NATIONAL UNIVERSITY OF SINGAPORE

FACULTY OF ENGINEERING

EXAMINATION FOR

(Semester II: 2000/2001)

EE5912 - High Speed Networks

April / May 2001 - Time Allowed: 3 Hours

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **SEVEN (7)** questions and comprises **SIX (6)** pages.
2. Answer question Q.1 and ANY FOUR of questions Q.2 to Q.7.

Q.1

(a) An advantage of SONET systems is that they are downward and upward compatible. What does the above statement mean? (2 marks)

(b) The rate of OC-12 is approximately, but not exactly equal to four times the rate of OC-3. State if the above statement is TRUE or FALSE. Justify your answer. (2 marks)

(c) A data stream has a peak rate of 100 Mbps and an average rate of 4 Mbps. What type of service would you recommend: circuit-switched or packet-switched? Why? (2 marks)

(d) A traffic manager monitors the incoming cell rate of an application using a leaky bucket mechanism. The leaky bucket has a capacity of 100 tokens and adds a token every 1 micro-second. The actual cell rate varies linearly from 800,000 to 1,400,000 cells/second. Is there any possibility of the bucket becoming empty? Why? (2 marks)

(e) Is there any possibility of the parallel MTV-WR scheme migrating two lightpaths to the same wavelength channel ? Justify your answer. (2 marks)

(f) Explain why the sharing efficiency of the share-per-link wavelength-convertible switch is lower than that of the share-per-node wavelength-convertible switch. (2 marks)

(g) Explain why a 4-fiber network with 8 wavelengths per fiber performs better (in terms of connection blocking probability) than a single-fiber network with 32 wavelengths. (2 marks)

(h) What is the key idea used in MLDA to ensure that a shortest (propagation delay) path exists for every pair of nodes in the optical layer? (2 marks)

(i) Define the traffic grooming problem in the context of combined WDM-SONET network design. (2 marks)

(j) List the TWO major advantages of optical burst switching over optical circuit switching. (2 marks)

Q.2

(a) It is required to route six OC-12 connections on a SONET ring with four nodes, one for each of the node-pairs <1,2>, <1,3>, <4,3>, <3,2>, <1,4>, and <4,2>. The fiber capacity is assumed to be the same as that of OC-48. Explain how the above traffic is routed on each of i) UPSR-2 and ii) BLSR-2. Also explain how the affected traffic is rerouted when the link (with all its constituting fibers) between node 1 and node 2 fails.

Q.2 (a) is continued on page 3

The nodes are labelled 1 through 4 in clockwise direction. Route the connections one by one in the given order. In case of UPSR-2, use the clockwise ring for routing primary paths. In case of BLSR-2, choose the shortest free path. In case of a tie, break the tie in favour of the path in anti-clockwise direction. Reject a connection if and only if there is no free route available.

(14 marks)

(b) Consider the SONET network operating over the optical layer, as shown in Fig. Q.2. Trace the path of the connection through the network, and show the termination of different SONET layers at each SONET network element.

(6 marks)

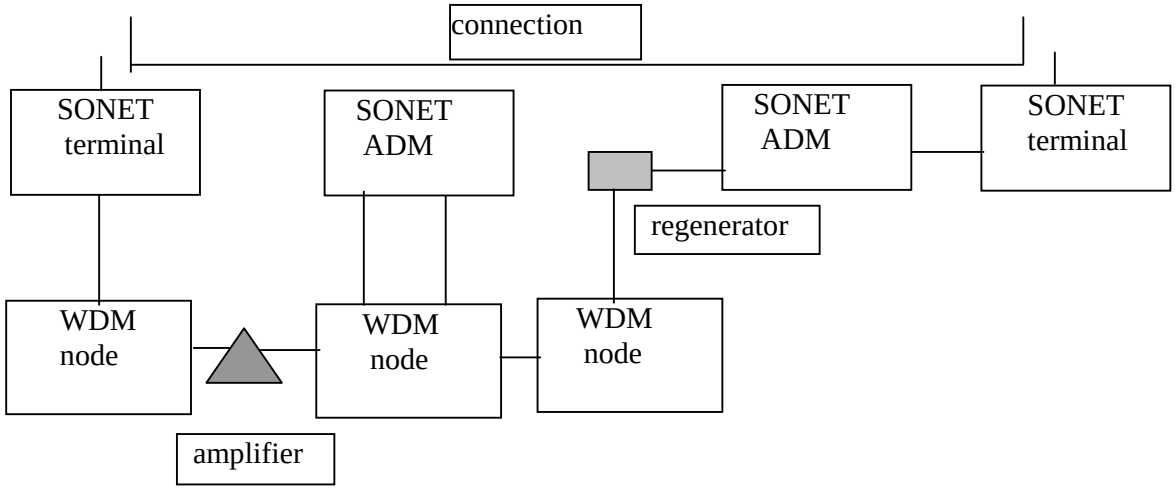


Fig. Q.2.

Q.3

(a) Consider the ATM network shown in Fig. Q.3. with four user nodes A, B, C, and D and four network element nodes 1, 2, 3, and 4. ATM connections are routed between each of the node-pairs <A,B>, <C,D>, <D,A>, <A,D>, and <B,C> . The routing is carried out in the order in which the above node-pairs are listed. Show the VCI table at each of the four network nodes indicating the VCIs in the input and output ports. Assume that every link is a VP.

(14 marks)

Q.3 (a) is continued on page 4

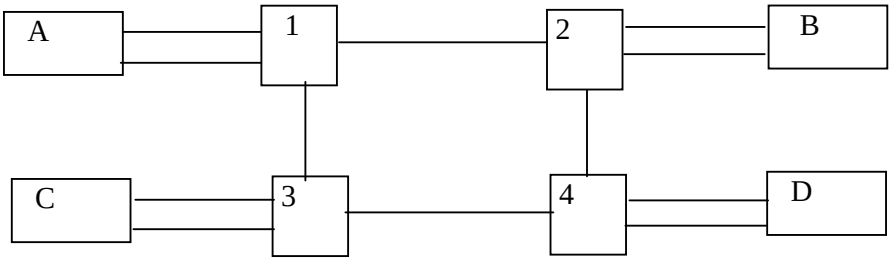


Fig. Q.3.

(b) An ATM node is connected to 100 channels and has a throughput of 100 Mcells/s. The 100 channels have the following traffic parameters: 50% of them have a constant cell rate of 1 Mcells/s; 20% of them have a variable cell rate with a minimum of 0.4 Mcells/s and a maximum of 0.6 Mcells/s; 20% of them have a variable cell rate with a minimum of 0.3 Mcells/s and a maximum of 0.4 Mcells/s; and 10% of the channels are not active. A new customer requests all bandwidth available. Calculate the best and worst-case bandwidth that can be allocated to the new customer if the node should operate up to 80% capacity. Assume that all the cells are at high priority, i.e. CLP=0.

(6 marks)

Q.4

(a) Consider a WDM network with 8 wavelengths per fiber. A request *r* arrives at node *s* requesting a lightpath to another node *d*. Assume that a physical route *R* traversing 3 links from node *s* to node *d* is used to satisfy the request. The probability that a given wavelength is used on a link is 0.6. Assume that the above event is independent of the use of other wavelengths on the link and is also independent of the use of this wavelength and other wavelengths on other links. Calculate the probability that the lightpath request *r* is accepted for each of the following two cases.

Case 1: No node in the network has wavelength conversion capability.

Case 2: Every node in the network has full degree wavelength conversion capability.

(14 marks)

(b) State the key idea used in each of the following fairness improvement methods: i) wavelength reservation, ii) threshold protection, and iii) limited alternate routing.

(6 marks)

Q.5

(a) Consider a uni-directional ring network with four nodes and links connected as 0->1->2->3->0. Each link carries two wavelengths w_0 and w_1. Assume that lightpath request and release events occur in the sequence as given in Table Q.5. The events are processed one by one in the given order. The network uses fixed-order wavelength assignment policy and it chooses the free wavelength with the lowest index.

Q.5 (a) is continued on page 5

Table Q.5.

Event	id	node-pair
Request	r1	<0,1>
Request	r2	<2,3>
Request	r3	<1,2>
Request	r4	<3,1>
Request	r5	<3,0>
Release	r1	<0,1>
Request	r6	<0,3>

(b) List the routes and wavelengths assigned to the above requests. Verify that request r6 cannot be established.

(c) What is (are) the lightpath(s) chosen for migration by parallel MTV-WR algorithm in order to accommodate r6?

(d) Is it possible to accommodate r6 by employing only one wavelength converter at only one node? Explain.

(14 marks)

(b) Is least-congested path routing based on alternate routing the same as selecting a route using alternate routing and then applying the least used wavelength selection method? Justify your answer using a simple illustration.

(6 marks)

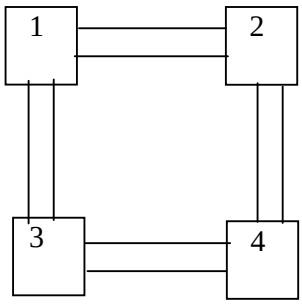
Q.6

(a) A WDM network and the traffic demand between node-pairs are shown in Fig. Q.6. 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 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.

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 precedes the other route in a vector notation. A lightpath traversing nodes $a_1,a_2,a_3\ldots,a_n$ is said to precede another lightpath traversing nodes $b_1,b_2,\ldots,b_n$ only if there exists some j such that $a_1=b_1$, $a_2=b_2$, …,$a_{j-1}=b_{j-1}$, $a_j=b_j$ and $a_{j+1}<b_{j+1}$. Use fixed-order wavelength assignment method and choose the free wavelength with the lowest index.

(14 marks)

Q.6 (a) is continued on page 6



Physical Topology

0.0	0.90	0.60	0.85
0.80	0.00	0.45	0.40
0.70	0.65	0.00	0.30
0.75	0.55	0.50	0.00

Traffic Demand Matrix

Fig. Q.6.

(b) Consider the following traffic:

0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.2

When HLDA is used to design the virtual topology, it is possible that the node- pair with traffic 0.4 will get 2 lightpaths while the node-pairs with higher traffic get only one. Explain why this happens and suggest a way to resolve this problem.

(6 marks)

Q. 7

(a) Consider a combined WDM-SONET ring with four nodes and links connected as 0->1->2->3->0. It is required to route twelve OC-48 SONET connections, one from each node to every other node in the ring. The wavelengths operate at the speed of OC-48.

i) How many wavelengths and SONET ADMs are required if wavelength routing approach is used with the following wavelength assignment policy? Group the node-pairs into several sets in such a way that each set consists of a minimum number of node-pairs (OC-48 SONET connections) required to form a circle, for example, node-pairs <0,1> and <1,0> form a circle. Assign different wavelengths to different sets. All the connections in the same set will receive the same wavelength.

ii) How many wavelengths and SONET ADMs are required if point-to-point WDM links are used?

(14 marks)

(b) Compare the performance of the following survivability techniques in terms of service restoration time, restoration guarantee, and bandwidth utilization:

i) protection-based versus dynamic-restoration-based.
ii) pro-active, exclusive reservation versus pro-active, backup multiplexing.
iii)pro-active, backup multiplexing versus pro-active primary-backup multiplexing.

(6 marks)

END OF PAPER