CS 549: Performance Analysis of Computer Networks
Theory Assignment 4

Assigned: April 30, 2025 *Due*: May 6, 2025

Write your answers by hand on plain paper, scan and submit on Moodle. Descriptive answers must be written in your own words, copying verbatim from the textbook will not fetch you any marks.

1. Packets arrive at a node with two output links according to a Poisson Process. Each output link has an interface within the node which can process packets independently. Give the Kendall's notation for the following cases:

   (a) the packet lengths are exponentially distributed, the buffer can store B packets.

   (b) the packet length is fixed, the buffer capacity is infinite.

   (c) the packet length is L with probability p_L and G with probability p_G and the system can accommodate at most 10 times the number of packets under service.

2. The inter-arrival time of packets arriving at a single-server queue is exponentially distributed with a mean of 12 seconds. The time taken to serve the packets is exponentially distributed with a mean of 8 seconds. Find the

   (a) average wait time in the queue,

   (b) average number of packets waiting in the queue,

   (c) average time spent by a packet in the system,

   (d) average number in the system and

   (e) proportion of time the server is idle.

3. A telephone exchange receives calls as per a Poisson process with mean rate of 1 call per 5 mins and the duration of the calls is exponentially distributed with mean 4 mins. A caller who finds all telephone operators busy patiently waits until one becomes available. Determine the number of operators the exchange should employ so that the average non-zero waiting time of the customer is at most half a minute.

4. A single server queue has exponential inter-arrival and service times with mean $1/\lambda$ and $1/\mu$, respectively. Suppose that new customers are sensitive to the length of the queue, such that if the queue length is i when a customer arrives, then that customer will join the queue with a probability of $1/(i+1)$, otherwise he/she departs and does not return.

   (a) Find the steady state probability distribution of this queueing system.

(b) Derive an expression for the average number of customers in the system.

(c) Derive an expression for the average time spent by a customer in the system.

5. Consider a single-server queue where the inter-arrival time of the packets has a γ distribution with shape parameter 5 and scale parameter 2. The service time has the normal distribution with a mean of 8 mins and a variance of 20 min^2. Find Q3(a)–(e) for this system.

6. Two edge routers (R_1 and R_2) are connected to one core router (C_1). Packets entering R_1 at rate 100 pkts/sec and R_2 are rate 120 pkts/sec. Both the edge routers have a service capacity of 150 pkts/sec. The core router has a service capacity of 400 pkts/sec. After being served at R_1, packets enter C_1 with probability 0.6. After being served at R_2, packets enter C_1 with probability 0.7. Fresh packets arrive at the C_1 at rate 50 pkts/sec.

   (a) Write the routing matrix for the network.

   (b) Find the total arrival rate at C_1.

   (c) Find the expected number of packets in the queueing system.