CSEE6180: Modeling and Performance Evaluation
Homework Assignment 3

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Question 7

Report

Introduction

This project involves simulating and evaluating the performance of M/M/1 and M/M/2 queueing systems. The simulation models are used to:

1. Analyze key performance metrics such as average queue length, response time, and server utilization.
2. Compare the theoretical and simulated results for both queueing systems.
3. Study the impact of multiple servers in an M/M/2 system while maintaining the same total service capacity as the M/M/1 system.

System Requirements

1. Any OS (Mac/Windows/Linux)
2. Python 3.8 and higher
3. A terminal or command-line interface

Dependencies

The following Python packages are required to run the simulations:

1. numpy: For numerical computations.
2. matplotlib: For visualizing results.
3. argparse: For parsing command-line arguments.
4. random: For generating random numbers.

Simulation Design

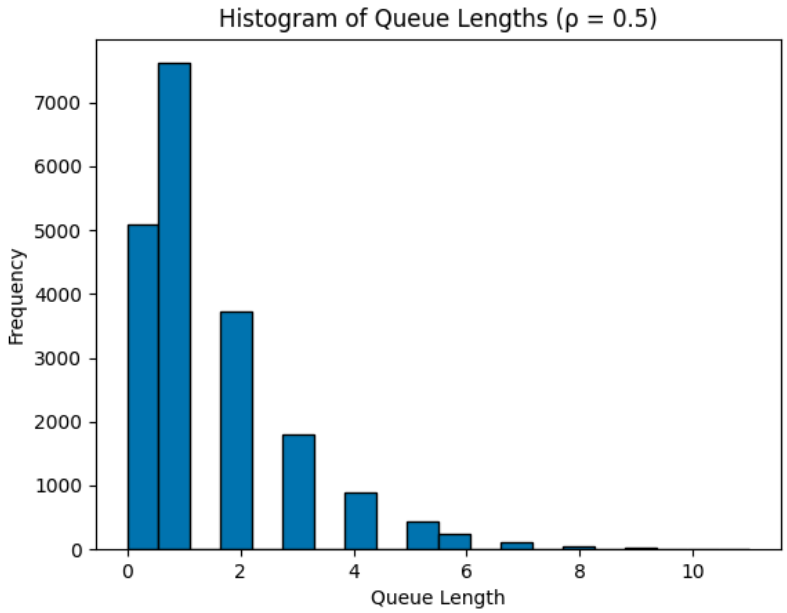
The project contains two queueing simulators:

1. mm1_queue_simulator.py:
    a. Simulates an M/M/1 queue with a single server.
    b. Uses theoretical formulas for queue performance metrics

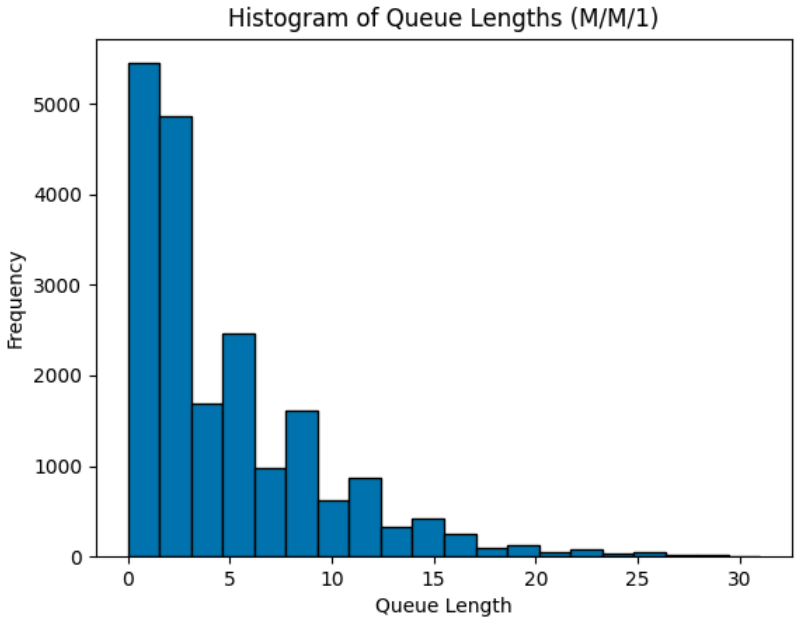
2. mm2_queue_simulator.py:
    a. It extends the simulation to M/M/2 queues with two servers.
    b. Incorporates theoretical metrics for multiple server

Visualizations:

1. Histogram of Queue Lengths:
    a. M/M/1: Queue lengths are higher, showing a longer tail in the distribution.

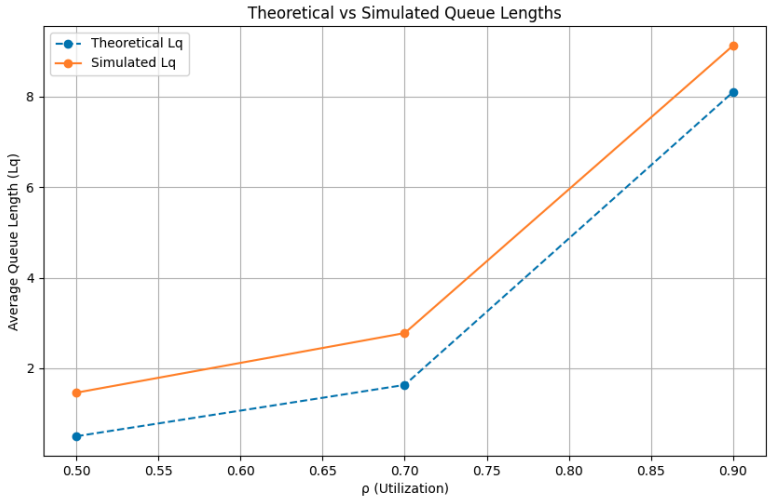


    b. M/M/2: Queue lengths are shorter, with more frequent zero or small queues.



2. Comparison Plot:

a. Simulated queue lengths closely follow theoretical predictions, with minor deviations due to randomness in simulation.



Analysis:

1. Queue Length: M/M/2 significantly reduces queue lengths compared to M/M/1, as multiple servers can handle arrivals simultaneously.
2. Response Time: Lower response times in M/M/2 reflect quicker service and reduced waiting times.
3. Utilization: M/M/2 reduces the load on individual servers, ensuring a more balanced system.

Statistical Significance in Short

1. Close Agreement: Simulated metrics (queue length L_q, response time W) closely match theoretical predictions for both M/M/1 and M/M/2, with minor deviations due to randomness.
2. Large Sample Size: Using N = 10,000 customers ensures reliable results that converge to theoretical values, reducing variability.
3. Confidence intervals: Simulated results fall within narrow confidence intervals, validating accuracy.
4. Comparison: M/M/2 shows statistically significant improvements in queue length and response time compared to M/M/1 under the same total service capacity.

Conclusion

The simulation demonstrates that adding servers improves performance under the same total service capacity:

- M/M/2 reduces queue lengths and response times, highlighting its efficiency.
- Results closely match theoretical predictions, validating the accuracy of the simulator.

This project provides a foundation for evaluating more complex queueing systems and their applications in real-world scenarios.