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SO8
ISE3.31

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2005

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

COMMUNICATION NETWORKS

Wednesday, 27 April 10:00 am

Time allowed: 3:00 hours

Corrected Copy

There are FIVE 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) : P.J. Beevor

a)

In ARQ protocol utilisation is defined as:

$$U = \frac{T_f}{N_r T_t}$$

Where N_r is the expected number of re-transmissions, T_f is the transmission time and T_t is the time line is engaged.

i) Derive N_r for stop and wait protocol.
ii) Derive N_r for the selective repeat protocol.
iii) Derive N_r for go back N protocol.
iv) Discuss the effect of propagation time and transmission time in the derivations of i), ii) and iii).

[8]

b)

i) Discuss a price based flow control scheme for a delay sensitive service known to you.
ii) Derive and describe a congestion price that would assign rates amongst i users taking into account users utility functions.
iii) If the delay faced by each byte that is being transmitted is given by

$$d = \frac{\Lambda}{\mathrm{M}(\mathrm{M} - \Lambda)}$$

where Λ is the total arrival rate to the system and M is the total capacity of the system.

Derive the optimal congestion price p_c.

[12]

2.

a) Derive the channel efficiency of a 1-persistent CSMA/CD.
Clearly state all assumptions made in your derivations.

[10]

b) For the network of Figure 2.1 assume the following data:

Link	*C(i)* [Kbit/s]	*x(i)* [Kbit/s]
1	10	5
2	10	5
3	10	1
4	10	4
5	30	6
6	20	6
7	10	4
8	10	4

i) Solve the shortest path problem with the Dijkstra algorithm using link cost $l_0(i) = 1$.

ii) Solve the shortest path problem with the Belman Ford using link cost $l_1(i) = \dfrac{x(i)}{C(i)}$.

iii) Solve the shortest path problem with the Dijkstra algorithm and using link cost $l_2(i) = \dfrac{C(i)}{[C(i) - x(i)]^2}$.

[10]

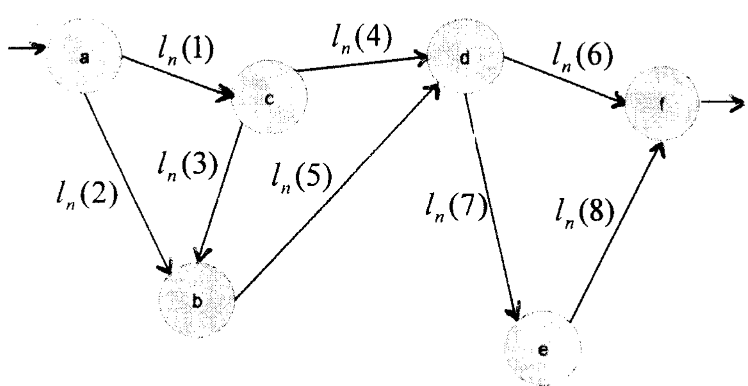

Figure 2.1:

3.

a) A proposed formulation of a combined optimal routing problem and flow control problem has been suggested as follows:

Minimise: $D(x) + \sum_{w \in PW_w} e_w(r_w)$

i) Describe and discuss a suitable function $D(x)$. State clearly the meaning of x and associated constraints.

ii) Suggest, describe and discuss the meaning of a suitable function $e_w(r_w)$.

[10]

b)

i) For the network of Figure 3.1 formulate a combined optimal routing and flow control problem. State clearly the optimality condition.

ii) Assume C(1) = C(2) = 100 kbit/s. Suggest a suitable function $e_w(r_w)$ and the value of its parameters if it is required that the flow carried by the network should be kept bellow 10 kbit/s (i.e. $r \leq 0$). (1 ; 30

$r \leq 10$

[10]

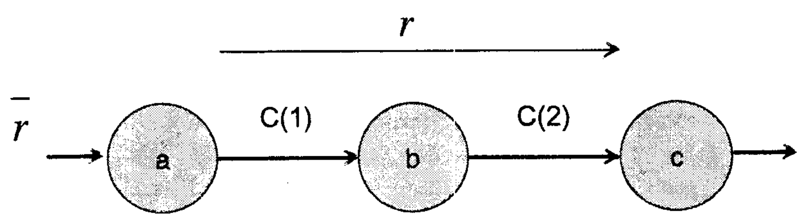

Figure 3.1:

4.

a) Network survivability is an issue of great importance to the telecommunication industry. Describe and discuss briefly three class of survivability network architecture known to you.

[10]

b)

i) Explain and discuss the notion of equivalent capacity and its relevance in the context of traffic management in ATM networks.

ii) Explain and discuss traffic policing in ATM networks. Give examples of possible algorithrns that could implement a traffic policing mechanism.

[10]

5.

a) Describe and discuss three gate protocols which may be Interior or Exterior gate protocols.

[7]

b) Describe and compare DiffServ and IntServ models.

[6]

c) Classify and discuss routing protocols in ad hoc networks known to you.

[7]

SOLUTIONS - COMMUNICATION NETWORKS - 2005

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MODEL ANSWER and MARKING SCHEME

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Second Examiner — Question — Page 1 out of 5

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1(a) i) $N_R = \sum_{i=1}^{\infty} i p^{i-1}(1-p) = \frac{1}{1-p}$ 2

ii) $N_R = \frac{1}{1-p}$ 2

iii) $N_R = \sum_{i=1}^{\infty} f(i)\, p^{i-1}(1-p)$ 2

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

$N_R = (1-K)\sum_{i=1}^{\infty} p^{i-1}(1-p) + K\sum_{i=1}^{\infty} i p^{i-1}(1-p)$

$= 1-K + \frac{K}{1-p}$

$= \frac{1-p+Kp}{1-p}$ $\quad K \sim 2a+1$ if $N > 2a+1$

$K \sim N$ if $N < 2a+1$

iv) $a = \frac{\text{propagation time}}{\text{transmission time}}$

propagation time $= \frac{\text{distance}}{\text{velocity}} = \frac{d}{V}$

transmission time $= \frac{\text{length of frame}}{\text{data rate}} = \frac{L}{R}$ 2

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MODEL ANSWER and MARKING SCHEME

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1(b) The benefit of user i:

$$u^i(\lambda^i) - \gamma^i d \lambda^i$$

$u^i(\lambda^i)$ – value of transmitting λ^i bytes/s

d – delay faced by each byte

γ^i – converts delay into user i's cost 4

User i charged a congestion price of P_c

Then the user will choose to transmit λ^i:

$$\max_{\lambda^i} u^i(\lambda^i) - \gamma^i d \lambda^i - P_c \lambda^i$$

optimal rate is obtain by solving

$$\frac{\partial u^i}{\lambda^i} = \gamma^i d + P_c$$

$$\Lambda = \sum \lambda^i$$ 4

Planner will try to max $\sum_i [u^i(\lambda^i) - \gamma^i d \lambda^i]$

$$d = f(\Lambda, M)$$

$$\frac{\partial u^i}{\partial \lambda^i} = \gamma^i f(\Lambda, M) + \underbrace{\frac{\partial f}{\partial \Lambda}(\Lambda, M) \sum_j \gamma^j \lambda^j}_{\text{congestion price}}$$

$$f(\Lambda, M) = \frac{1}{M} \frac{\Lambda}{M - \Lambda}$$

$$P_c = \frac{\partial f}{\partial \Lambda} \sum_i \gamma^i \lambda^i = \frac{\sum_i \gamma^i \lambda^i}{M^2} \left[\frac{\rho}{1-\rho} + \frac{\rho^2}{(1-\rho)^2} \right]$$ 4

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MODEL ANSWER and MARKING SCHEME

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2(a) 1-persistent CSMA/CD

$A = \binom{N}{1} p^1 (1-p)^{N-1} = Np(1-p)^{N-1}$ 2

N = nr of stations

p = probability that a station transmit during an available slot

Slot = twice the end to end propagation

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

. probability that a successful transmission will take j attempts

$A(1-A)^{j-1}$ 2

. Mean number of slots per contention

$\sum_{j=0}^{\infty} jA(1-A)^{j-1} = \frac{1}{A}$ 2

. Mean contention interval $2t/A$ 2

. channel efficiency (L = frame size)

$C_{eff} = \frac{L}{L + 2t/A}$ 2

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MODEL ANSWER and MARKING SCHEME

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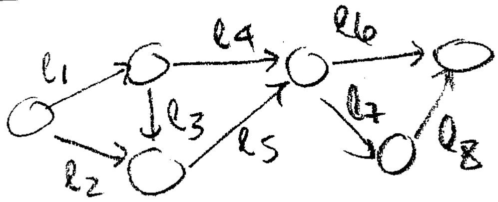
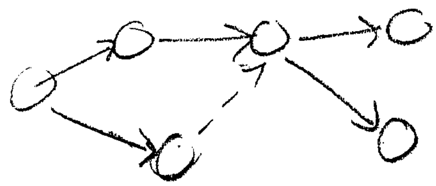
2b



(Explanation) 1

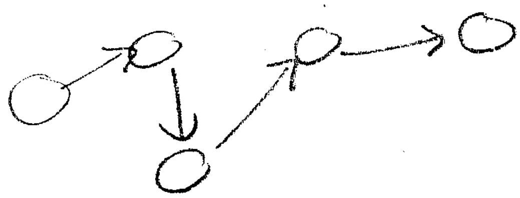
	$(c_i - x_i)^2$
1	25
2	25
3	81
4	36
5	576
6	196
7	36
8	36

i)



3

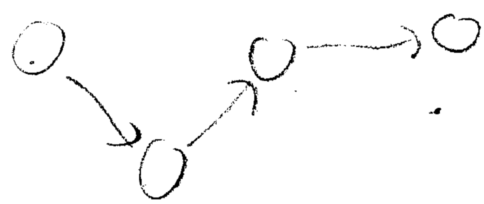
ii)



	$l_1(i)$
1	.5
2	.5
3	.1
4	.4
5	.2
6	.3
7	.4
8	.4

3

iii)



	$l_2(i)$
1	0.4
2	0.4
3	0.123
4	0.277
5	0.052
6	0.102
7	0.277
8	0.277

3

3a i) $$D(x) = \sum_{(i,j)} D_{ij}\left(F_{ij}(x_p)\right)$$

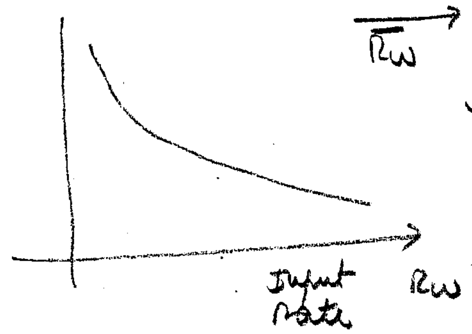
$$\sum_{p \in P_w} x_p = R_w \quad \forall\, w \in W$$

$$x_p \geq 0 \quad \forall\, w \in W$$

$$F_{ij} = \sum_{\substack{\text{all paths} \\ \text{containing link } (i,j)}} x_p$$

$$0 \leq R_w \leq \overline{R_w} \quad \forall\, w \in W$$ 5

ii) $$e_w(R_w) = \frac{a_w}{R_w}$$



$\overline{R_w} \longrightarrow \quad \longrightarrow R_w$

$\downarrow y_w$

If $\min D = \sum_{(i,j)} D_{ij}(F_{ij})$ wrt $\{x_p\}$ and $\{R_w\}$

the optimal solution is $x_p = 0$ and $R_w = 0$

therefore the need to include a penalty for inputs $\{R_w\}$ becoming too small 5

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MODEL ANSWER and MARKING SCHEME

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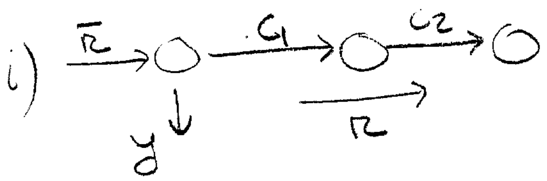
3(b) i)



$$D = \frac{R}{C_1 - R} + \frac{R}{C_2 - R} + \frac{a}{R}$$

optimality condition

$$\frac{c_1}{(C_1 - R)^2} + \frac{c_2}{(C_2 - R)^2} = \frac{a}{(\bar{R} - y)^2}$$ 5

ii) if $C_1 = C_2 = 100$

$y = 0, \quad R = \bar{R}$

$$\frac{2 \cdot 100}{(100 - R)^2} = \frac{a}{R^2}$$

$$200R^2 = a(100 - R)^2$$

$$\sqrt{2}\,10\,R = \sqrt{a}\,(100 - R)$$

$$\sqrt{a} \geq \left.\frac{\sqrt{2}\,10\,R}{100 - R}\right|_{R=10} = \frac{\sqrt{2}\,100}{90}$$

5

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MODEL ANSWER and MARKING SCHEME

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4(a) Survivable fibre network architecture

- Protection switching: established pre-assigned replacement connection (no network management function)
- Re-Routing: establishment of replacement of connection (by a network management control connection)
- Self-healing: establishment of a replacement connection by network (no network management function) 10

4(b) Equivalent capacity is relevant to call admission control (CAC) scheme

- Two entirely different time scales involved (call and cell level)
- Lack of traffic descriptor may compromise potential effectiveness 5

$G\_x(m) = f(R_p, b, m, u\, x)$

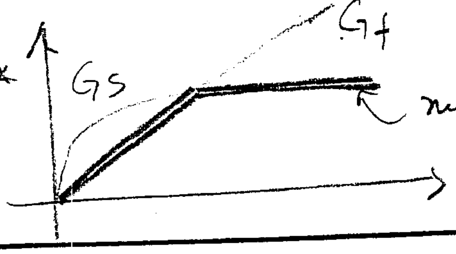
R_p = peak rate, b = mean burst length, u = utilisation, x = capacity of buffer

m = no. of VC

Two approximation

Fluid flow approx ($G\text{-}f$)

Stationary approx ($G\text{-}s$)



5

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MODEL ANSWER and MARKING SCHEME

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5(a) Routing Protocols in Internet

IGP: relies on IP addresses to construct paths

~~Examples:~~

- Routing Information Protocol (RIP)
- Open Shortest Path First (OSPF)

EGP: relies on Autonomous Systems numbers to construct AS paths

~~Example~~

- Border Gate Protocol (BGPv4)

Discussion on above protocols 7

(b) IntServ : discussion on

- packet classifier
- Packet schedulers
- Admission control
- Explicit resource reservation (RSVP)

DiffServ : discussion on

- Simpler model and more scalable than IntServ
  - per flow → aggregate service
  - complex processing from core to edge
- Service level Agreement (SLA) 6
- Per Hop Behaviour (PHB)
- Traffic classification
- Traffic conditioner

5(c) Routing protocols in mobile ad hoc network

MANET

- Table driven protocols
  - Best effort Routing
- Demand driven protocol
  - Best effort routing
  - QoS routing
    - Source routing
    - Flooding
    - Restrictive routing 7

Discussion on the above