ELEC3500 TELECOMMUNICATIONS NETWORKS

Simulation Experiment II

Experiment: Characterisation of M/D/1, M/M/1 and M/M/1/K Queuing Systems in a Packet Switched Network.

Required Reading Materials:

1. Recommend reading book pages **841-847 (2nd edition)**, Little's Formula and Basic Queuing Models.
2. Lecture slides: Lecture_6-7.

Objective: In this simulation experiment, the behaviour of M/D/1, M/M/1 and M/M/1/K queuing systems will be studied for different input traffic load and traffic patterns. The laboratory will also examine the effect of buffer size selection on the traffic throughput in an M/M/1/K queue model.

Procedure:

This laboratory is designed based on queuing lectures and the FIFO model located in the ELEC3500 folder of the OMNET++ simulator. The simulation model is configurable from the omnetpp.ini file. No model development is necessary for this laboratory - you only need to change simulation parameters to obtain different results. To select appropriate simulation parameters you need to calculate several basic simulation parameters. Use equations (1)-(3) below to calculate your simulation parameters. First, you run the simulation model to obtain the delay and the queue length data for all three queuing models. Following the first set of simulation, you need to run the model with different parameters to obtain several simulation results with different random number seed values to examine the effect of traffic variability. Random seed values are used in discrete event simulations to represent different traffic and network operating conditions. Lastly, you need to examine the effect of buffer size of a packet switch on the network traffic QoS (Quality of Service). QoS of a traffic source is usually expressed in terms of packet delay and loss.

$$Load\ \rho = \lambda/\mu \quad (1)$$

$$Service\ time\ X = 1/\mu \quad (2)$$

$$Interarrival\ time\ t\_int = 1/\lambda \quad (3)$$

For all simulation models, run the simulation for **600 sec (i.e., 10 minutes)** to collect data for analysis. Use the service rate of 10,000 bits/sec and the packet size of 1000 bits. You need to collect and save simulation results for writing your lab reports.

M/D/1 Queuing System

First, you will use the simulation model to analyse the performance of an M/D/1 system which is characterised by the exponential interarrival time of packets, with deterministic service time and a single server. You can modify the omnetpp.ini file to configure the model to an M/D/1 system. You need to collect the following results for the offered load values ρ = 0.1, 0.3, 0.5. 0.7, 0.9 and 1. To simulate these load values, calculate the packet interarrival time.

Results to collect: Mean packet delay, mean queue length and mean queue delay. You can collect these values from scalar files. You can export scalar and vector files to an Excel spreadsheet to further process your results. You also need to collect the end-to-end delay and queue length plots for ρ = 0.3 and 0.9 (use the vector files).

M/M/1 Queuing System

Configure the simulation model for an M/M/1 system by changing the omnetpp.ini file. Use the exponential distribution to represent the packet size. Collect results similar to those for the M/D/1 queue system. Also, collect similar vector files.

M/M/1/10 System

Configure the simulation model for an M/M/1/10 system by selecting the queue size to 10 packets. Modify the omnetpp.ini file to convert your model from an infinite queue model to a finite queue model. Collect results (scalar and vector) similar to those of the previous experiment. Using this model, collect the packet loss statistics as well as the time-vs-packet-loss plots for ρ = 0.7 and 0.9.

Study the effect of queue size on traffic QoS:

For ρ = 0.95, increase the value of K in steps of 5 to obtain the packet loss of less than 15 packets. Collect the packet loss and end-to-end delay for all values of K that you have used to obtain the packet loss of less than 15 packets. Present these values in a table in your report.

Study effect of random number:

Use the M/M/1 model, set ρ = 0.6, collect the queue length plot using vector files. In this section, you will compare the results generated by using the default seed value of the random number generator and by using two other seed values. You can select any two seed values between 0 and 99, and run the simulation model with these two seed values to collect the packet delay plots. Note down your selected random number generator in the common section of the report as mentioned below.

Report Submission Instruction:

You need to submit a report with a common section and individual sections, preferably submitted together. This section will be marked out of 40.

The common section should contain the following sub-sections:

- **Introduction** to the experiment, a single paragraph (200 words maximum) explaining the objectives of the simulation laboratory.

- **Basic description** of the simulation model used in the experiment (300 words maximum, 2 figures).
- **Results**: Provide following plots:
- It is suggested that you use five figures and one table in the following format:
    1. Figure 1: Load versus M/D/1, M/M/1 and M/M/1/10 mean packet delays.
    2. Figure 2: For the above queue systems: Load versus mean queue lengths.
    3. Figure 3: For the above queue systems: Load versus mean queue delays.
    4. Figure 4: M/M/1/10: Packet loss plots for the load values of 0.7 and 0.9.
    5. Table 1: For ρ=0.95, Queue size vs packet loss.
    6. Figure 5: M/M/1 packet delay for three different random numbers.
- **Analysis:** Briefly analyse the delay-vs-load graphs obtained for all three queue models to differentiate the performance of these models.

Individual section: Answer the following questions. The answers are to be provided by each group member separately.

1. Calculate the theoretical end-to-end delay values for M/M/1/10 and M/M/1 models, using ρ = 0.5 and 0.7. Use the same service rate as that in the simulation model.

   [10]
2. Compare the theoretical values calculated in Question 1 with the simulation results obtained. Explain why these results are the same or different? To answer this question, you also use information from your vector plots.

   [10]
3. Compare the delay and packet loss values obtained using the M/M/1 and M/D/1 models. Explain the differences you can observe by examining the load vs delay and packet loss plots.

   [10]
4. Explain the effect of using a random number for different seed values in the simulation model. Do you see any change of the packet delay distribution? Explain any differences you have observed using the different seed values.

   [10]
5. Explain the effect(s) of buffer size selection on the QoS value of the outgoing traffic of a network switch.

   [10]
6. Consider a real communication network where you don't have control over the traffic arrival process. What changes can you make within a packet switched node to reduce the probability of packet losses and high end-to-end delay?

   [10]

Report submission date:

The lab report is due on Friday at 11.59pm of the following week after the lab is performed. Submit your report via the Assessment tab of the blackboard. One of the group member's submission should have the common section. Write the group members name on both reports. Please include the university assessment cover sheet with your submission.