CS556: Performances Modelling Of Communication And Computer Systems

Deadline: 11:59 pm, 23 March 2025

Instructions:

1. This assignment is to be done in groups of 2. Please attempt all questions.
2. The programs can be written in C/C++/Java.
3. Your code should have a readme file, a makefile, and it should be well commented. These will carry separate marks for each question.
4. No extensions in submission are allowed. Delay in submission will lead to penalty in marks.
5. Assignments submitted before the deadline will only be considered for evaluation. Please do not email your assignments separately to the TAs, it will not be considered for evaluation.
6. Submit your set of source code files along with a report clearly mentioning all observations, explanations, containing the graphs, and all the answers, as a zipped file on teams. The ZIP file's name should be the same as your group number, for example, "Group_3.zip", or "Group_3.rar", or "Group_3.tar.gz". Submission without a report will not be awarded any marks.
7. Write your own source code and do not copy from any source. Plagiarism and use of unfair means will be penalized by awarding NEGATIVE marks (equal to the maximum marks for the assignment).
8. No sharing of code between students is allowed.
9. TOTAL MARKS = 50 (Code:25; Report: 10; VIVA: 5; README, Makefile, Code structure, Comments: 10)

Q1) A bank operates with a variable number of tellers throughout the day to handle customer transactions. Customers arrive according to a Poisson process with an average rate of 40 customers per hour. Each teller can serve customers with exponentially distributed service times, averaging 4 minutes per customer.

Task:

1. Implement a simulation of an M/M/c queuing system where c (number of tellers) varies as follows:
    a. 2 tellers from 9:00 AM to 11:00 AM
    b. 4 tellers from 11:00 AM to 2:00 PM (peak hours)
    c. 3 tellers from 2:00 PM to 5:00 PM
2. Run the simulation for the entire 8-hour workday (9:00 AM to 5:00 PM).
3. Calculate and display the following performance metrics for each time period and for the entire day:
    a. Average waiting time for customers in the queue
    b. Average time spent in the system (waiting + service time)
    c. Utilization rate of tellers

    d. Average number of customers in the queue
    e. Probability of all tellers being busy
4. Plot the queue length and average waiting time.
5. Analyze how the varying number of tellers affects the system performance during different periods.
6. Suggest an optimal teller allocation strategy to minimize customer waiting times while maintaining efficient teller utilization.
7. Provide a brief report discussing your findings and recommendations for improving the bank's service efficiency.

Q2) A call center operates with a single agent to handle incoming customer calls but has a limited waiting capacity. Calls arrive following a Poisson distribution, and the center employs one agent to handle these calls. The agent's service time follows an exponential distribution. The system has a finite capacity, including the customer being served.

Task:

1. Simulator Implementation: Create a simulation model to replicate an M/M/1/c queuing system for the call center.
   Use the following parameters:
    a. Arrival rate (λ): 20 calls per hour
    b. Service rate (μ): 24 calls per hour (single agent)
    c. System capacity (c): 5 (including the customer being served)
2. Calculate the following measures of effectiveness:
    a. Average waiting time for customers in the queue
    b. Average time spent in the system (waiting + service time)
    c. Utilization rate of the agent
    d. Average number of customers in the queue
    e. Probability of the system being full (all waiting spots occupied)
    f. Probability of customer rejection (arriving when system is full)
3. Implement functions to:
    a. Vary the system capacity from 3 to 7
    b. Analyze how changing the system capacity affects the performance metrics
4. Additional Analysis:

a. Plot the average waiting time, agent utilization, and rejection probability as functions of the system capacity.
b. Determine the optimal system capacity to maintain an average waiting time of less than 5 minutes while minimizing rejections.
c. Discuss how the system capacity impacts overall performance.

5. Optimization Strategies:
    a. Suggest strategies for efficient capacity planning based on your findings.
    b. Propose improvements to optimize the performance of the call center.
6. Report:
    a. Provide a brief report discussing your implementation, results, and recommendations.
    b. Include any assumptions made in your simulation model.
    c. Compare your simulation results with analytical results for the M/M/1/c queue.

Q3) A small coffee shop operates with a single barista serving customers on a first-come, first-served (FCFS) basis. Customers arrive randomly throughout the day and may need to wait in line before being served. The goal is to analyze the performance of the shop's service process using an M/M/1 queue model and explore different performance aspects.

1. System Description:

1.1 Customers arrive following a Poisson process at an average rate of $\lambda = 10$ customers per hour.
1.2 The barista serves customers one at a time, and the service times follow an exponential distribution with an average rate of $\mu = 15$ customers per hour.
1.3 If the barista is busy, incoming customers must wait in a queue until they are served.
1.4 The coffee shop operates for a simulated period covering 500 customers.

2. Simulation Requirements:

Develop a program to simulate this M/M/1 queue system and compute the following key performance metrics:

2.1 Basic Performance Metrics:

2.1.1 Average Waiting Time in Queue – the average time a customer spends waiting beforeordering.
2.1.2 Average Time in System – the total time a customer spends in the shop (waiting +

service).
2.1.3 Utilization Factor – the proportion of time the barista is busy.
2.1.4 Idle Time of the Barista – the fraction of time the barista is not serving any customer.
2.1.5 Maximum Queue Length – the longest the waiting line ever gets.
2.1.6 Probability of an Empty Queue – the fraction of time when there is no line.

3. Additional Analysis Tasks:

3.1 Peak Hours Analysis – Identify when the queue length is highest during the simulation period.
3.2 Customer Abandonment (Reneging) Simulation – Introduce a rule where customers leave if their waiting time exceeds a given threshold (e.g., 5 minutes).
3.3 Service Rate Experiment – Simulate what happens if the barista speeds up (e.g., $\mu = 20$ customers per hour) or slows down ($\mu = 12$ customers per hour).
3.4 Multiple Server Comparison (M/M/c) – Simulate a scenario where the coffee shop hires a second barista and compare results with the original single-server model.
3.5 Revenue Impact Analysis – Calculate how much revenue the coffee shop loses when customers leave due to long wait times. Assume an average customer spends $5 per visit.

4. Final Documentation Requirement:

4.1 Create a Full Report Document

- A structured document summarizing all the key findings, analysis, and visualizations.
- The report should include:

4.2 System Description and problem formulation.

4.3 Simulation Methodology and assumptions.

4.4 Performance Metrics and Results – Summarized data from the simulation.

4.5 Graphs and Visualizations with explanations.

4.6 Comparative Study of multiple servers (M/M/2) are analyzed.

4.7 Conclusion with potential improvements and business recommendations.

4.8 Complete Program Implementation

- The code should have detailed explanations and comments to help understand how the simulation is executed.

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