# Assignment 3

## Problem 1:

Consider a system with arrival rate $\lambda = 4$ pkt/s and service rate $\mu = 8$ pkt/s. (Hint: The average packet in the system can be calculated by $E[N] = \frac{\rho}{1-\rho}$ , where $\rho = traffic\ load$)

a) Compute the expected time a packet needs to go through the system.

# Problem 2:

Consider a system with arrival rate $\lambda = 4$ pkt/s and service rate $\mu = 8$ pkt/s.

a) What is the average inter-arrival time?
b) Compute the probability that the next inter-arrival is larger than 2
c) Compute $P(A(2) = 4)$

# Problem 3:

Consider a system with arrival rate $\lambda = 4$ pkt/s and service rate $\mu = 8$ pkt/s.

a) What is the average time a packet spends in service?

Now assume that the system has an infinite number of servers and the service rate for each server i is $\mu_i = 8$ pkt/s.

b) What is the average time a packet spends in service?
c) What is the average number of packets that exist in the system at any point in time?
d) Assume that the probability of a packet to be dropped is $P_b = 0.75$, what is the average number of packets that exist in the system at any point in time?

# Problem 4:

Consider a system where user#1 is making a phone call using VoIP. During the transit of user#1's call packets are begin received by a router according to a Poisson process $\{N_1(t) = t \geq 0\}$ with rate $\lambda_1 = 10$ packets/second.

a) What is the expected number of packets that the router must receive from user#1's call after 1 minute? I.e. compute $E[N(60)]$

Now assume that user#1 begins a new call and suppose that two other users (#2 and #3) begin making independent calls at the same time using VoIP that must pass through the same router according to respective poisson processes

$\{N_2(t) = t \geq 0\}$ with rate $\lambda_2 = 20$ packets/second and $\{N_3(t) = t \geq 0\}$ with rate $\lambda_3 = 30$ packets/second

b) What is the probability that the router will receive 1000 packets in the next 15 seconds?
c) If the router's queue is only large enough to hold 1500 packets and if the three users continue to send at the same rate, will we expect see a buffer overflow in the router after 30 seconds?

## Problem 5:

Assume that some large organization is using a single switch to route all traffic between the two halves of the organization's 2 LANs. Suppose that at time $t = 0$ the switch is empty and that at time $t = 3$ it is the case that 100 packets have arrived, 50 have departed, and 8 have been blocked.

a) What is the number of packets that are at the switch at time t = 3? (i.e. compute N (t))

b) Now suppose some clever engineer has discovered that the number of arrivals at the switch in the interval from time 0 to time t can be described by the function

$$A(t) = 12t^2 \sin\frac{1}{t}$$

What is the long-term arrival rate at the switch?

c) Now suppose that same clever engineer has discovered that the number of departures from the switch in the same interval from time 0 to time t can be described by the function

$$D(t) = (13t \cdot e)(1 - (\frac{1}{t}))^t$$

What is the throughput of the switch?