HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory
S-38.145 Introduction to Teletraffic Theory, Spring 2005

Examination
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1. Consider elastic data traffic at flow level on a link with speed 10 Mbps in an interval $[0, T]$, where $T = 20$ (time unit: second). The system is empty at time $t = 0$. New flows arrive at times 2, 4, 6, and 10. The sizes (in Mbits) of these flows are 100, 20, 25, and 15, respectively. The link capacity is shared evenly among all competing flows.

   (a) Construct a figure that describes the flow arrival times, the delays for all flows, and the number of flows in the system (that is, the traffic process) as a function of time $t \in [0, T]$.

   (b) What is the average delay of a flow?

   (c) What is the average number of flows in the system during the interval $[0, T]$?

2. Give the definition of the Erlang model, and write the call blocking probability as a function of the model parameters.

3. Consider the M/M/1/2/2 model where the mean idle time of a customer is $1/\nu$ time units and the mean service time is $1/\mu$ time units. Let $X(t)$ denote the number of customers in the system at time t.

   (a) Draw the state transition diagram of the Markov process $X(t)$.

   (b) Derive the equilibrium distribution of $X(t)$.

   (c) Assumed that $\nu = \mu = 1$, determine the probability that the server is busy at an arbitrary time.

4. Consider a queueing system with n parallel servers and m waiting places. Let $1/\mu$ denote the average service time. Customers are served in their arrival order. Assume an excessive arrival stream, that is, every time a customer leaves the system, a new customer arrives immediately. Therefore the system is always full. What is the average time a customer spends in the system?

5. Consider the following network with 4 nodes and 8 links. The set of nodes is denoted by $\mathcal{N} = \{\mathrm{a}, \mathrm{b}, \mathrm{c}, \mathrm{d}\}$, and the set of links by $\mathcal{J} = \{1, 2, \ldots, 8\}$. The properties of various links are given in the table below (j = link index, n_j = origin node, m_j = destination node, c_j = link capacity, w_j = link weight).

j	n_j	m_j	c_j	w_j
1	a	b	6	1
2	b	a	6	1
3	a	d	3	2
4	d	a	3	2
5	b	c	1	6
6	c	b	1	6
7	c	d	3	2
8	d	c	3	2

   (a) Draw the network topology. (b) What is the total number of paths? (c) List all shortest paths.