E3.17
SO8
ISE3.31

IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2004

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

COMMUNICATION NETWORKS

Wednesday, 28 April 10:00 am

Corrected Copy

Time allowed: 3:00 hours

One correction Q2
Clarification – Figure 2.1

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

© University of London 2004

1.

a)

i) Derive the maximum utilisation of a link when the stop and wait protocol is used.

ii) Describe and explain the timing sequence of a sliding window protocol.

iii) In relation to (ii) derive the utilisation of a link when $N > 2a+1$ and $N < 2a+1$.

iv) Clearly state the meaning of *a*, *1* and *N*.

[12]

Hint: Use Figure 1.1 as reference for your answers.

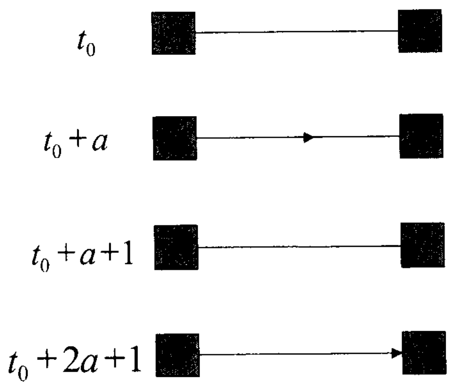


Figure 1.1

b)

~~i)~~ Describe and discuss the FDDI protocol and its operation.

[8]

2.

a) A proposed formulation of the Optimal Routing Problem (ORP) has been suggested as:

Minimise: $D(x)$

Subject to: $\sum_{p \in P_w} x_p = r_w, \quad for\ all \quad w \in W,$

and, $x_p \geq 0, \quad for\ all \quad w \in W,$

where

$$D(x) = \sum_{(i,j)} D_{ij} \left[\sum_{\substack{all\ path\ p \\ containing\ link\ (i,j)}} x_p \right]$$

and,

$$D_{ij}(F_{ij}) = \frac{F_{ij}}{C_{ij} - F_{ij}}$$

i) State clearly the meaning of all the variables involved in this optimisation problem.

ii) State clearly with respect to which variables the minimisation is being carried out.

iii) State clearly and explain the optimality condition.

[10]

(Continue next page)

2.

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

R = 10 kbits/s
$C(1)$ = 3 kbits/s
$C(2)$ = 8 kbits/s

i) Solve the ORP using link cost $l_1(i) = \dfrac{1}{C(i) - x(i)}$

ii) Solve the ORP using link cost $l_2(i) = \dfrac{C(i)}{[C(i) - x(i)]^2}$

iii) If the following function is defined to account for a fair distribution of traffic flows:

$$F = \frac{\max \mu_i - \min \mu_p}{\min \mu_p}$$

where μ_k is the average packet delay for the path k.

Which link cost -$l_1(i)$ *or* $l_2(i)$- would you choose and why ?.

[10]

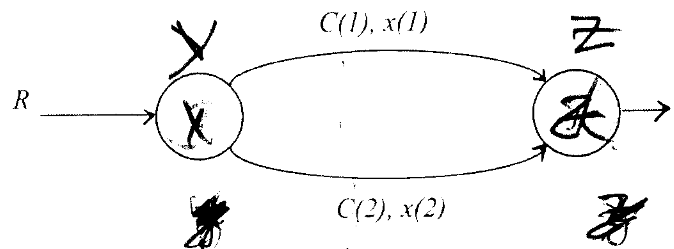


Figure 2.1 11.5 2

3.

a) Consider the network of Figure 3.1 and its associated link costs $l(i,j)$.

i) Using node one (1) as your reference node, show step by step all the iterations of:
- the Dijkstra's shortest path algorithm,
- the Bellman-Ford's shortest path algorithm.

ii) If you know the following probability that a link is operational:
- Link $l(7,10) = 0.9$ and
- Link $l(3,6) = 0.8$.

State clearly which route you would choose and discuss your reasons.

[12]

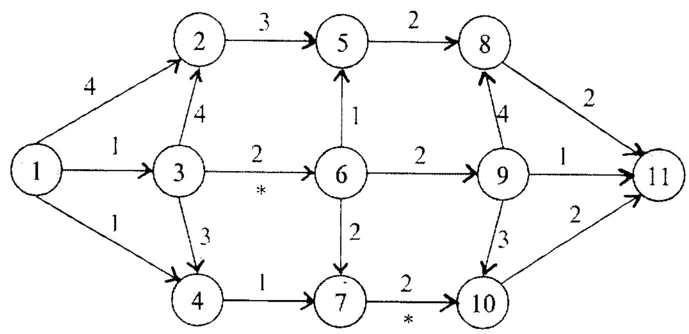


Figure 3.1

b) For flow control schemes at the network layer known to you, explain and discuss advantages and disadvantages of:

i) End-to-end window flow control
ii) Node-by-node window flow control

[8]

4.

a) For each one of the ATM service classes included in Figure 4.1:

i) Describe and discuss suitable service examples.

[10]

	CBR	VBTR-RT	VBR-NRT-COD	VBR-NRT-CLD	UBR	ABR
Service Class	Class A	Class B	Class C	Class D	Class X	Class Y
Timing relation	Required		Not Required			
Bit Rate	Constant	Variable				
Connection mode	CO (PVC and SVC)			CL	CO	
Service Examples						
AAL Type	AAL-1	AAL-2 AAL-1/5	AAL-3/4 AAL-5	AAL-3/4	Any	AAL-3/4 & AAL-5

CBR: Constant Bit rate; VBR: Variable Bit Rate; RT: Real Time;
COD: Connection-oriented Data; CLD: Connectionless Data;
UBR: Unspecified Bit rate; ABR: Available Bit Rate

Figure 4.1

b) Discuss the relevance of Call Admission Control (CAC) in ATM networks.

[5]

c) In an ATM network the connection contract between the user and the network specify the manner in which the source offers cells.

i) Define and explain the traffic descriptors that have been defined in ITU-T to specify a pattern of demand for transmission.

[5]

5.

a) In the DiffServ (DS) model, different values in the DS field correspond to different packet-forwarding treatments at each router, called the per-hop-behaviour (PHB).

i) Describe and explain three PHB packet-forwarding schemes known to you

[9]

b) For the label-switching paradigm that integrated layer 2 switching with layer 3 routing, IETF has established MPLS.

i) Describe and discuss the key characteristics of MPLS.

[6]

ii) Fill the gaps of the different components of the Label-switching router (LSR) of Figure 5.1

[5]

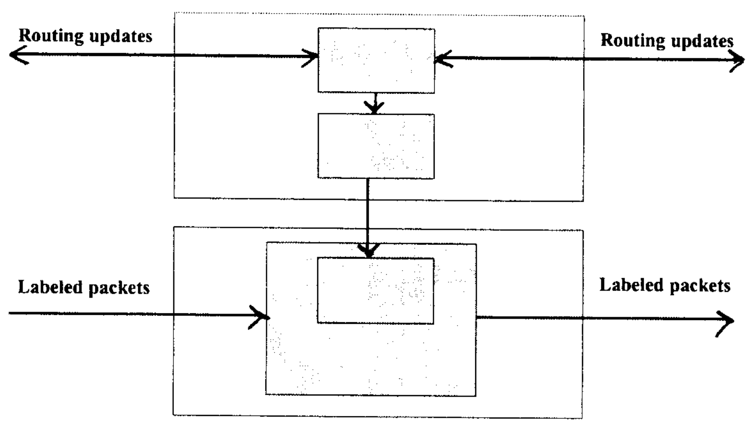


Figure 5.1

Communication Networks 2004

Examinations : **Session** ***Confidential***

MODEL ANSWER and MARKING SCHEME

First Examiner	Dr Barria	Paper Code	E3.17 - ISE 3.31 - S08
Second Examiner	Dr Beevor	Question	Page 1 out of 8

Question labels in left margin — Marks allocations in right margin

Q1 a) i) $U = \frac{1}{1+2a}$ 3

ii) If $a > 1$ link under utilised

sender: - Keep a list of sequence numbers allow to site

- Keep frames in memory until acknowledge
- if buffer is full: stop transmitting

Receiver: - Keep a window size with the number of frame sequence it is permitted

- Frames falling outside window ⇒ discard 3

iii) $N > 2a+1$: $U = 1$

$N < 2a+1$: $U = \frac{N}{2a+1}$ 3

iv) a = propagation delay

1 = Transmission time (normalised)

N = number of frames in window 3

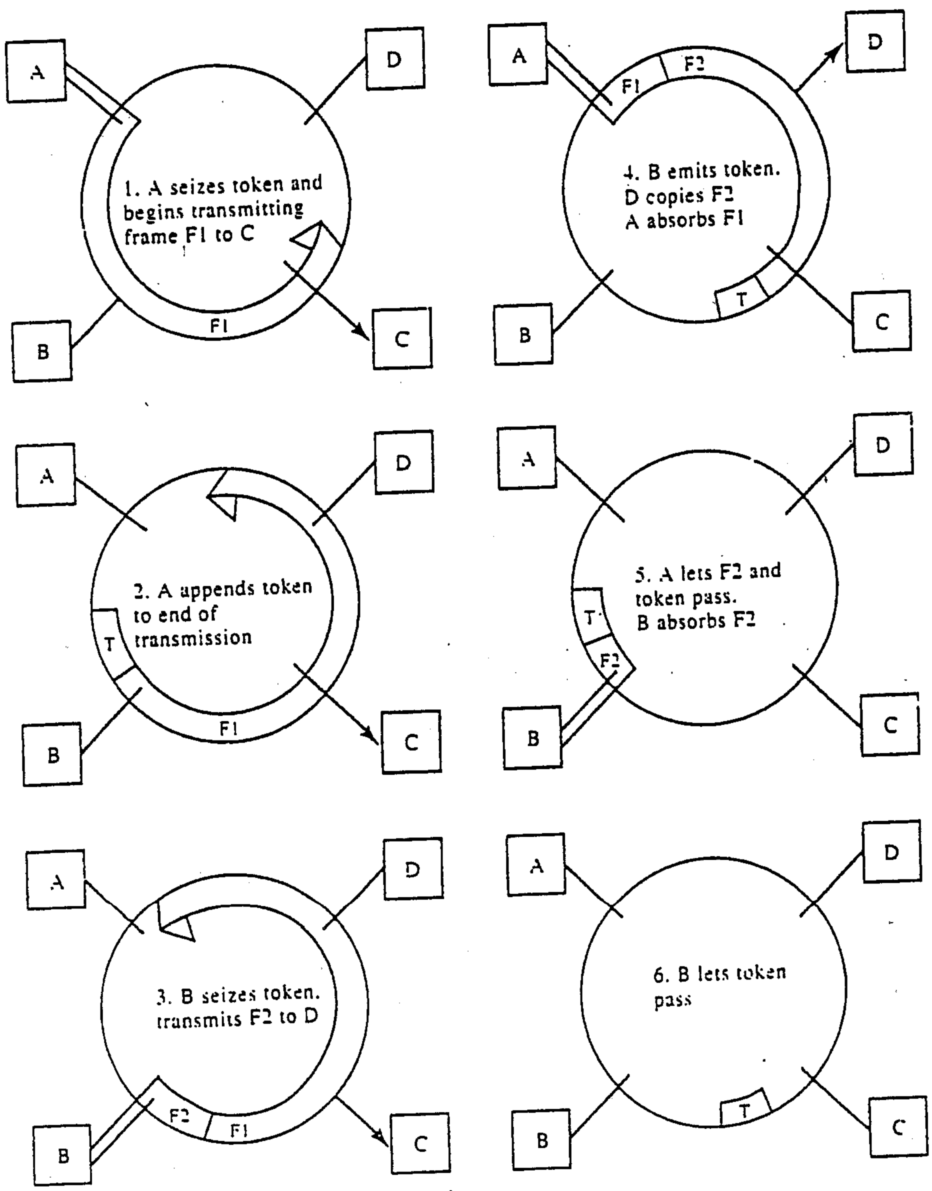
2004

Examinations : ~~1999~~ Session	Confidential
MODEL ANSWER and MARKING SCHEME	

First Examiner	Paper Code	
Second Examiner	Question	Page 2 out of 8

Question labels in left margin — Marks allocations in right margin

Q1 b) FDDI token ring operation
Ref: Stallings, W.



FDDI token ring operation. 4

discussion 4

2004

Examinations : ~~199~~ -9 Session — *Confidential*

MODEL ANSWER and MARKING SCHEME

First Examiner | Paper Code
Second Examiner | Question | Page 3 out of 8

Question labels in left margin | Marks allocations in right margin

Q2

a) i) x_p = flow of path p

P_w = set of positive paths that have O-D w

r_w = arrival rate of traffic entering and exiting the network O-D w

(i,j) = link between nodes i and j

C_{ij} = capacity of link (i,j)

F_{ij} = flow carried by link (i,j) — 3

ii) given capacities $\{C_{ij}\}$ and the network topology

minimise $D(x)$ with respect to the flows $\{F_{ij}\}$

$$F_{ij} = \sum_{\substack{\text{all paths} \\ \text{containing link } (i,j)}} x_p$$ — 3

iii) For an optimal x_p^* the following conditions must be true

$$x_p^* > 0 \Rightarrow \frac{\partial D(x^*)}{\partial x_{p'}} \geq \frac{\partial D(x^*)}{\partial x_p} \quad \forall p' \in P_w$$ — 4

discuss.

Q2 b)

i) $$\frac{1}{3 - x(1)} = \frac{1}{8 - x(2)} \qquad R = 10 = x(1) + x(2)$$

$x^*(1) = 2.5$, $x^*(2) = 7.5$

ii) $$x_1^* = \frac{\sqrt{c_1}\,(R - (c_2 - \sqrt{c_1 c_2}))}{\sqrt{c_1} + \sqrt{c_2}} \qquad c(1) = 3,\ c(2) = 8$$

$x_1^* = 2.621$

$x_1^* + x_2^* = R = 10$

$x_2^* = 7.379$

iii) $$D = \frac{x(1)}{c(1) - x(1)} + \frac{x(2)}{c(2) - x(2)}$$

$D_1 = 5 + 15 = 20$

$D_2 = 6.89 + 11.90 = 18.79$

iv) Average packet delay path 1 $= \dfrac{1}{c(1) - x(1)}$

Average packet delay path 2 $= \dfrac{1}{c(2) - x(2)}$

hence choose (i)(ii)

2004

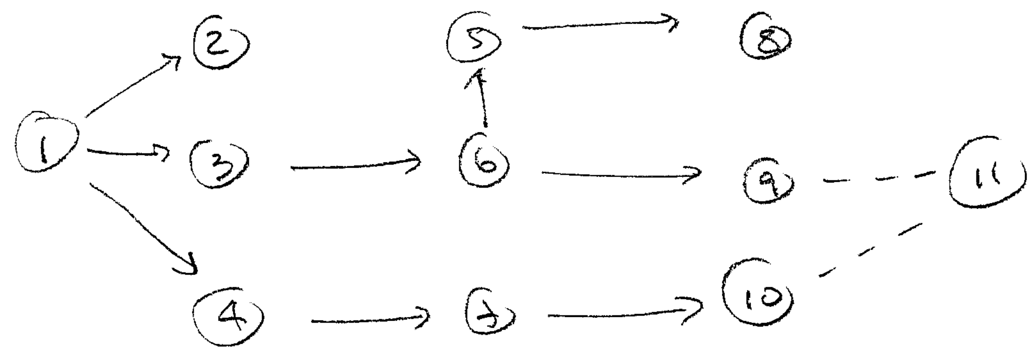
Examinations : ~~199-9~~ Session *Confidential*

MODEL ANSWER and MARKING SCHEME

First Examiner	Paper Code
Second Examiner	Question Page 5 out of 8

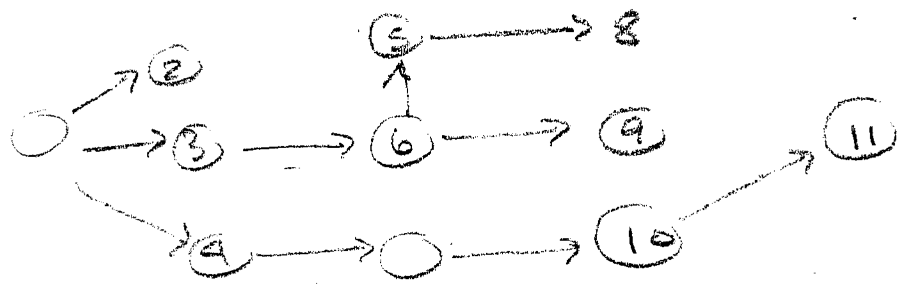
Question labels in left margin — Marks allocations in right margin

3a) i)



6

ii



6

3b) end to end

- cannot guarantee a minimum communication rate
- trade off of window size: delay-throughput tradeoff is acute for high speed session in high speed wide area network because of high propagation delay relative to packet transmission time.
- can also perform poorly with respect to fairness
- packets will concentrate at congested links 4

node by node

- much of the discussion on end-to-end windows applies to this scheme as well.
- for moderate-speed terrestrial link the size of the window is typically two-three packets
- For high-speed networks, the required window size might be much longer; therefore less attractive 4
- packets uniformly distributed

2004

Examinations : ~~199~~ -9 Session *Confidential*

MODEL ANSWER and MARKING SCHEME

First Examiner	Paper Code
Second Examiner	Question Page 6 out of 8

Question labels in left margin — Marks allocations in right margin

4a) i) CBR: Voice and private line 2

VBR-RT: VBR packet video 2

VBR-NRT-COD: X.25 / F.R. 2

VBR-NRT-CLD: SMDS / IP / LAN 2

UBR: LAN 2

ABR: LAN / Internet 2

discussion on the above

c)

i)

PCR : Peak cell rate

CDV : Cell delay variation tolerance

SCR : Sustainable cell rate

MBT : Maximum burst tolerance 5

b) CAC

- Two entirely different time scale issues:
  - virtual call (VC) level (seconds, minutes)
  - cell levels (milliseconds)

VC profile is quasi-static in respect to cell arrivals

- CAC may be powerful but lack of traffic description may compromise potential effectiveness 5

2004

Q5 a)

i) The standard best effort treatment when forwarding traffic is define as the default (DE) PHB.

Two additional one: 1

- Expedite Forwarding PHB: provides a low-loss, low-latency, low-jitter, assured-bandwidth, end-to-end service through DS domain. EF PHB is equivalent to a "virtual leased line", such service is often called a "premium service" 4

- Assured Forwarding PHB: delivers the aggregate traffic from a particular customer with high assurance (i.e. high probability of the traffic being delivered to the destinations) as long as the aggregate traffic does not exceed the traffic profile (e.g. the subscriber information rate). The customer, is allowed to send its traffic beyond the traffic profile with the caveat that the excess traffic may not be given high assurance. AF PHB is not intended for low-latency, low jitter application 4

2004

Examinations : ~~199~~ ~~9~~ Session *Confidential*

MODEL ANSWER and MARKING SCHEME

First Examiner	Paper Code
Second Examiner	Question Page 8 *out of* 8

Question labels in left margin — Marks allocations in right margin

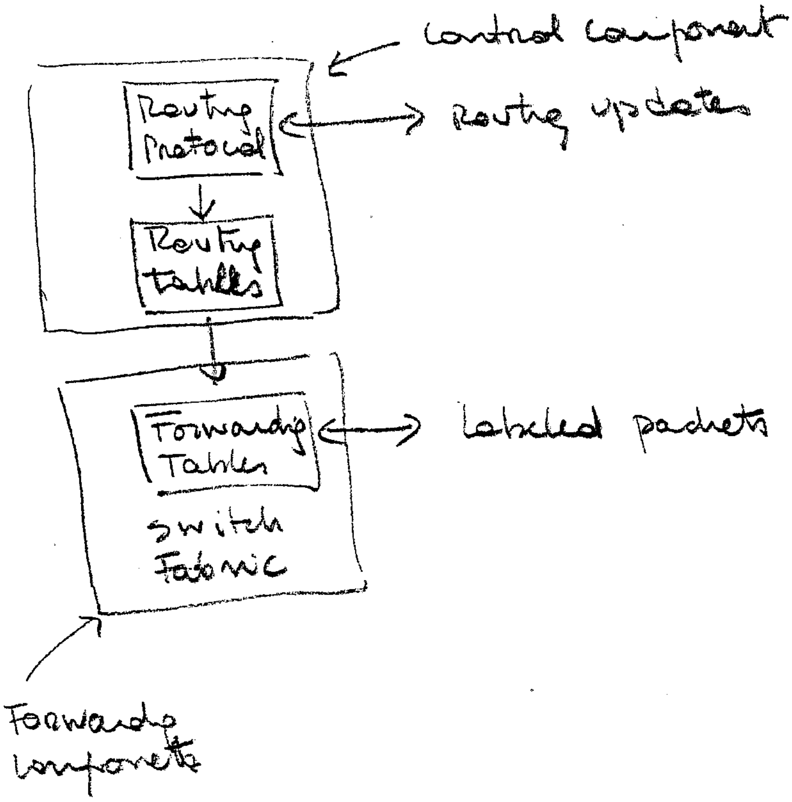
Q5 b)

i) MPLS integrates layer 2 switching with layer 3 Routing

- A key feature in the separation of
  - control plane & forwarding data plane

  in a label switching router
- MPLS label switching router (LSR): solve performance scalability by decoupling control and data planes
- MPLS focuses on IPv4 and IPv6
- MPLS operates with multiple layer 2 technologies
- Improve forwarding performance: simplified lookup process
- Improve scalability: label stacking and merging
- provide traffic engineering: efficient explicit routing 6

ii)



5

discuss above