

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

Time allowed: 3:00 hours

Corrected Copy

**There are FIVE questions on this paper.**

**Answer FOUR questions.**

One correction Q2  
Clarification -  
Figure 2.1

*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)

- 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.

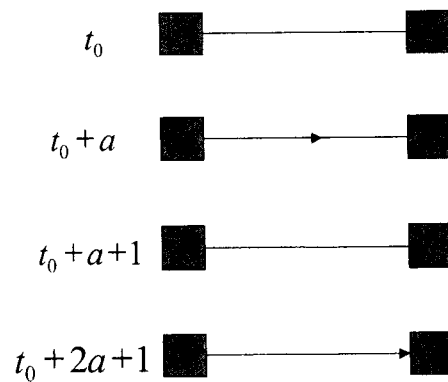


Figure 1.1

b)



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

and,  $x_p \geq 0, \text{ for all } w \in W,$

where

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

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:

$$\begin{aligned}
 R &= 10 \text{ kbits/s} \\
 C(1) &= 3 \text{ kbits/s} \\
 C(2) &= 8 \text{ kbits/s}
 \end{aligned}$$

- i) Solve the ORP using link cost  $l_1(i) = \frac{1}{C(i) - x(i)}$
- ii) Solve the ORP using link cost  $l_2(i) = \frac{C(i)}{[C(i) - x(i)]^2}$
- 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  $\mu_k$  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]

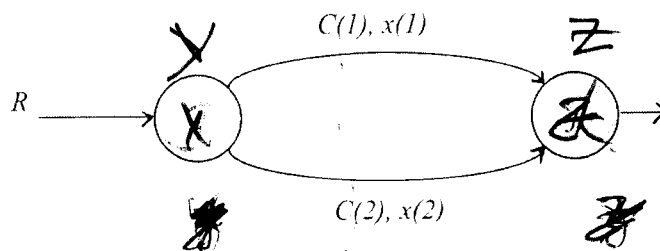


Figure 2.1

3.

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

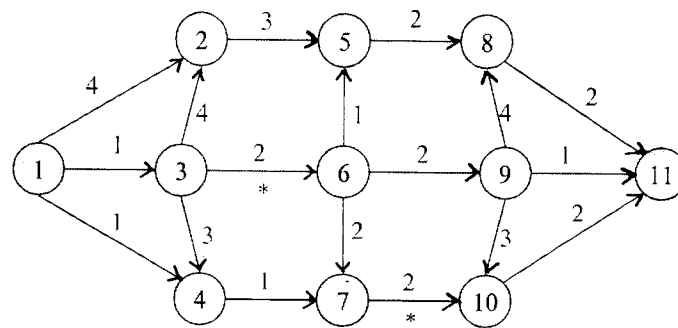


Figure 3.1

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

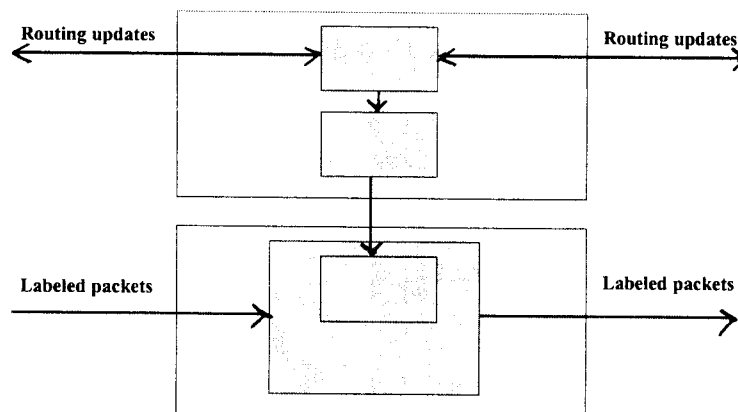


Figure 5.1



Examinations :		Session	Confidential
MODEL ANSWER and MARKING SCHEME			
First Examiner	Dr. Barua	Paper Code	E317 - BE3.31-508
Second Examiner	Dr. Beever	Question	Page 1 out of 8
Question labels in left margin		Marks allocations in right margin	
Q1	<p>i) <math display="block">U = \frac{1}{1+2a}</math></p> <p>ii) If <math>a &gt; 1</math> link underutilised Sender :- Keep a list of sequence numbers allows to sit - 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 <math>\Rightarrow</math> discard</p> <p>iii) <math>N &gt; 2a+1 : U = 1</math> <math>N &lt; 2a+1 : U = \frac{N}{2a+1}</math></p> <p>iv) <math>a =</math> propagation delay <math>t =</math> Transmission time (normalised) <math>N =</math> number of frames in window</p>	3	

2009

MODEL ANSWER and MARKING SCHEME

First Examiner

Paper Code

Second Examiner

Question

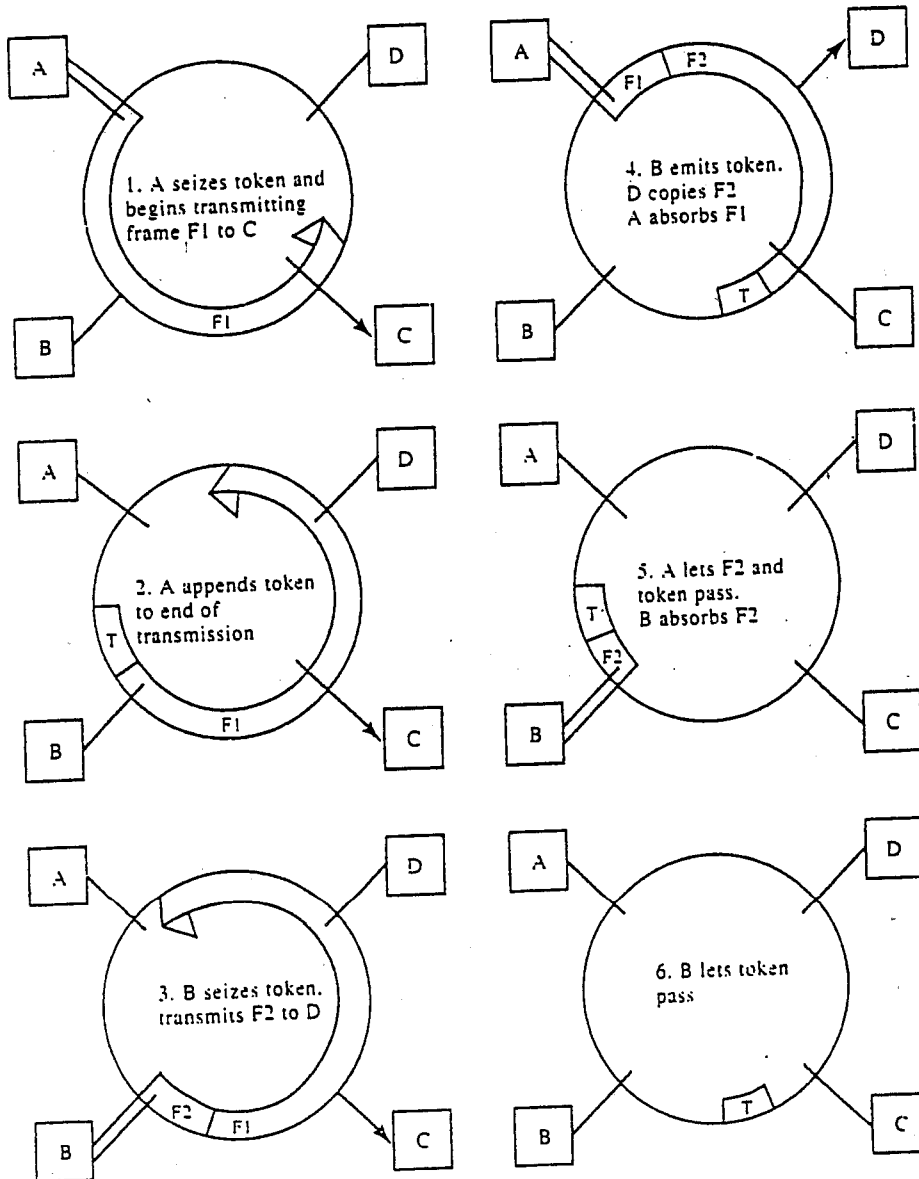
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Marks allocations in right margin

Q1  
5)

FDDI token ring operation  
Reg: Stallings, W.



FDDI token ring operation.

discovery

4

4

## MODEL ANSWER and MARKING SCHEME

First Examiner

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Question

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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 topologyMinimise  $D(x)$   
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.

## MODEL ANSWER and MARKING SCHEME

First Examiner

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Question

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Q2  
a)

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

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

$$ii) \quad x_1^* = \frac{\sqrt{c_1} (R - (c_2 - \sqrt{c_1 c_2}))}{\sqrt{c_1} + \sqrt{c_2}} \quad \begin{matrix} c(1) = 3 \\ c(2) = 8 \end{matrix}$$

$$x_1^* = 2.621$$

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

$$x_2^* = 7.379$$

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

$$D_1 = 5 + 15 = 20$$

$$D_2 = 6.89 + 11.90 = 18.79$$

$$iv) \quad \begin{aligned} \text{Average packet delay path 1} &= \frac{1}{c(1) - x(1)} \\ \text{Average packet delay path 2} &= \frac{1}{c(2) - x(2)} \end{aligned}$$

hence choose (ii)

## MODEL ANSWER and MARKING SCHEME

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Question

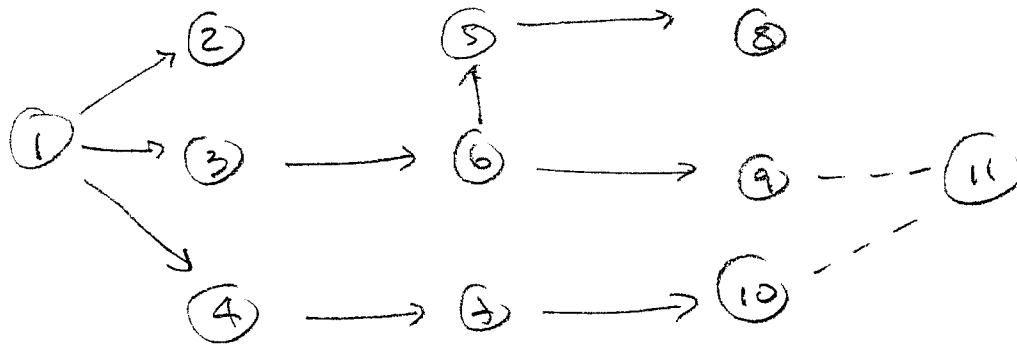
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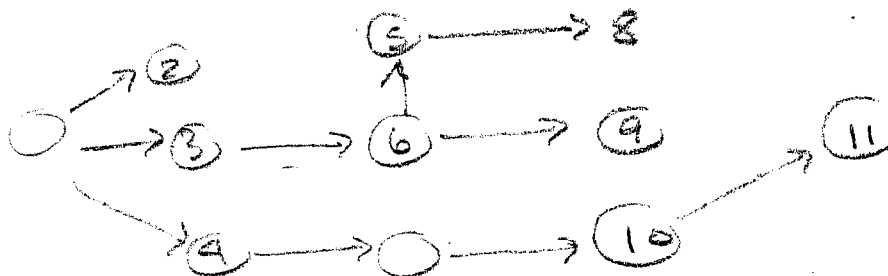
3a)

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 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 larger, therefore less attractive
- packets uniformly distributed

4

4

## MODEL ANSWER and MARKING SCHEME

First Examiner

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Question

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4a) i) CBR: Voice and private line

2

VBR-RT: VBR packet video

2

VBR-NRT-EO: X.25 / FR.

2

VBR-NRT-CLD: SMDS / IP / LAN

2

VBR: LAN

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)

CBR

- Two entirely different time scale views:

- virtual cell (VC) level (seconds, minutes)

- cell levels (microseconds)

VC process is quasi-static in respect to cell arrivals

- CBR may be powerful but lack of traffic

description may compromise potential effectiveness

5

## MODEL ANSWER and MARKING SCHEME

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Second Examiner

Question

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Q5  
a)

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

Two additional are:

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

- 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 destination) 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 applications.

1

4

4

## MODEL ANSWER and MARKING SCHEME

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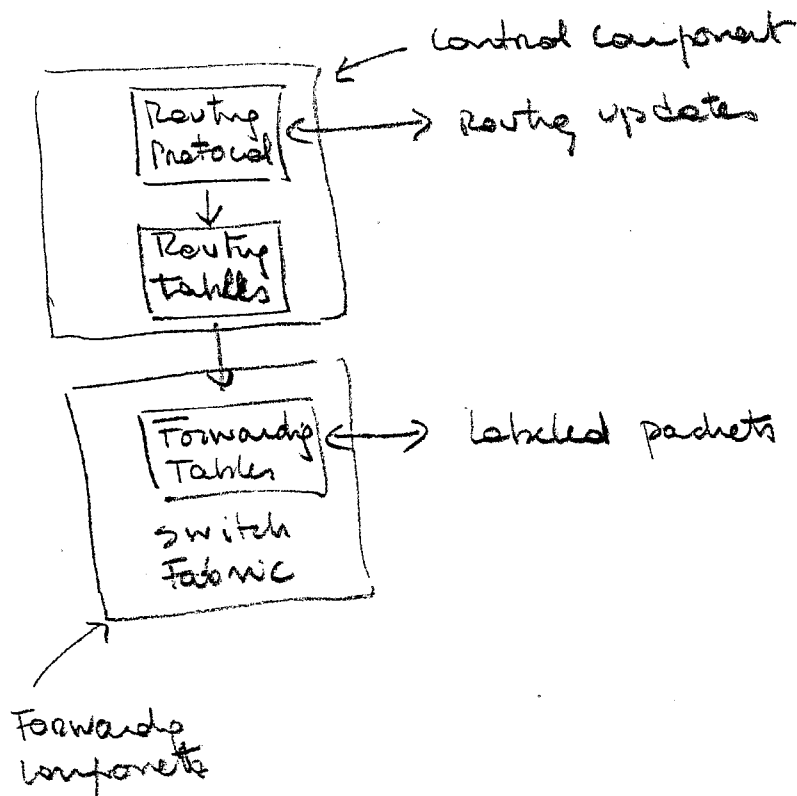
Q5

b)

i) MPLS integrates layer 2 switching with layer 3 routing

- A key feature is the separation of
  - control plane & forwarding data plane in a label switching router
- MPLS label switching router (LSR) : some personnel 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

ii)



discuss above

6

5