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 find the optimal operation model (cost vs. good customer service).

2. General

The simulator is built in Arena as well as written in Python as an M/M/c program. The results are cross-compared for verification. The model and source codes can be accessed on GitHub at https://github.com/shreyjain241/CS-5233.

3. Simulation Setup

- Number of Replications = 30 times
- Replication Length $\geq$ 12 hours (720 minutes)
  * Our assumption is that the travel agency opens for 12 hours per day. Customers who arrive during opening hours will all be served before the closing.
- Inputs (configuration parameters):
  - Mean InterArrival Time
  - Mean Service Time
  - Number of Terminals (Service Desk)
- Outputs of interest:
  - Average Waiting Time of all Customers
  - Service Desk(s) Utilization
  - Total Number of Customers Served
  - Percentage of Customers Waited for more than 5 mins
  - Percentage of Customers Waited for less than 4 mins

4. Experiments and Results

The experiments are aimed at answering the following questions:

a. What is the average waiting time of the customers if there is a single customer service desk (or terminal)?
b. What percentage of customers will wait longer than 5 minutes if there is a single terminal?

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

Inter-arrival and service times are assumed to be distributed exponentially. We started with the average arrival rate of 10 customers per hour and each customer needs 8-min service on average, i.e.:

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

The results are shown in the table below.

Number of Terminals (Service Desk)	**Average Waiting Time (mins)**		**Service Desk Utilization (%)**		**Number of Customers Served**		**Customers waited < 4 mins (%)**		**Customers Waited > 5 mins (%)**	
	Average	HW	Average	HW	Average	HW	Average	HW	Average	HW
1	**135.13**	20.21	97.50%	1%	118	4	5.30%	1.34%	**94.13%**	4.58%
2	5.71	1.27	65.94%	3%	120	4	61.32%	4.39%	35.56%	6.40%
3	0.81	0.22	44.57%	2%	120	4	**92.10%**	3.41%	6.32%	2.06%
4	0.18	0.10	33.60%	1%	120	4	98.30%	3.26%	1.22%	0.94%
5	0.02	0.02	27.10%	1%	121	4	99.75%	3.24%	0.17%	0.17%

** HW: half width results from Arena.*

5. Conclusions

Relevant results are highlighted in Green in the table above.

- A single service desk results in very poor customer service with an average waiting time of **135.13 mins** and **94.13%** of customers need to wait for more than 5 mins. Furthermore, the service desk needs to operate on average of 16.32 hours to finish serving all customers in the queue (i.e. 4 hours more after the closing of the travel agency).
- In order to meet the SLA : *"90% customers wait less than 4 mins"*, a minimum of **3** service desks are required. Hence, to operate the travel agency at the most optimum cost, while maintaining a good customer service, the travel agency should open 3 terminals to serve the customers.

6. Appendix

Furthermore, we have experimented on different values of Mean InterArrival Time and Service Time to gain more insights, trying to address the same 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	Number of Terminals (Service Desk)	Average Waiting Time (mins)	Number of Customers Served	Customers waited < 4 mins (%)
6 mins	4 mins	1	7.12	121	51.96%
	4 mins	**2**	0.48	121	**95.89%**
	6 mins	1	51.61	121	12.84%
	6 mins	2	2.23	122	81.40%
	6 mins	**3**	0.25	120	**97.86%**
	10 mins	3	2.96	123	79.76%
	10 mins	**4**	0.41	121	**96.15%**
	12 mins	**4**	0.86	120	**92.14%**
	18 mins	4	8.03	120	60.56%
8 mins	8 mins	2	3.07	91	78.37%
8 mins		**3**	0.34	90	**96.93%**
10 mins		2	1.78	72	85.78%
11 mins		2	1.32	66	88.46%
12 mins		**2**	1.03	60	**90.61%**

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 (1) or new (2) system is in place.
  - Number of channels from X to Y
  - Number of channels from Y to X #If System = 2, all channels are bi-directional.
- Each simulation runs until 1000 calls have been 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.