Aalto University School of Electrical Engineering
Department of Communications and Networking
ELEC-C7210 Modeling and analysis of communication networks, Autumn 2016

Examination
25
~~23~~.10.2017
Lassila

Please answer to all five (5) questions. Use of calculators/additional material is not allowed in the exam.

1. Consider a pure single server queueing system with average service rate of 2.5 customers/s. New customers arrive at rate 2.0 customers/s. The average total delay is 3.0 s (including both the waiting time and the service time).
   (a) What is the average number of customers in the whole system?
   (b) What is the average number of waiting customers?
   (c) What is the average number of customers in service?
   (d) What is the average number of departing customers during an interval of length 10 s?

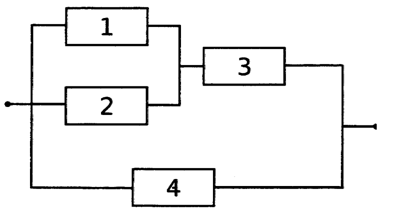
2. Consider a queueing system with two parallel servers. The service times are independent and identically distributed following the Exp(1/2) distribution. The system is empty at time 0. Two new customers arrive at times 1 and 2, respectively, and no other customers enter the system. In addition, it is known that both customers are still in the system at time 3. Let Z_1 denote the time at which the customer with the shorter service time leaves the system. Correspondingly, let Z_2 denote the time at which the customer with the longer service time departs. Thus, $Z_2 > Z_1 > 3$. Determine the mean values $E[Z_1]$ and $E[Z_2]$.

3. Consider elastic data traffic carried by a 10-Mbps link in a packet switched network. Use a pure sharing system model with a single server. New flows arrive according to a Poisson process at rate 9 flows per second, and the sizes of files to be transferred are independently and exponentially distributed with mean 1 Mbit. Let $X(t)$ denote the number of ongoing flows at time t.
   (a) What is the traffic load?
   (b) Derive the equilibrium distribution of $X(t)$.
   (c) What is the throughput of a flow?

4. Consider the M/M/3/4 model where customers arrive at rate λ customers per time unit 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) Assuming that $\lambda = \mu$, what is the probability that the arriving customer can enter service directly without any waiting?

Last question on the other side of the paper

5. (a) Determine the structure function $\phi(\mathbf{x})$ of the system of independent components in the reliability block diagram below.



(b) If the components in above diagram are repairable, what is the availability of the above system? The mean time to failure of each component i, MTTF_i, are $\text{MTTF}_1 = \text{MTTF}_2 =$ 2 hours and $\text{MTTF}_4 = 1$ hour. The mean down time of component i, MDT_i, for components 1, 2 and 4 is one hour. The component 3 cannot break down so the availability for component 3 is 1.