Simulation Project 2

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Simulate the following system. If possible, verify with the theoretical result (if available). Last but not least, in all your result, you need to specifies *ALL* necessary parameters for your simulation.

1. Simulate the **transient behavior** of a $M/M/1$ system. Assume that the system utilization, ρ, is equal to 0.9. Assume that at time $t = 0$ the system is empty (no job in the system). Plot the
   (a) Probability distribution function of the number of jobs in the system at $t = 10.0$ second.
   (b) average number of jobs in the system for $0 \leq t \leq 110.0$ second.
   (c) average response time of jobs in the system for $0 \leq t \leq 10.0$ second.

2. Simulate a closed queueing network. Assume that we have 4 nodes $n_i, i = 1, 2, 3, 4$. For node n_i, it has an exponential service rate of μ_i. We have $\mu_1 = 2.0, \mu_2 = 4.0, \mu_3 = 3.0, \mu_4 = 10.0$. The job routing is :

$$
\begin{aligned}
p_{1,2} &= 0.3 \\
p_{1,3} &= 0.7 \\
p_{2,1} &= 0.7 \\
p_{2,3} &= 0.3 \\
p_{3,1} &= 0.6 \\
p_{3,2} &= 0.2 \\
p_{3,4} &= 0.2 \\
p_{4,1} &= 0.3 \\
p_{4,2} &= 0.4 \\
p_{4,4} &= 0.3
\end{aligned}
$$

   Let $N = 30$ be the number of jobs in the closed queueing network. Find:
   (a) The average number of jobs in node n_i, $i = 1, 2, 3, 4$.
   (b) The average throughput in node n_1.

   In your simulation, make sure that I can alter different values of μ_i and N.