HELSINKI UNIVERSITY OF TECHNOLOGY **Exercise 4**
Laboratory of Telecommunications Technology 11.10.2000
S-38.145 Introduction to Teletraffic Theory, Fall 2000 Aalto/Nyberg

Note: Problem 3 is a homework exercise. Deliver your answer sheet (labelled with your student id, name, and signature) into the mail box of the course, or directly to the course assistant *before* the next exercise class on 18 October.

1. Consider a connectionless packet switched trunk network. There are 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. Assume that 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

   Assume that, 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. Assume further that the packet lengths are independent and exponentially distributed with mean 400 bytes. Assume finally that the delays due to processing packets in the nodes are negligible (if compared to delays due to packet transmission).

   Model this system as a queueing network. Draw a picture describing this queueing network model. Compute the traffic loads ρ_j in each link j. What is the probability that the network is totally empty of packets (at an arbitrary time). Compute further the average end-to-end delays for each route r.

2. Consider the connectionless packet switched network defined in the previous problem. However, contrary to the previous problem, we will now take also into account the delays due to processing packets in the nodes. Assume that, in each node, there is a single processor taking care of the routing decisions. Model this processor (and the related buffer) as a pure waiting system of the M/M/1 type, with processing rate of 50 packets per ms. All the packets arriving a node visit first the processor, after which they are directed to the appropriate output port.

   Expand your queueing network model so that this new feature is included. Draw a picture describing this modified queueing network model. Compute further the traffic loads for each processor, and, finally, the average end-to-end delays for each route r.

3. *Homework exercise* (deadline 18 October at 9 o'clock): Consider the expanded queueing network model defined in the previous problem. Assume now that the connection between nodes b 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 4 (c $\rightarrow$ b) are rerouted to a new route 6 (c $\rightarrow$ a $\rightarrow$ b).

   Modify the expanded queueing network model so that this new feature is included. Draw a picture describing this modified queueing network model. Compute further the average end-to-end delays for each route r.