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Model Answers and Mark Schemes First Examiner: E3.17 1/8

Paper Code: Second Examiner: ISE 3.31 (ISE 4.13)

Communication Networks – SOLUTIONS 2003

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Q1 (a) Performance of ARQ protocol (bookwork)

$U = \dfrac{\text{transmission time}}{N_R\,(\text{time line engaged})}$

N_R = Expected number of retransmission

$p^{i-1}(1-p)$ = probability that a transmission will take exactly i attempts

$N_R = \sum_{i=1}^{\infty} i\,p^{i-1}(1-p) = \dfrac{1}{1-p}$ = Expected number of retransmissions of one frame

Selective repeat ARQ

$U\ (N > 2a+1) = 1-p$

$U\ (N < 2a+1) = \dfrac{N(1-p)}{1+2a}$

$a = \dfrac{\text{propagation time}}{\text{transmission time}}$

N = size of window

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Q1 (a)

1-persistent CSMA/CD (bookwork)

$A = \binom{N}{1} p^1 (1-p)^{N-1} = Np(1-p)^{N-1}$ (probability exactly one station attempts transmission in slot)

N = no. of stations

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

slot = twice end to end propagation delay.

mean number of slot per contention

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

mean contention interval $(= 2t/A)$ t = propagation delay.

channel efficiency $C_{eff} = \frac{L}{L + 2t/A}$ L = frame length

Q1 (c)

(i) RQA = 2 ; RQB = 0, CDB = 1 ; RQC = 1 ; RQD = 1 ; RQE = 0, CDE = 0

(ii) RQA = 3 ; RQB = 1, CDB = 1 ; RQC = 0, CDC = 1 ; RQD = 1 ; RQE = 0, CDE = 0

(iii) RQA = 2 ; RQB = 1, CDB = 0 ; RQC = 0, CDC = 0 ; RQD = 0 ; RQE = 0

(iv) RQA = 1 ; RQB = 1 ; RQC = 0, CDC = 0 ; RQD = 0 ; RQE = 0

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Q2 (a)

(bookwork)

Little's express the natural idea that crowded system are associated with long customer delays.

$N(t)$ = number of customers in the system at time t

$\alpha(t)$ = number of customers who arrive in $[0,t]$

T_i = time spent in the system by the i-th arriving customer

- Record the observation from $t=0 \to \infty$ and take the time averages of the observation then

$N = \lambda T$

$N = \lim N_t \quad ; \quad N_t = \frac{1}{t}\int_0^t N(\tau)\,d\tau$

$\lambda = \lim \lambda_t \quad ; \quad \lambda_t = \frac{\alpha(t)}{t}$

$T = \lim T_t \quad ; \quad T_t = \frac{\sum_{i=0}^{\alpha(t)} T_i}{t}$

In the derivation of the Mean network packet delay Little's result is used:

- At the network level $\gamma T = N = \sum_{i=1}^{L} \lambda_i t_i$

- At the queue level (representing each one of the links of the network)

$q_i = \lambda_i t_i$

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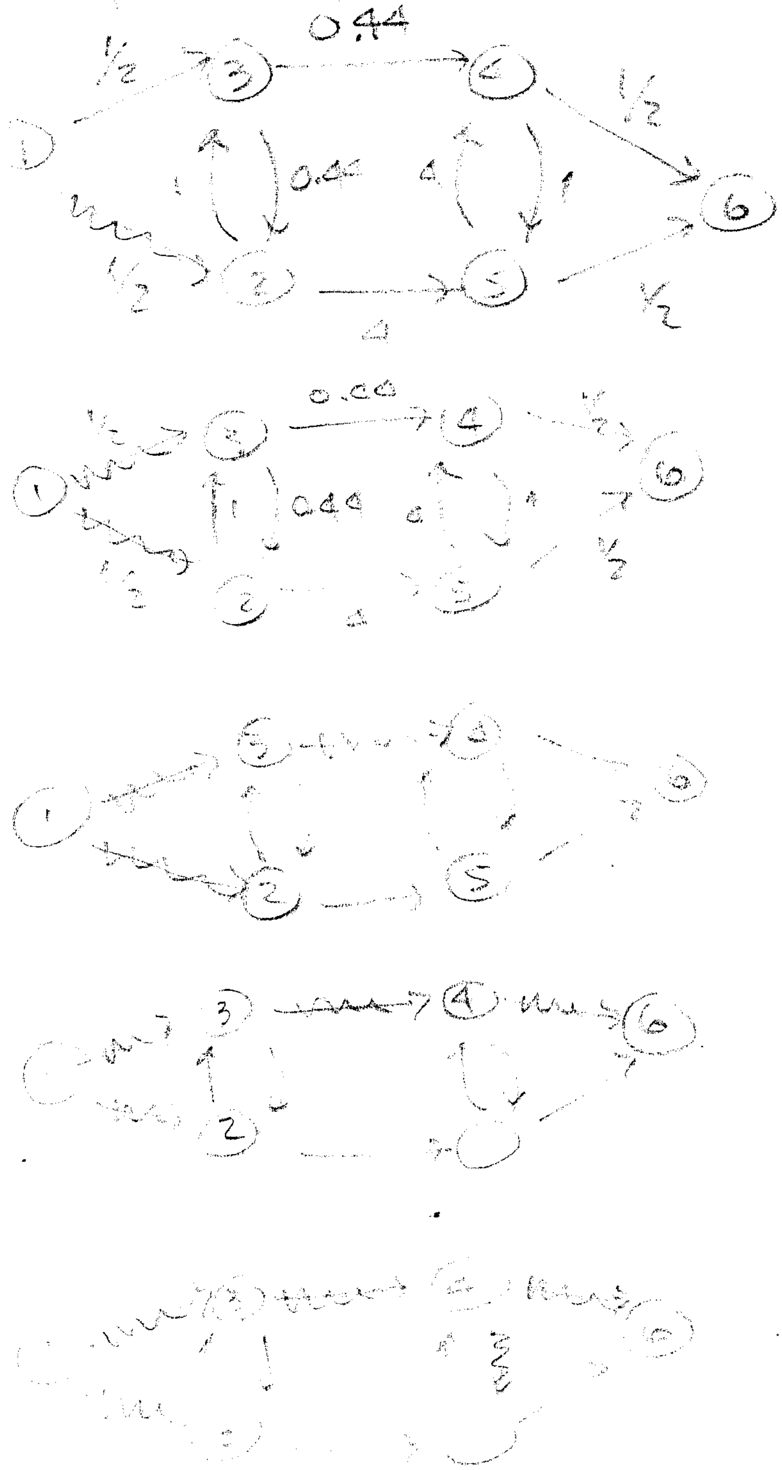
Q2 (v) (New computed example)



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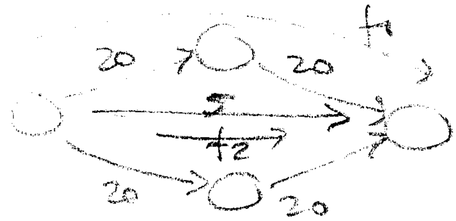
Q3 (a)



$$\left.\begin{array}{l} R = 2f_1 + f_2 \\ \text{if } f_2 = 0 \end{array}\right\} \Rightarrow f_1 = \frac{R}{2}$$

$$l_1 = \frac{2 \times 20}{(20-f_1)^2} \qquad l_2 = \frac{5}{(5-0)^2} = \frac{1}{5}$$

$$l_1 > l_2 \qquad \frac{2 \times 20}{(20-f_1)^2} > \frac{1}{5}$$

$$200 > (20-f_1)^2$$

$$\sqrt{200} > 20 - f_1$$

$$-5.85 > -f_1 \Rightarrow f_1 > 5.85$$

$$R > 11.71$$

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Q2 (5)

$R(1,4) = 10$ Kbit/s [illegible]

$10 = 2f_1 + f_2$

$$\frac{2\times 20}{(20-f_1)^2} = \frac{10}{(10-f_2)} = \frac{10}{(2f_1)^2}$$

$f_1 = 4.0 \quad \left(f_1 = \frac{\sqrt{10}\,20}{2\sqrt{40}+\sqrt{10}} \right)$

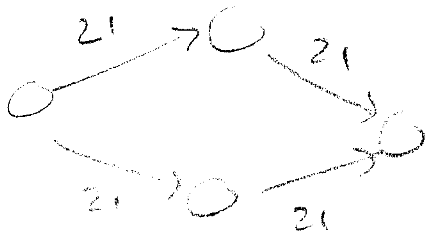
$f_2 = 2.0$

$$D = \frac{4.8}{20-4} + \frac{2}{10-2} = 1.25 \qquad T = 0.125$$

Q3 c

$C = £50$

$T = 0.125$



$C = £84$

$T = 0.125$

Discussion based on reliability aspects

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Q4 Restoration categories

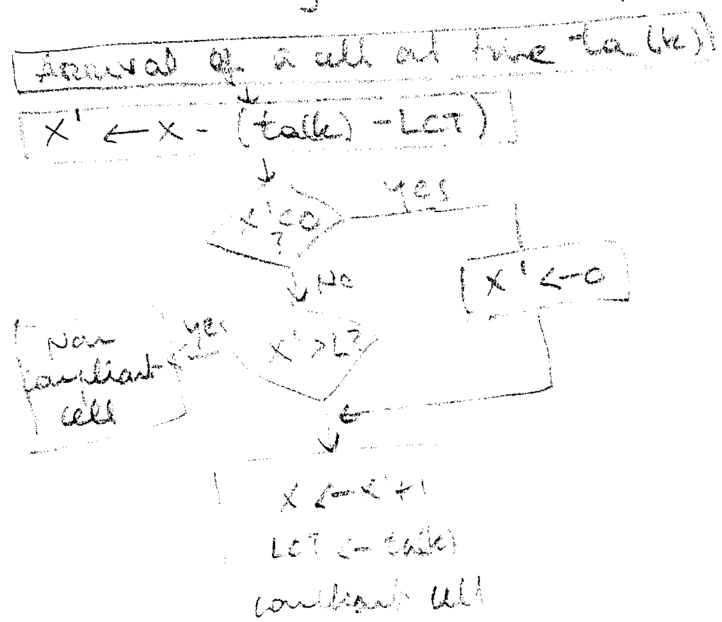
(a) - Traffic restoration: individual cells

- Facility restoration: network facilities e.g. multiplexers, ADM, cross connect syst.
- Protection switching: Established pre-assigned replacement connections (no network management function)
- Re-routing: Establishment or replacement of connection (by a network management control connection)
- Self-healing: Establishment of a replacement connection by network (no network management control function).

(b) (i) Describe and discuss:

- PCR: Peak Cell Rate
- CDV: Cell Delay Variation Tolerance
- SCR: Sustainable Cell Rate
- MBT: Maximum Burst Tolerance

ii) Continuous-state Leaky Bucket Algorithm



X = value of the leaky bucket counter

X' = aux. variable

LCT = last compliance time

note at $t_a(1)$ $X = 0$ and $LCT = t_a(1)$

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Q5 UDP is an unreliable connectionless transport layer protocol

It is a simple extension to IP that provides
- Demultiplexing of IP packets
- Error checking of data, and
- multiple applications in the host

TCP is a connection oriented data streaming service transport layer protocol

TCP provides
- Full duplex reliable, sequenced, flow-controlled
- A recovery mechanism from out-of-order packets, duplicate packets, lost packets, corrupt packets
- A flow and congestion control mechanism
- Support for multiple application processes in the same end system

MPLS
- Integrates layer 2 switching with layer 3 routing
- A key feature is the separation of the control (plane) and the forwarding data (plane) in a label switching router.
- MPLS focuses on IPv4 and IPv6
- MPLS operates with multiple layer 2 technologies e.g. ATM, FR ... and Ethernet
- Improve forwarding performance (using a simplified look up process)
- Improve scalability (using label stacking and merging)
- Provide traffic engineering (via explicit efficient routing)