda \leq \sqrt{C(1)}\left(\sqrt{C(1)} - \sqrt{C(2)}\right) \qquad l = 2$$

Q5 ii)

$$\left.\frac{\partial P(1)T(1)}{\partial P(1)}\right|_{P^*_{(1)}} = \left.\frac{\partial P(2)\,T(2)}{\partial P(2)}\right|_{P^*_{(2)}}$$

$$\frac{c(1)}{\left(c(1) - \lambda P^*(1)\right)^2} = \frac{c(2)}{\left(c(2) - \lambda P^*(2)\right)^2}$$

$\Rightarrow$

$$P^*_{(1)} = \frac{\sqrt{c(1)}}{\sqrt{c(1)} + \sqrt{c(2)}}$$

$$+ \frac{\sqrt{c(1)c(2)}}{\lambda\left(\sqrt{c(1)} + \sqrt{c(2)}\right)}\left(\sqrt{c(1)} - \sqrt{c(2)}\right)$$

$$P^*_{(2)} = 1 - P^*(1)$$

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Q6 a) i) A = packet arrival process discussion on feature

B = Queue of packets without a permit

C = Queue of packets with a permit

D = Permit queue

E = Finite buffer size W

F = permits arrive at a rate of 1/R seconds (lost if there is no space in the permit queue)

ii) To join the transmission queue a packet must get a permit from the permit queue. A new permit is generated every 1/R s, where R is the desired input rate, as long as the permit does not exceed a given threshold.

- discussion on the mechanism and its relevance and relation to user parameter control (UPC)

Q6 b) - Complete the Figure

- First phase: prevention of network failure. Minimise problem created by people and environment

- Second phase: quick detection of network component failures.

- Third phase: network self-healing capability during network component failure. (protection is build into the network)

- Forth phase: planning and practicing restoration in case the network cannot fix the problem itself.

- discussion and examples in all above points