Exercise 5
20.2.2007

Problems 2, 4, and 6 are homework exercises. Return your answers into the course box of the laboratory (G-wing, 2. floor) latest at 10.00 on Tuesday 20.2.

1. *Demo*
   Consider data traffic on a link between two routers at flow level. The traffic consists of TCP flows sharing the link, generated with rate λ. The link capacity is denoted by C and the random flow size by L. In addition to the shared link, the rate of TCP flows is limited by access links. Let r denote the capacity of each access link.
   (a) Consider this as an M/M/n-PS queueing model. Suppose that $\lambda = 80$ flows per second, $E[L] = 0.125 \cdot 10^6$ bytes, $C = 100$ Mbps, and $r = 10$ Mbps. Determine the throughput θ.
   (b) What if $C = 10$ Gbps?

2. *Homework exercise*
   As in the previous problem, consider elastic data traffic on a link. Assume now that $\lambda = 80$ flows per second, $E[L] = 0.125 \cdot 10^6$ bytes, and $C = r = 100$ Mbps. Let $X(t)$ denote the number of flows sharing the link at time t. In addition, there is an admission control scheme (to avoid overload situations) that allows at most 10 concurrent flows.
   (a) Draw the state transition diagram of Markov process $X(t)$.
   (b) Derive the equilibrium distribution of $X(t)$.
   (c) What is the mean number of flows sharing the link?

3. *Demo*
   Consider the following simple circuit switched trunk network. There are three nodes connected in a tandem by two links: a — b — c. Each link has capacity of 2 channels. In addition, there are three traffic classes:
   - Class 1 uses link a — b
   - Class 2 uses link b — c
   - Class 3 uses both link a — b and link b — c

   Determine the state space of this system. Furthermore, determine the blocking states for each class separately.

4. *Homework exercise*
   Consider again the circuit switched trunk network defined in the previous problem. Assume that, for each class r, new calls arrive according to a Poisson process at rate λ_r. Let $\lambda_1 = 1/3$, $\lambda_2 = 2/3$, and $\lambda_3 = 0$ calls per minute. Call holding times (for all classes) are assumed to be independently and identically distributed with mean $h = 3$ min. Compute the end-to-end blocking probabilities for each class using
   (a) the exact formula,
   (b) the approximative Product Bound method.

5. *Demo*
   Consider a connectionless packet switched trunk network with three nodes connected to each other as a triangle. Each node pair is connected with two one-way links (one in each direction) of capacity 155 Mbps. The following five routes are used in this network:

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

For each route, new packets arrive according to an independent Poisson process with intensities $\lambda(1) = 20$, $\lambda(2) = 10$, $\lambda(3) = \lambda(4) = \lambda(5) = 5$ packets per ms. The packet lengths are independent and exponentially distributed with mean 400 bytes. Draw a picture describing this queueing network model. Compute the traffic loads for each link j. In addition, compute the mean end-to-end delays for each route r.

6. *Homework exercise*
Consider again the queueing network model defined in the previous problem. Assume now that the connection between nodes a and c breaks down so that the packets following route 2 (a $\rightarrow$ c $\rightarrow$ b) are rerouted to route 1 (a $\rightarrow$ b), and the packets following route 3 (a $\rightarrow$ c) are rerouted to a new route 6 (a $\rightarrow$ b $\rightarrow$ c). Compute the new mean end-to-end delays for each route r.