CS 5233
Simulation and Modelling Techniques

Assignment 1

Group 17 (Mission Simpossible)

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A. Simulation and Analysis of a Travel Agency

1. Problem Statement

Simulate the operation of a travel agency in Singapore using a multi-server single queue model (M/M/c) to reduce cost of operation while maintaining good customer service (shorter waiting times)

2. Simulation Setup

The simulator is written in Python as an M/M/c program and can be accessed on GitHub at https://github.com/shreyjain241/CS-5233.

Salient features of the simulator include:

- Takes input values of
  - Mean InterArrival Time
  - Mean Service Time
  - Number of Terminals
- Runs each simulation 1000 times
- Each simulation ends after 960 minutes (16 hours). The assumption here is that the travel agency operates for 16 hours in a single day and closes after 16 hours.
- Returns outputs of interest (mean and standard deviation) of
  - Average Waiting Time per customer
  - Customers delayed
  - Percentage Customers delayed more than 5 mins
  - Percentage Customers delayed less than 4 mins

3. Experiments and Results

The experiments are aimed at answering the following questions

- What is the average waiting time of the customers if there is a single customer service desk (or terminal)?
- What percentage of customers will wait longer than 5 minutes if there is a single terminal?
- How many terminals would be needed to guarantee that 90% or more of the customers will wait less than 4 minutes for service?

Initially we assume that inter-arrival times and service times are exponentially distributed. Given that Arrival rate is 10 customers per hour and mean service time is 8 minutes, we get:

- Mean InterArrival Time = 6 mins
- Mean Service Time = 8 mins

The following table summarises findings of the simulations for the above. Each simulation is run 1000 times and the mean and standard deviation (in brackets) of the output is reported:

Mean InterArrival Time	Mean Service Time	Number of Terminals (servers)	Avg Waiting Time	# Customers delayed	% customers delayed > 5 mins	% customers delayed < 4 mins
6 mins	8 mins	1	130 (47) mins	118 (11)	94 (5) %	5 (4) %
6 mins	8 mins	2	6 (4) mins	160 (12)	33 (12) %	64 (11) %
6 mins	8 mins	3	1 mins	161 (12)	6 (4) %	92 (5) %
6 mins	8 mins	4	0 mins	160 (13)	1%	99 (2) %
6 mins	8 mins	5	0 mins	161 (13)	0%	99 (1) %

* *Figures in bracket indicate standard deviation*

4. Conclusions

Relevant results are highlighted in Green in the table above.

- A single terminal results in very poor customer service with an average wait time of 130 ± 47 mins per customer and 94 ± 5 % wait longer than 5 mins. The SLA of "*90% customers wait less than 4 mins*" cannot be met with a single terminal
- In order to meet the SLA : "*90% customers wait less than 4 mins*", a minimum of 3 terminals would be required.
- Hence, to operate the travel agency at the most optimum cost, while maintaining a good customer service, we must operationalise 3 terminals to serve the customers.

5. Appendix

Furthermore, we ran experiments on different values of InterArrival Time and Service Time to answer the question:

- How many terminals would be needed to guarantee that 90% or more of the customers will wait less than 4 minutes for service?

Results are summarised in the table below:

Mean InterArrival Time	Mean Service Time	Minimum Terminals required to meet guarantee (90% delay less than 4 mins)
6 mins	6 mins	3
6 mins	8 mins	3
6 mins	10 mins	4
6 mins	12 mins	4
6 mins	14 mins	5
8 mins	6 mins	2
8 mins	8 mins	3
8 mins	10 mins	3
8 mins	12 mins	4
8 mins	14 mins	4
10 mins	6 mins	2
10 mins	8 mins	3
10 mins	10 mins	3
10 mins	12 mins	3
10 mins	14 mins	4
12 mins	6 mins	2
12 mins	8 mins	2
12 mins	10 mins	3
12 mins	12 mins	3
12 mins	14 mins	3
14 mins	6 mins	2
14 mins	8 mins	2
14 mins	10 mins	3
14 mins	12 mins	3

B. Simulation and Analysis of a Telephony System

1. Problem Statement

Simulate the operation of a unidirectional and bidirectional telephony system in order to conclude whether the unidirectional system should be upgraded to a new bidirectional system while maintaining a reasonable QoS guarantee.

2. Simulation Setup

The simulator is written in Python and can be accessed on GitHub at https://github.com/shreyjain241/CS-5233.

Salient features of the simulator include:

- Takes inputs for:
  - Mean InterArrival Time of calls at X
  - Mean InterArrival Time of calls at Y
  - Mean Call Length
  - System = {1,2} #This defines whether the old or new system is in place
  - Number of channels from X to Y
  - Number of channels from Y to X #if system=2, then all channels are bi-directional
- Each simulation runs until 1000 calls have originated
- Furthermore, each simulation runs 100 times and the mean and standard deviation of the outputs is reported. Outputs of interest are:
  - Total calls patched
  - Total calls blocked
  - Percentage calls blocked
  - Total channel utilisation

3. Experiments and Results

The experiments are aimed at answering the following questions:

- How many channels would be needed in the old system to achieve a QoS guarantee of maximum 5% blocked calls, if there were equal number of channels in each direction?
- How could the old system be re-configured to reduce the number of blocked calls further if it is allowed to assign different number of channels to each direction?

- For the new system, how many channels are needed to provide the same QoS guarantee of maximum 5% blocked calls? How are the channels utilized in this case?

We assume the following about the inputs:
- InterArrival Times for calls originating at X are exponential with mean 12 seconds
- InterArrival Times for calls originating at X are exponential with mean 15 seconds
- Length of calls is exponential with mean of 5 mins (300 seconds)

Under the old unidirectional system, we ran experiments where there were an equal number of channels in both directions. Number of channels was set between 10 and 30 each way. A snapshot of the results is presented below:

Telephony System	Channels from X to Y	Channels from Y to X	Percentage calls blocked	Average channel utilisation
Unidirectional	10	10	37 (2) %	89 (1) %
Unidirectional	20	20	21 (3) %	85 (1) %
Unidirectional	25	25	10 (2) %	78 (2) %
Unidirectional	26	26	8 (2) %	76 (2) %
Unidirectional	27	27	6 (2) %	74 (2) %
Unidirectional	28	28	5 (1) %	73 (2) %
Unidirectional	29	29	4 (1) %	71 (2) %
Unidirectional	30	30	3 (1) %	70 (2) %

* *Figures in bracket indicate standard deviation*

Results highlighted in Green suggest that we would need a total of 56 channels (28 each way) to achieve a QoS guarantee of maximum 5% blocked calls. If this system, with 56 channels was to be reconfigured to assign a different number of channels in each direction, the following results can be looked at:

Telephony System	Channels from X to Y	Channels from Y to X	Percentage calls blocked	Average channel utilisation
Unidirectional	30	26	4 (1) %	74 (2) %
Unidirectional	28	26	5 (1) %	75 (2) %

* *Figures in bracket indicate standard deviation*

If the new system were to be implemented, the following results can be looked at:

Telephony System	Total channels	Percentage calls blocked	Average channel utilisation
Bidirectional (new)	30	35 (2) %	93 (1) %
Bidirectional (new)	35	26 (3) %	91 (1) %
Bidirectional (new)	40	17 (3) %	89 (1) %
Bidirectional (new)	45	10 (3) %	86 (2) %
Bidirectional (new)	49	6 (2) %	83 (2) %
Bidirectional (new)	50	5 (2) %	82 (2) %
Bidirectional (new)	60	1 (1) %	72 (3) %

* *Figures in bracket indicate standard deviation*

4. Conclusions

- Under the old system, a total of **56** channels would be needed (**28** each way) to achieve a QoS guarantee of maximum 5% blocked calls. Average utilisation of the channels would be ~**73**%

- If the old system could be reconfigured to assign a different number of channels to each direction, then a better QoS can be achieved with the same number of channels. Total of **56** channels (**30** from X to Y and **26** from Y to X) would give a maximum of 4 % blocked calls. Average utilisation of the channels would be ~**74**%.

- Alternatively, if the old system could be reconfigured to to assign a different number of channels to each direction, then only **54** channels (**28** from X to Y and **26** from Y to X) would be needed to achieve the same QoS guarantee of maximum 5% blocked calls. Average utilisation of the channels would be ~**75**%

- If the new (bidirectional) system was to be implemented, then a total of **50** channels would be needed to achieve the same QoS guarantee of maximum 5% blocked calls. Average utilisation of the channels would be ~**82**%

- It can be seen that the new system would be more cost effective than the old system and the reconfigured old system since a smaller number of channels would be needed to achieve the same QoS guarantee. These bidirectional channels would also be better utilised than the unidirectional channels of the old system.