IMPERIAL COLLEGE LONDON

E3.17
SO8
ISE3.31

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2006

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

COMMUNICATION NETWORKS

Monday, 8 May 10:00 am

Time allowed: 3:00 hours

There are FIVE questions on this paper.

Corrected Copy

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) : P.J. Beevor

1.

a)

For the following Media Access Control (MAC) protocols,

i) Describe 1-persistent CSMA/CD protocol.

ii) Derive the mean contention interval of a 1-persistent CSMA/CD.

iii) Describe the Token Ring protocol.

iv) Derive the throughput of a Token Ring.

Clearly state all assumptions and approximations made.

[10]

b)

For the Go back N ARQ scheme, and assuming that each frame in error will generate *K* retransmissions, the following expression for the utilisation can be derived:

$$U_{Go\ backN}(N > 2a+1) = \frac{1-P}{1+2aP}$$

$$U_{Go\ backN}(N < 2a+1) = \frac{N(1-P)}{(1+2a)(1-P+NP)}$$

i) State the meaning of *P*, *a* and *N*.

ii) State and discuss key steps in these derivations.

iii) Clearly state and discuss all approximations made.

[10]

2.

a) Define and derive the average number of outstanding packets in a Jackson networks of M/M/1 queues. State clearly any assumptions made.

[10]

b) For the network of Figure 2.2 it is required to send traffic ***R*(1,4)** from node 1 to node 4. Assume the following data:

Link i	*C(i)* = Capacity link *i*	*P(i)* = Probability of failure link *i*
1	3 kbit/s.	0.2
2	2 kbit/s.	0.1
3	5 kbit/s.	0.1
4	2 kbit/s.	0.1
5	4 kbit/s.	0.3

- Path length = $PL(l) = \sum_{k \in \text{path } l} \frac{1}{C(k)}$

- Path availability = $PA(l) = \prod_{k \in \text{path } l} (1 - p(k))$, where *p(k)* is the probability of failure of link *k*.

i) Solve the shortest path problem by using $1/C(i)$ as link *i* length, where *C(i)* is the capacity of link *i*. Use the Bellman-Ford algorithm.

ii) Identify the path with highest availability.

iii) Solve the shortest path by using the path length $\frac{PL(l)}{PA(l)}$. Use the Dijkstra algorithm.

iv) Discuss your findings.

[10]

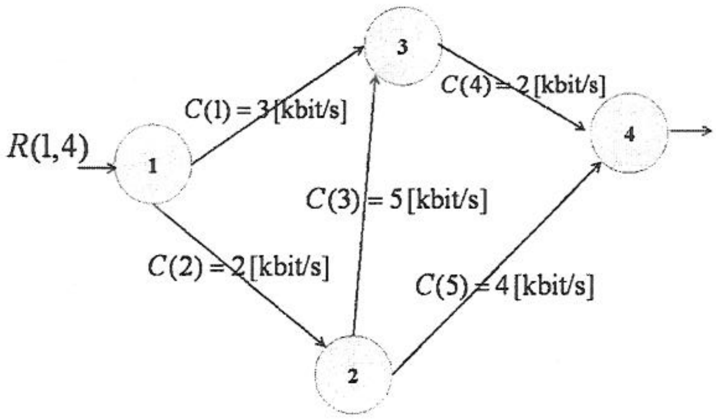

Figure 2.2.

3.

a)

i) Briefly describe and discuss key elements in service survivability planning.

ii) Briefly discuss the importance and scope of traffic restoration and facility restoration.

[10]

b)

i) For the network of Figure 3.1 state the optimal routing flow conditions.

ii) Find the path that will first carry traffic if the traffic ***R*(1,4)** from node 1 to node 4 is gradually increased from zero.

Hint:
- Assume that links can be modelled by an M/M/1 queueing system.

[10]

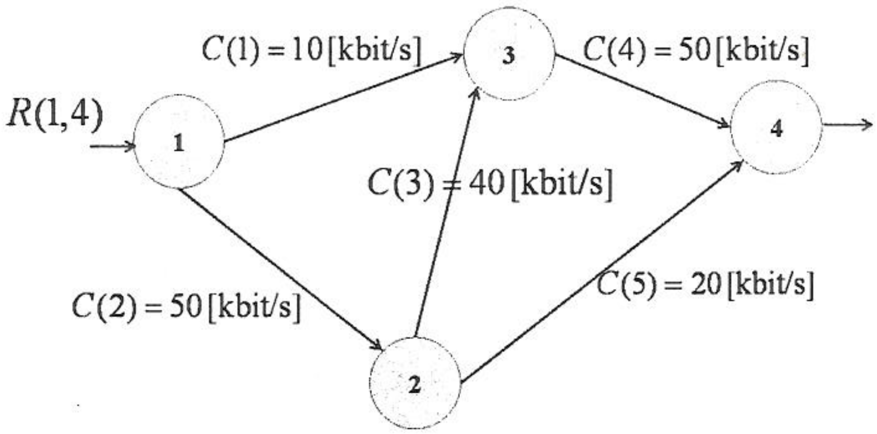

Figure 3.1.

4.

a) Describe the leaky bucket algorithm and explain how you could use it as a traffic control mechanism in a packet network.

[8]

b) In the context of IP switching forwarding models, discuss advantages of peer models over overlay models. Give examples of peer models.

[6]

c) Design and describe all components of a generic label switching router.

[6]

5.

a) Describe and discuss three ATM congestion control mechanisms.

[10]

b) One packetised voice source model can be represented by the two state model of Figure 5.1. When the source is in the active state, packets are being offered at an average rate of L [bit/s].

For this model, the steady state probability of one voice source being active is $P = \frac{\lambda}{\lambda + \alpha}$; where λ and α are rates of transition in the underlying Markov chain.

Derive the probability that i sources out of a total of N independent sources are active. Clearly state all assumptions and approximations made.

[10]

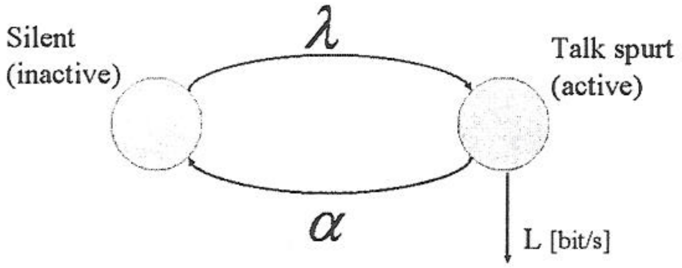

Figure 5.1

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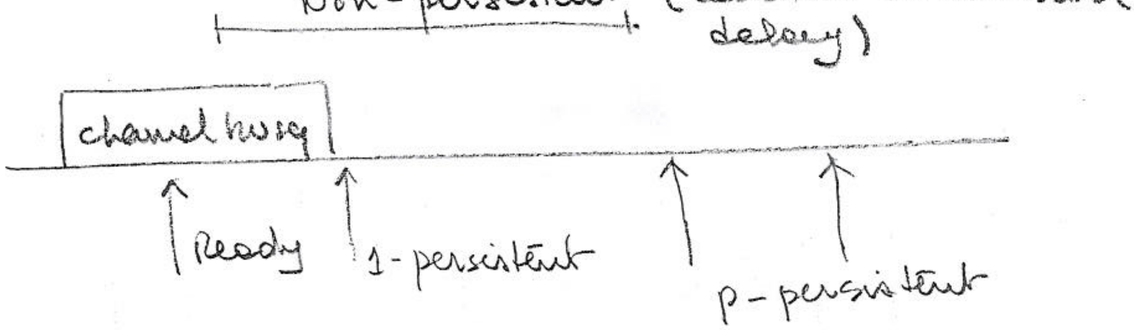
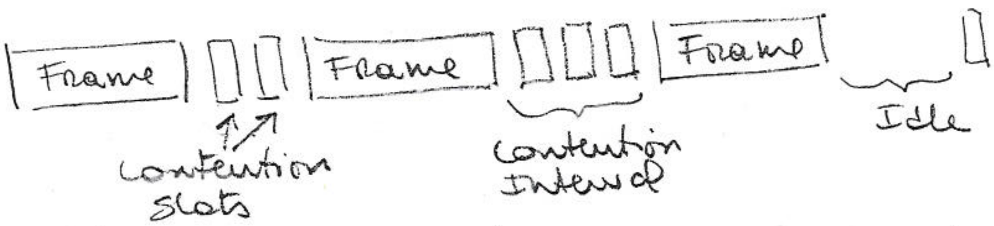
Q1 a) i) - Explain persistent and non-persistent carrier sense multiple access



- Explain collision detection



2,5

ii) Mean contention interval:

$A = NP(1-P)^{N-1}$ = probability exactly one station attempt to transmit

N = nr stations

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

assume one slot twice the end to end propagation

$\frac{1}{A}$ = mean number of slots per contention interval

Mean contention interval $2t/A$

2,5

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Q1

a) iii) Token Ring

- Point to point interfaces
- Token circulates around the ring
- Seize token to transmit
- The token is released after the station finishes transmitting and the receipt of the physical transmission edge

2.5

Performance Token Ring

iv) Assumptions

- Normalised throughput to system capacity
- Packet transmission = 1
- Propagation delay = a
- N stations ready to transmit and placed in equidistant to each other

Case 1 $a \leq 1$

$$S = \frac{1}{1 + a/N}$$

Case 2 $a > 1$

2.5

$$S = \frac{1}{a + a/N}$$

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Q1

b) i) P = probability a single frame is in error
a = propagation time (normalised)
N = size of window 2

ii) $U = \dfrac{\text{transmission time}}{N_R\,[\text{time line engaged}]}$

N_R = Expected number of retransmission

$$N_R = \sum_{i=1}^{\infty} f(i)\, P^{i-1}(1-P) = \frac{1-P+KP}{1-P}$$

$f(i) = 1 + (i-1)K$ (Explain & discuss) 5

iii) Approximation

If $N > 2a+1$ then an approximate number of outstanding frame in the window can be found by $K \sim 2a+1$ 3

If $N < 2a+1$ then an approximate number of outstanding frames in the window can be found by $K \sim N$

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Q2 a) For a Jackson network of M/M/1 queues:

External workload

$$\gamma = \sum_{j=1}^{N} \sum_{k=1}^{N} \gamma_{jk}$$

Average Nr of packets in the network $N = \gamma T$ (using Little's) 2

Use Little's in queue i (Nr of packets in link i)

$q_i = \lambda_i t_i$ 2

Nr packets in the network

$$\sum_{i=1}^{L} \lambda_i t_i = N = \gamma T$$

Delay at queue i

$$t_i = \frac{1}{\mu C_i - \lambda_i}$$ 3

- $1/\mu$ = average length of packets
- C_i = transmission speed link i
- μC_i = service rate link i $\left(F_i = \frac{\lambda_i}{\mu} \right)$
- λ_i = arrival rate link i

$$N = \gamma T = \sum_{i=1}^{L} \lambda_i t_i = \sum_{i=1}^{L} \frac{\lambda_i}{\mu C_i - \lambda_i} = \sum_{i=1}^{L} \frac{F_i}{C_i - F_i}$$ 3

5)

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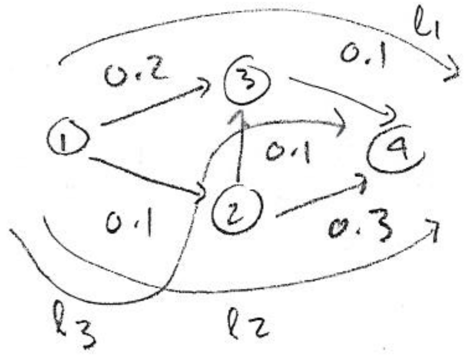
Q2

b) i) Bellman-Ford iterate

$PL(l_2) = \frac{1}{2} + \frac{1}{4} = 0.75$

ii)



3

$PA(l_1) = (1-0.2)(1-0.1) = 0.72$

$PA(l_2) = (1-0.1)(1-0.3) = 0.63$

$PA(l_3) = (1-0.1)(1-0.1)(1-0.1) = 0.729$ (*)

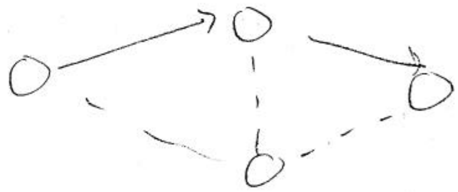
3

iii) Dijkstra iterations

$P(l_1) = 0.83/0.72 = 1.15$

$P(l_2) = 0.75/0.63 = 1.19$

$P(l_3) = 1.2/0.729 = 1.64$



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iv) Discuss conjestion measurement

1

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Q3 a) i) Service Survivability planning and examples

- Prevention
  - Environmental control
  - Limited building access
- Detection
  - Dual fire system
- Robust Network Design
  - Survivable architecture
  - Survivability strategies
- Manual restoration Plan
  - Personnel training and Management
  - Back up procedures 5

ii) Restoration categories

- Traffic restoration (~ individual calls)
- Facility restoration (~ network facilities e.g. multiplexers, cross connect systems etc)
  - Not service specific
  - Requires fewer steps than restoring individual calls
- Discussion on dedicated facility restoration and dynamic facility restoration
- Discussion on traffic restoration of end-to-end circuits

5

7/

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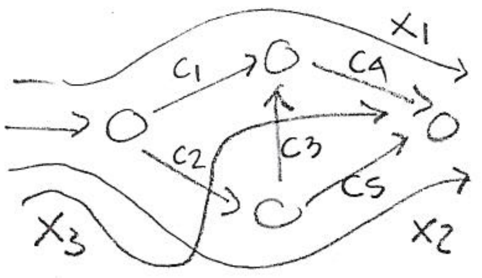
Q3 b) i)



$c_1 : x_1$

$c_2 : x_2 + x_3$

$c_3 : x_3$

$c_4 : x_1 + x_3$

$c_5 = x_2$

$$\frac{c_1}{(c_1-x_1)^2} + \frac{c_4}{(c_4-x_1-x_3)^2} = \quad \text{(path 1)}$$

$$\frac{c_2}{(c_2-x_2-x_3)^2} + \frac{c_5}{(c_5-x_2)^2} = \quad \text{(path 2)}$$

$$\frac{c_2}{(c_2-x_2-x_3)^2} + \frac{c_3}{(c_3-x_3)^2} + \frac{c_4}{(c_4-x_1-x_3)^2} \quad \text{(path 3)}$$

5

ii) First path to carry traffic:

$$\frac{1}{10} + \frac{1}{50} = \frac{5}{50} + \frac{1}{50} = 6\left(\frac{1}{50}\right)$$

$$\frac{1}{50} + \frac{1}{40} + \frac{1}{50} = \frac{2}{50} + \frac{5}{4}\left(\frac{1}{50}\right) = \left(2 + \frac{5}{4}\right)\frac{1}{50} \quad (*)$$

$$\frac{1}{50} + \frac{1}{20} = \frac{1}{50} + \frac{5}{2}\left(\frac{1}{50}\right) = \left(1 + \frac{5}{2}\right)\frac{1}{50}$$

Path 3 (x_3) will be the first path to carry traffic

5

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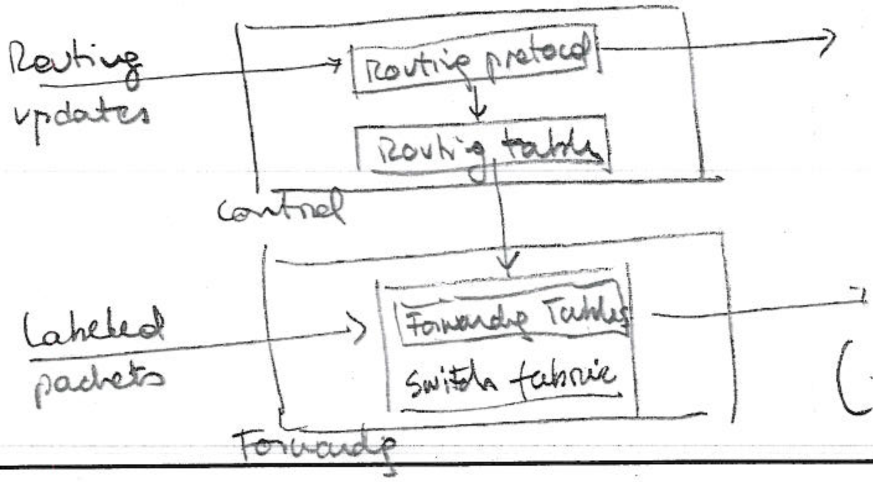
Q4 a) - In the leaky bucket scheme arriving packets join a queue and must get a permit before joining a transmission queue
- Permits arrive to a permit queue at a rate of e.g. 1/2 sec. and they are lost if there is no space for new permits
- In this way traffic regulation is possible by tuning the rate of arrival of permits and the size of the bucket
- Alternatively packets without permit are allowed to join the transmission queue but they will be tagged. If the network becomes congested, tagged packets will be discarded. 8

b) Peer Models

- overlay model (e.g. IP over ATM) has the disadvantage that two network infrastructures need to be managed: each with its own addressing, routing, and management concerns.
- In a peer model, only a single network infrastructure need to be manage
MPLS: Multiprotocol label switching: integrate layer 2 switching with layer 3 routing.

c) Label switching Router: key feature is the separation of the control and forwarding data plane 6



(+ discussion) 6

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Q5

a) ATM congestion control mechanism - discussion on:

- Call admission control (CAC)
  - Two different time scale: virtual call level and virtual cell level
  - Traffic descriptor
- Traffic policing.
  - Monitor the calls that are established
  - leaky bucket algorithm
  - window policing mechanism
  - Rate control and traffic shaping
- Routing
  - multi service environment 10

b) N - multiplexed independent voice sources

If N-sources are independent, the probability of having i sources on is:

$$\pi_i = \binom{N}{i} p^i (1-p)^{N-i}$$

10

+ discuss assumptions