HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory
S-38.1145 Introduction to Teletraffic Theory, Spring 2006

Exercise 1
24.1.2006

Problems 2, 5 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 24.1.

1. *Demo*
   Consider a part of a trunk network, which is connected to the rest of the network through four of its nodes. In this subnetwork, the average number of packets has been measured to be 1000. Let the arrival rates of the packets from other parts of the network to these four nodes be $\lambda_1 = 200$ pps, $\lambda_2 = 300$ pps, $\lambda_3 = 400$ pps, and $\lambda_4 = 500$ pps (pps = packets per second). How long does a packet stay in the subnetwork on average?

   (*Tip:* Use Little's formula)

2. *Homework exercise*
   Consider a lossy queueing system (cf. Lectures: Slide 1/27) with 3 parallel servers and 3 waiting places. The average interarrival time between two customers is 4 minutes, and the loss ratio is 10%. In addition, the average waiting time (before service) is 3 minutes, and the average service time is 10 minutes.

   (a) What is the average number of waiting customers?
   (b) What is the average number of customers in service?
   (c) The customers departing from this system are directed to a pure queueing system (cf. Lectures: Slide 1/26) with only a single server. Tell what happens if the average service time in the latter system is 5 minutes.

3. *Demo*
   Traffic measurements over Funet are available at

   `http://www.csc.fi/suomi/funet/noc/looking-glass/wm`

   Click the link between nodes `helsinki0-rtr` and `NORDUnet` to get access to the traffic measurements related to the link. All measurements are presented graphically. The two curves represent the two different directions of the link (`in` = from Stockholm to Helsinki and `out` = from Helsinki to Stockholm). A single point on the curve tells the average traffic at the corresponding time and with the resolution given. The default or raw resolution is 3 minutes. Find the curves from which you can estimate the following quantities (in both directions):

   (a) The average traffic and time of the busiest and the lightest 3-minute periods on Friday, 13 January 2006.
   (b) The average traffic and time of the busiest and the lightest 1-hour periods on Friday, 13 January 2006.
   (c) The average traffic and date of the busiest and the lightest days in November 2005.

4. *Demo*
   Consider telephone traffic on a link in an interval $[0, T]$, where $T = 16$ (time unit: minute). The system is empty at time $t = 0$. New calls arrive at times 1, 2, 4, 5, 6, 9, and 12. The holding times of these calls (if they are not blocked) are, respectively, 9, 5, 4, 2, 7, 2, and 4. The capacity of the link is $n = 3$ channels.

(a) Construct a figure that describes the call arrival times, channel-by-channel occupation, and the number of channels occupied (that is, the traffic process) as a function of time $t \in [0, T]$.

(b) What is the ratio between the number of blocked calls and the total number of calls?

(c) What is the ratio between the time the system is full and the total time?

(*Tip*: Cf. Lectures: Slide 2/15)

5. *Homework exercise*

Consider data traffic at packet level in an output port of a router in an interval $[0, T]$, where $T = 20$ (time unit: μs). The system is empty at time $t = 0$. New packets arrive at times 1, 3, 4, 14, and 15. The transmission times of these packets are 5, 5, 1, 2, and 2, respectively. Packets are sent in their arrival order. No packets are lost.

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

(b) What is the average waiting time of a packet?

(c) What is the average total delay (including both the waiting and the transmission time)?

(*Tip*: Cf. Lectures: Slide 2/20)

6. *Homework exercise*

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 $[0, T]$?

(*Tip*: Cf. Lectures: Slide 2/30)