COE 444 - Internetwork Design and Management
Fall 2004 (Term 041)

Homework 7

Date: Saturday, December 11th, 2004

Problem 1

Q1. Consider the terminal assignment problem defined in the following table showing the cost matrix:

	A	B	C
a	3	6	5
b	5	7	2
c	1	3	4
d	2	8	5
e	7	1	9
f	10	2	3

The problem consists of 3 concentrators A, B, C, and 6 terminals, a, b, c, d, e, and f. Assume that each terminal has a weight of 1 and each concentrator has a capacity of 2.

Use the ***Augmenting Path Algorithm*** to find an optimal solution to this terminal assignment problem.

Q2. Assume that the three concentrators are connected according to a unidirectional ring topology **(A-B-C-A)** and that all links have the same capacity of **2 Mbps**. Assume that the terminals are connected as follows: **(a, C), (b, C), (c, A), (d, A), (e, B), (f, B).**

The average packet size has been estimated equal to **2000 bits**. It has also been observed that the traffic generated by the various terminals is Poissonian with rates as indicated in the following table showing the **Inter-terminals traffic in pps**.

	a	b	c	d	e	f
a	-	20	50	10	30	20
b	20	-	10	20	40	60
c	50	10	-	80	20	10
d	10	20	80	-	50	50
e	30	40	20	50	-	100
f	20	60	10	50	100	-

a. Find the inter-concentrators traffic in pps (γ_{jk}, j, k = A, B, C).

b. Find the internal traffic rates on the links AB, BC, and CA, that is, λ_{AB}, λ_{BC}, and λ_{CA}.

c. Which link constitutes the primary bottleneck link?

d. What is the average number of links $\tilde{n}$ traversed by a packet to go from any source to any destination?

e. Find T, the average delay per packet.

f. Assume that the external traffic from all terminals is multiplied by a constant factor α. What is largest value α_{max} that will cause the network to saturate?

Problem 2

Q1. Assume that you are faced with the following situation. A company has 6 divisions, each serviced by a 10 Mbps Ethernet workgroup switch, labelled S_1 to S_6. The company has acquired three backbone switches B_1, B_2, and B_3, each with four interfaces. Two of these interfaces are 10 Mbps Ethernet interfaces, and the two others are 100 Mbps Fast Ethernet interfaces.

Assume that the cost of connecting each of the workgroup switches to each of the backbone switches is as specified in the following cost matrix:

	B_1	B_2	B_3
S_1	6	3	8
S_2	2	9	4
S_3	3	1	4
S_4	2	5	9
S_5	1	6	3
S_6	2	7	9

Find a minimum cost feasible assignment of the workgroup switches to the Backbone switches, and give the cost of such an optimum assignment.

You must show all the steps.

Q2. Assume that the three backbone switches are interconnected with full duplex links according to a tree topology with B_1 as the root of the tree, and B_2 and B_3 as the children of B_1. The links are running at Fast Ethernet speed.

Suppose that the 6 workgroup switches are assigned as follows: S_4 and S_6 to B_1, S_1 and S_3 to B_2, and S_2 and S_5 to B_3. The workgroup switches are connected to the backbone switches with full duplex links of 10 Mbps speed. The average packet size has been estimated equal to 1000 bits. It has also been observed that the traffic (in pps) generated by the various workgroups is Poissonian with rates as indicated in the following table:

	S_1	S_2	S_3	S_4	S_5	S_6
S_1	-	200	500	100	300	200
S_2	200	-	100	200	400	600
S_3	500	100	-	800	200	100
S_4	100	200	800	-	500	500
S_5	300	400	200	500	-	1000
S_6	200	600	100	500	1000	-

a. Find the internal traffic rates on all the links, that is $\lambda_{Si,Bj}$, and $\lambda_{Bj,Si}$, i = 1, …, 6, j = 1, 2, 3, where S_i is connected to B_j, and $\lambda_{Bi,Bj}$, i, j = 1, 2, 3, i ≠ j and the link between B_i and B_j exists.

b. Find the utilizations of all the links, that is $\rho_{Si,Bj}$, and $\rho_{Bj,Si}$, i = 1, …, 6, j = 1, 2, 3, where S_i is connected to B_j, and $\rho_{Bi,Bj}$, i, j = 1, 2, 3, i ≠ j and the link between B_i and B_j exists.

c. Which link constitutes the primary bottleneck link?

d. What is the average number of links **ñ** traversed by a packet to go from any source to any destination?

e. Find ***T***, the average delay suffered by a packet to go from any workgroup switch to any other workgroup switch.

f. What is the largest load that can be sustained by the network before any of its links saturate?

Q3. For the tree network in question **Q2.**, assume that the MTBF and MTTR of any link are respectively 5 years and 1 day, and the MTBF and MTTR of any switch are respectively 15 years and 5 days. (1 year = 365.25 days)

a. Find P_l and P_s, the links and switches reliabilities (use precision at 10^{-5})

b. Find the overall network reliability, that is, the probability that the network is connected.

c. Find $E(B_1)$, the expected number of nodes communicating with the root node B_1. Recall that, for any node i:

$$E(i) = P_i \times (1 + \sum_{k \in Succ(i)} P_{j_k} E(k))$$

where j_k is the link between node ***i*** and its successor node ***k***.

d. Find $EPR(B_1)$, the expected number of node pairs communicating through the root node B_1. Recall that,

$$EPR(B_1) = \sum_{\substack{i,k \in Succ(B_1) \\ i \neq k}} P_{B_1} P_{j_i} E(i) P_{j_k} E(k) + \sum_{i \in Succ(B_1)} P_{B_1} P_{j_i} E(i)$$

where P_{j_i} and P_{j_k} are respectively the reliabilities of the links between nodes ***i*** and ***k*** and the root B_1. P_{B_1} is the reliability of switch B_1, and $E(i)$, $E(k)$ are as defined above.