HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory
S-38.1145 Introduction to Teletraffic Theory, Spring 2007

Examination
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1. Consider elastic data traffic at flow level on a link with capacity 2 Mbps in an interval $[0, 20]$ (time unit: second). The system is empty at time $t = 0$. New flows arrive at times 1, 2, 4, 7, and 16. The sizes (in Mbits) of these flows are 8, 4, 5, 5, and 2, respectively. The link capacity is shared evenly among all competing flows. In addition to the joint (shared) link, each flow is throttled by its own access link with capacity 1 Mbps.

   (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 $t \in [0, 20]$.

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

   (c) What is the average number of flows in the system during the interval $[0, 20]$?

2. Buses arrive at a bus stop according to a Poisson process with an average interarrival time of 10 minutes. You arrive at the bus stop just after the departure of the previous bus.

   (a) Let T denote the time until the arrival of the next bus. What is the distribution of the random variable T?

   (b) Let X denote the number of buses that arrive during the next 5 minutes after your arrival. What is the distribution of the random variable X?

3. Consider the M/M/3/3 model with mean customer interarrival time of $1/\lambda$ time units and mean service time of $1/\mu$ 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) Suppose that $\lambda = \mu$. What is the probability that an arriving customer is lost?

4. Suppose that you can utilize a random number generator producing random numbers $Z \in \{0, 1, \ldots, m-1\}$. Tell how to generate

   (a) a random number U from the U(0, 1) distribution?

   (b) a random number X from the Exp(λ) distribution?

5. Consider a packet switched trunk network with three nodes connected to each other as a tandem by two link pairs: a — b — c. The capacity of each separate (one-way) link is 100 Mbps. The following six routes are used in this network:

   - Route 1: a $\rightarrow$ b
   - Route 2: b $\rightarrow$ c
   - Route 3: a $\rightarrow$ b $\rightarrow$ c
   - Route 4: b $\rightarrow$ a
   - Route 5: c $\rightarrow$ b
   - Route 6: c $\rightarrow$ b $\rightarrow$ a

   For each route, new packets arrive according to an independent Poisson process with intensities $\lambda(1) = \lambda(2) = 5$, $\lambda(3) = 15$, $\lambda(4) = \lambda(5) = 1$, $\lambda(6) = 3$ packets/ms. The packet lengths are independently and exponentially distributed with mean 500 bytes.

   (a) Draw a picture describing this queueing network model.

   (b) Compute the traffic loads for each link.

   (c) Compute the mean end-to-end packet delays for the routes 3 and 6.