NATIONAL UNIVERSITY OF SINGAPORE

FACULTY OF ENGINEERING

EXAMINATION FOR

(Semester II: 2001/2002)

EE5912 – High Speed Networks

April / May 2002 - Time Allowed: 2.5 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **SIX** (6) questions and comprises **SEVEN** (7) printed pages.
2. Answer any **FOUR** (4) questions.
3. All questions carry equal marks.
4. This is a CLOSED BOOK examination.
5. Calculators can be used.

Q.1

(a) Consider a SONET BLSR-2 with five nodes labeled 0 through 4 in a clockwise direction. A possible way of handling a single-node failure is as follows. When a node fails, each of the adjacent nodes of the failed node sees that the link connecting it to the failed node has failed. Each of these adjacent nodes assumes that it is a single-link failure and tries to reroute the traffic. The above method has a severe undesirable consequence. Give an example to illustrate this consequence. Suggest a way to handle single-node failures which avoids any undesirable consequence.

(9 marks)

(b) How many OC-48 connections can be routed on a OC-48 SONET UPSR-2? Prove your answer. (9 marks)

(c) Construct a traffic distribution for which the (aggregate) traffic-carrying capacity of a SONET BLSR-4 is maximized. What is this (aggregate) capacity as a multiple of the bit rate on a working fiber and the number of nodes? (7 marks)

Q.2

(a) In a WDM network with 8 wavelengths per fiber, a fixed-alternate routing method is employed. For node-pair <1,6>, the following alternative routes R_1 and R_2 are searched in the given order.

R_1: 1-> 2->3->4->5->6
R_2: 1->7->8->6

A wavelength is assumed to be used on a link with probability 0.3. The above event is assumed to be independent of the use of other wavelengths on the link and is also independent of the use of the same and other wavelengths on other links. It is assumed that node 4 has full-degree wavelength conversion capability and no other node in the network has wavelength conversion capability. Now, for a connection request <1,6>, determine

(i) the probability that route R_1 is assigned to the request,

(ii) the probability that route R_2 is assigned to the request,

(iii) the probability that the connection request is accepted.

(12 marks)

(b) Develop a backward-reservation based distributed control protocol for least congested path routing. Include details of the control messages exchanged and the actions performed by the source, destination, and intermediate nodes.

(13 marks)

Q.3

(a) Consider a linear network with IP routers located at nodes A, B, C, and D in that order. There is a traffic demand of 2 Gbps from node A to node C, 4.5 Gbps from node A to node D, 2.2 Gbps from node B to node C, and 2.5 Gbps from node B to node D. It is decided to employ WDM network elements at these nodes to meet the traffic demand. Assume that a wavelength operates at the rate of 2.5 Gbps. Determine the number of wavelengths, and ports and buffers required at each of the nodes, when: (i) point-to-point WDM links with LTs are employed, and (ii) WADMs are employed. (12 marks)

(b) It is required to design fixed-WXCs for use in a network in which every node has two input fibers (top and bottom) and two output fibers (top and bottom), and every fiber carries four wavelengths w_0, w_1, w_2, and w_3. A WXC at node i drops w_i from the top input fiber and w_{i+1} from the bottom input fiber. Further, it adds w_i to the bottom output fiber and w_{i+1} to the top output fiber. Here, modular arithmetic is used, for example, 3+1 is 0. Other wavelengths are "crossed", i.e. a wavelength from the bottom input fiber is switched to the top output fiber and vice versa.

(i) Show the architecture of a fixed-WXC at node 2.

(ii) Show how the lightpaths originating at node 0 are routed in a 4-node unidirectional network. Assume that the nodes are labeled 0 through 3 in the clockwise direction. (13 marks)

Q.4

(a) A converter placement heuristic chooses nodes in non-increasing order of the amount of the transit traffic passing through them. Consider the network with 10 nodes shown in Figure Q.4a. Assume that 1 unit of traffic is routed from each node to every other node. It is required to place two converters using the abovementioned heuristic.

(i) Which of the nodes will be chosen for converter placement?

(ii) Comment on the network performance in terms of blocking probability. (9 marks)

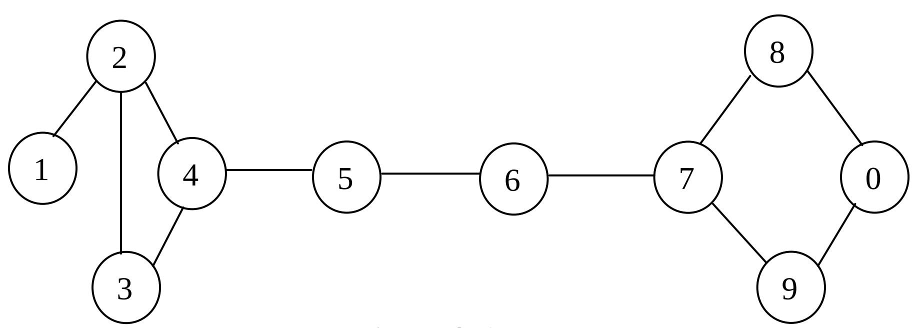

Figure Q.4a

Q.4 is continued on page 4

(b) Consider a single-fiber unidirectional ring with *W* wavelengths per fiber. Develop a wavelength rerouting algorithm to select the minimum number of rerouted lightpaths in order to establish a lightpath from node *s* to node *d*. Assume that the parallel MTV-WR scheme is followed. (9 marks)

(c) Explain how to protect the working traffic in WDM BLSR-2 against single-link failures. What is the major difference between WDM BLSR-2 and SONET BLSR-2? (7 marks)

Q. 5

(a) Consider a combined SONET-WDM ring network with four nodes and links connected as $0 \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 0$. It is required to route a SONET OC-x connection from each node to every other node. Assume that the multiplexing factor is 2.

(i) Derive a lower bound on the number of SADMs required.

(ii) Derive a lower bound on the number of wavelengths required.

(iii) Use the following heuristic to form circles. Assume a matrix A where rows and columns correspond to nodes and the entry A[i,j] is the number of OC-x connections to be routed from node i to node j. Examine the entries row-wise starting from the top left corner. When you examine a non-zero entry, group the corresponding node-pair with other nearest entries so as to form a circle with the minimum number of node pairs. For instance, node pair <0,1> can be grouped with <1,0> to form a circle. When all the entries are considered, carefully assign wavelengths to circles considering the multiplexing factor, and at the same time minimizing the number of SADMs required.

Use the above heuristic and design the SONET-WDM ring using not more than 9 SADMs.

(9 marks)

(b) A variant of HLDA algorithm works as follows. Instead of subtracting the next highest value whenever a lightpath is established between a node-pair, it subtracts a fixed value which is equal to the lowest non-zero entry in the initial traffic demand matrix.

Consider a WDM network and the normalized traffic demand between node-pairs as shown in Fig. Q.5b, and Table Q.5b, respectively. Assume that there are two wavelengths w_0 and w_1 per fiber and each node is equipped with two transmitters and two receivers. Design a virtual topology using this variant of HLDA. For each iteration of the algorithm, list the node-pair considered and the physical route and wavelength chosen to establish the lightpath. Give the reason if a lightpath cannot be established.

Q. 5(b) is continued on page 5

For a node-pair, choose the shortest physical route which is free. If more than one (shortest) route with the same number of hops are free, choose the one which traverses in the clockwise direction. Use a fixed-order wavelength assignment method and choose the free wavelength with the lowest index.

(9 marks)

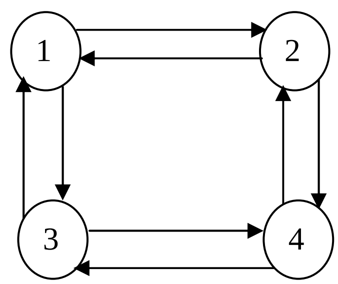

Figure Q.5b

Table Q.5b

Nodes	1	2	3	4
1	0	0.70	0.95	0.55
2	0.65	0	0.75	0.90
3	0.22	0.85	0	0.60
4	0.80	0.50	0.45	0

(c) Develop simple mathematical expressions to calculate the restoration time upon a link failure in terms of link propagation time, control message processing time etc. for each of the protection techniques in WDM networks.

(i) path-based protection with backup multiplexing,

(ii) link-based protection with backup multiplexing.

Assume that links are of equal length.

(7 marks)

Q.6

(a) Consider an ATM network with three switches labeled S1 through S3 and five hosts labeled A through E as shown in Fig. Q.6a. List all host-to-host VC connections when the VCI table entries at the switches are as shown in Tables Q6.a. (9 marks)

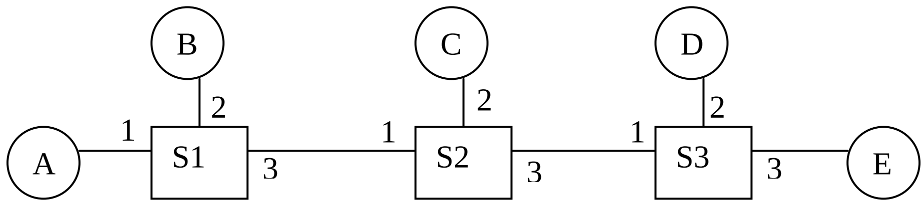

Figure Q.6a

Tables Q.6a

Switch S1

Port-in	VCI-in	Port-out	VCI-out
1	2	3	1
1	1	2	3
2	1	3	2

Switch S2

Port-in	VCI-in	Port-out	VCI-out
1	1	3	3
1	2	3	2

Switch S3

Port-in	VCI-in	Port-out	VCI-out
1	3	2	1
1	2	3	1

(b) Consider the ATM ABR virtual circuit in Figure Q6.b, segmented into two control loops at switch S2 which acts like a virtual destination (VD) and virtual source (VS).

(i) Suppose resource manager cell RM1 departs from S2 to H1 reporting a high available rate, but right afterwards an RM cell arrives at S2 from H2 reporting a low available rate for the second half of the circuit. What problem might S2 now face?

Q.6 (b) is continued on page 7

(ii) When S2 receives RM1 from H1, it might simply hold it while it sends its own RM2 back to H2. When RM2 returns, S2 would now send back RM1, reducing its rate specification, if necessary. Why might such a strategy be undesirable?

(9 marks)

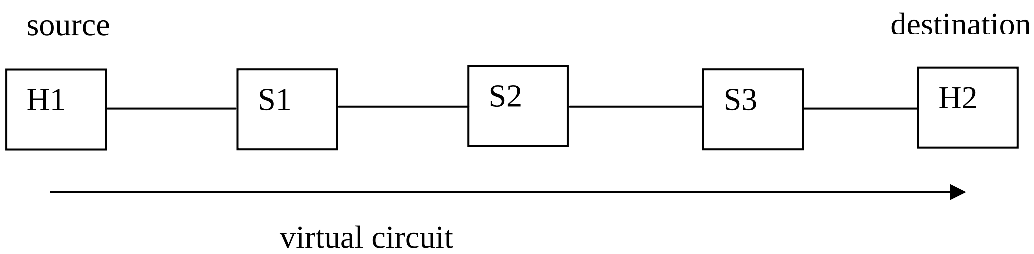

Figure Q6.b

(c) Consider a switch with an input link and an output link each operating at the rate of 10 Mbps. At time t = 0, a packet with a 20-byte header and a 1000-bit payload starts (i.e. the first bit of the packet) arriving at the node. Determine the time at which the packet is completely (i.e. the last bit in the packet) transmitted onto the output link. Also, determine the time at which the transmission is complete if the same payload is carried by a continuous stream of ATM cells.

(7 marks)

END OF PAPER