A Project Report on

Priority Queueing to Alleviate Packet Re-ordering Problem

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I. ABSTRACT

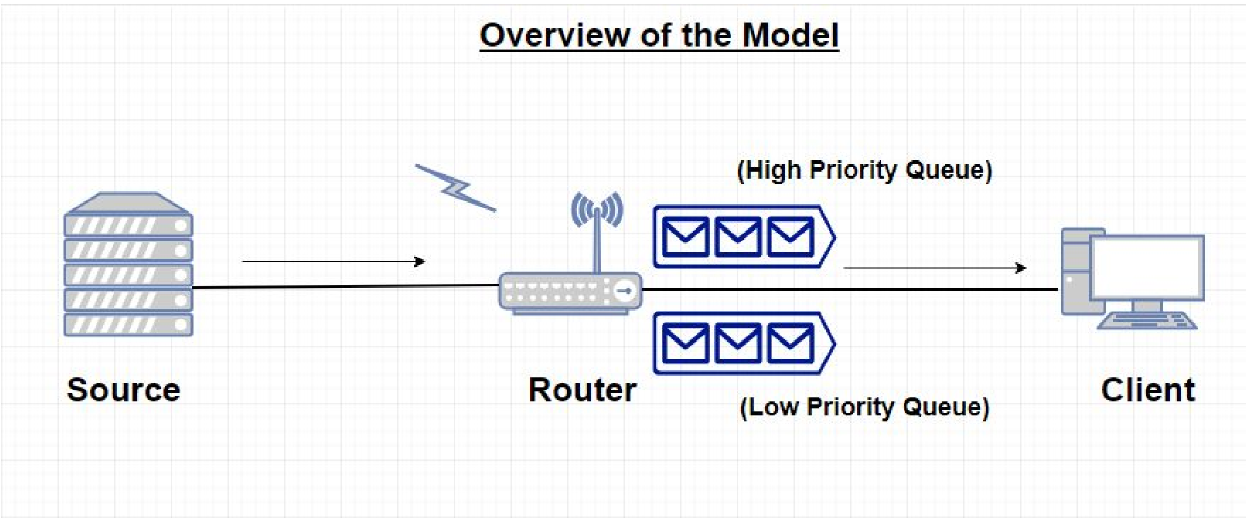
This project aims to build a model for the 'Transmission of data packets over the Network' from the real world. The report provides some background information on the priority queueing to alleviate packet re-ordering problem, and an existing FIFO queue approach. The methodology and configuration of the simulation experiments is described, then results of these experiments are presented and analyzed. It analyzes that how the loss of packets and packets delay time get affected by the prioritized queues.

II. INTRODUCTION

In the Internet, data packets from a source node (e.g., a web server) to a destination (e.g., a client computer) may experience different delay, resulting in out-of-order packet arrivals at the destination. A common solution is to buffer out-of-order packets at the destination and re-order the packets into correct order before sending them to the application layer. This project is to investigate the benefit of using priority queueing in the intermediate routers to alleviate the packet re-ordering problem. In first phase of the project, we examine a state where data packets arrive in a FIFO queue which is represented by a basic M/G/1 queue. For the Second phase, we extend our project to model and analyze the case where two queues are involved: one is low priority queue and the other is high priority queue.

III. SIMULATION MODEL

We assume that the network includes a source node, a router, and a destination. Data packets are transmitted from the source to the router and then to the destination. From the source to the router, packets experience a random delay which follows a normal distribution with the mean of x seconds and the standard deviation of y seconds. From the router to the destination, packets experience a fixed delay. Simulation done in the project can be related to the image shown below.



IV. ASSUMPTIONS

- The source node generates Poisson traffic, with average rate of 1125 packets per second.
- The transmission speed of the source node is 10 Mbps.
- Each packet has a unique sequence number and all data packets have the fixed length of 1000 Bytes (1 Byte = 8 bits).
- From the router to the destination, packets experience a fixed delay of 50 ms.
- The transmission speed of the router is 2.5 Mbps.
- Sizes of both queues in the router are 10M Bytes.

```java
package constant;

public class Constant {

    // number of packets to simulate
    public static long SIMULATION_LENGTH = 15000;
    // packet size in number of bytes
    public static final double PACKET_SIZE = Math.pow(10, 3);
    // queue size in number of packets
    public static final long MAX_QUEUE_SIZE = (long) (Math.pow(10, 7) / PACKET_SIZE);

    // number of packets generated by source per second
    public static final double DEPARTURE_RATE_SOURCE = 1125;
    // transmission speed in bytes per second
    public static final double TRANSMISSION_SPEED_SOURCE = Math.pow(10, 7) / 8;
    // represented by x in problem
    public static final double MEAN_TRANSMISSION_DELAY_SOURCE = 0.05;
    // represented by y in problem
    public static final double SIGMA_TRANSMISSION_DELAY_SOURCE = 0.05;

    // transmission speed in bytes per second
    public static final double TRANSMISSION_SPEED_ROUTER = TRANSMISSION_SPEED_SOURCE/4;
    // transmission delay in seconds
    public static final double TRANSMISSION_DELAY_ROUTER = 0.05;
    // departure event at source
    public static final int DEPARTURE_SOURCE = 1;
    // arrival event at router
    public static final int ARRIVAL_ROUTER = 2;
    // departure event at router
    public static final int DEPARTURE_ROUTER = 3;
    // departure event at router
    public static final int ARRIVAL_CLIENT = 4;
}
```

V. SIMULATION GOALS & PARAMETERS

The major goal of this project is to model and simulate the 'Transmission of data packets over the Network' and to calculate and analyze the performance metrics. The two phases of this project helps in understanding and simulating the real world scenario to as much extent as possible. These phases help to determine whether the priority factor for the data packets helps in the betterment of the overall system by reducing the time spent by each packet in the transmission from source node to the client & reducing the loss of packets. In a nutshell, we will observe the time spent by packets in the transmission in the complete system with one and two queues.

- **Packet out-of-order rate**: It is defined as the ratio of the total number of out-of-order packets over the total number of packets.
- **Average packet delay**: It is defined as sum of the end-to-end delay of all packets divided by the total number of packets.
- **Average packet loss rate**: It is defined as the ratio of total number of packets dropped by the router over the total number of packets.

VI. IMPLEMENTATION(Observations and Reasons)

The source node generates Poisson traffic, with average rate of 1125 packets per second. To handle the traffic, router has two queues, one having a higher priority than the other. It also keeps track the largest sequence number(say N) it has seen so far. If the sequence number of the incoming packet is larger than ‘N’, we call the incoming packet an in-order packet and update the ‘N’ as the same as the sequence number of the incoming packet. Otherwise, the incoming packet is considered out-of-order. When a packet arrives, if the router is idle, the router transmits the packet immediately. Otherwise, the packet will be put into the low priority queue if it is an in-order packet and will be put into the high priority queue if it is an out-of-order packet. We assume non-preemptive scheduling (i.e., when the router starts transmission a lower-priority packet, the transmission cannot be interrupted even if a higher-priority packet arrivals.) and work conserving (i.e., the router cannot be idle if there are packets waiting in the queues). Nevertheless, when the router finishes transmission of a packet, it always serves the high priority queue first if there are packets in that queue.

For single queue

seed	average drop rate	average out of order rate	average delay	server utilization
9439	0.536	0.536	17.168	0.732
6500	0.538	0.814	17.273	0.729
7853	0.534	0.816	17.193	0.727
1234	0.534	0.814	17.303	0.727
3432	0.536	0.815	17.254	0.731

For priority queue

seed	average drop rate	average out of order rate	average delay	server utilization
9439	0.352926	0.815979	15.88947	0.7287
6500	0.353	0.8147	15.879	0.729
7853	0.3514	0.8167	15.81	0.7271
1234	0.349	0.814	15.912	0.727
3432	0.352	0.815	15.89	0.731

The results obtained from the simulation on each queue are depicted in the table above. It can be noticed that **'average drop rate'** for single queue is around 0.5 and for priority queue is around 0.3. We can say that there is a significant difference in the average drop rate or packet loss rate between single queue and priority queue, suggesting that the priority queue has a upper hand over single queue in terms of packet loss. Also, if we consider other parameter like **'average delay'** then we can clearly observe that the priority queue is performing better than the single FIFO queue in terms of the delay each packet experienced during the transmission, which is around 17 seconds for single queue and 15 seconds for priority queue. Parameters like '**average out of order rate'** and **'server utilization'** are almost same for both the models, this is because queue has so control over these parameters whatsoever(in this case).

- **Calculations by changing the values of x(mean) and y(standard deviation).**
  Seed=1234

<u>Average delay for Single queue</u>

sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	17.156	17.165	17.255	18.154	27.145
0.01	17.157	17.160	17.250	18.149	27.140
0.1	10.639	17.160	17.176	18.056	27.047
1	17.171	17.171	17.173	17.278	25.97
10	16.176	16.176	16.167	16.062	15.955

Average out of order rate for Single queue

sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	0.338	0.391	0.391	0.391	0.390
0.01	0.472	0.732	0.851	0.851	0.851
0.1	0.492	0.531	0.828	0.978	0.978
1	0.496	0.499	0.533	0.835	0.997
10	0.454	0.455	0.458	0.490	0.794

Average drop rate for Single queue

sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	0.536	0.536	0.536	0.536	0.536
0.01	0.536	0.536	0.536	0.536	0.536
0.1	0.347	0.536	0.535	0.535	0.535
1	0.532	0.532	0.532	0.526	0.524
10	0.494	0.494	0.493	0.487	0.415

Average delay for Priority queue

Sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	4.132	6.710	6.800	7.699	16.690
0.01	9.961	14.984	16.268	17.167	26.158
0.1	10.639	11.547	16.054	18.057	27.048
1	10.914	10.994	11.881	16.316	26.137
10	11.983	11.990	12.059	12.720	16.276

Average out of order rate for Priority queue

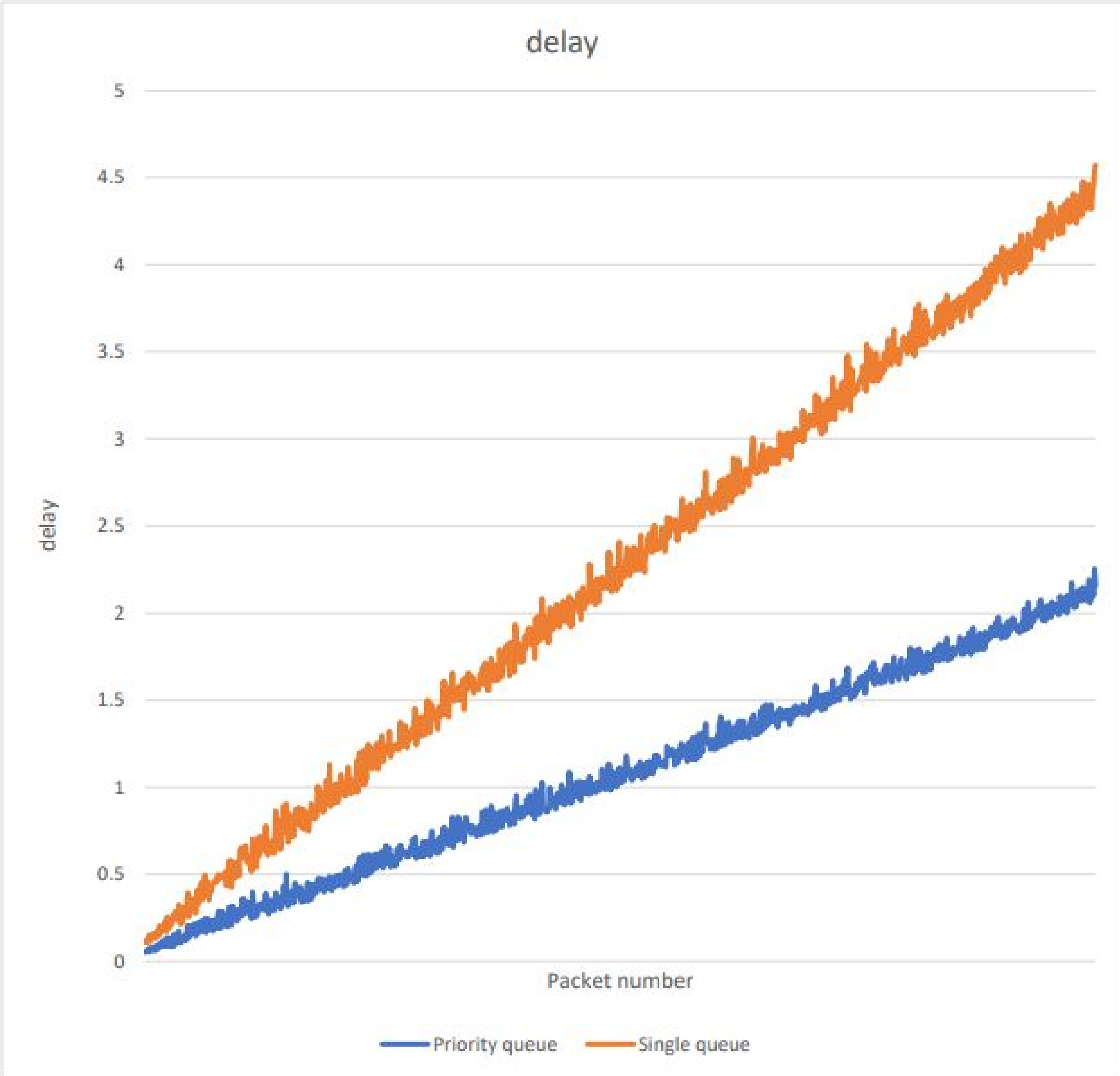
sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	0.333	0.382	0.382	0.382	0.382
0.01	0.468	0.729	0.844	0.844	0.844
0.1	0.492	0.528	0.827	0.976	0.976
1	0.491	0.495	0.531	0.835	0.995
10	0.451	0.451	0.454	0.489	0.794

Average drop rate for Priority queue

sigma	Mean=0.001	Mean=0.01	Mean=0.1	Mean=1	Mean=10
0.001	0.480	0.431	0.431	0.431	0.431
0.01	0.348	0.348	0.379	0.379	0.379
0.1	0.347	0.347	0.361	0.509	0.509
1	0.343	0.343	0.342	0.362	0.520
10	0.321	0.321	0.318	0.282	0.237

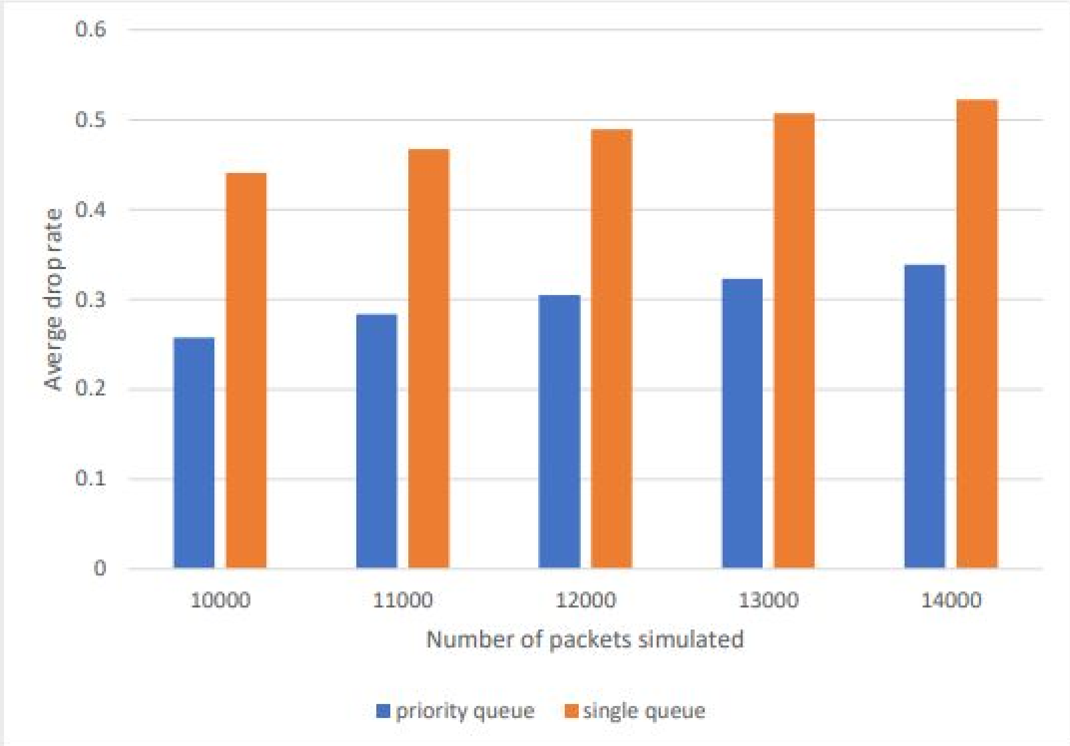
The results obtained from the simulation on each queue by changing the values of **x**(mean) and **y**(standard deviation) are depicted in the tables above. It can be noticed that **'average drop rate'** for single queue is much more than the priority queue. We can say that there is a significant difference in the average drop rate or packet loss rate between single queue and priority queue model, suggesting that the priority queue model has a upper hand over single queue in terms of packet loss. Also, if we consider other parameter like **'average delay'** then we can clearly observe that the priority queue is performing better than the single FIFO queue in terms of the delay each packet experienced during the transmission, which is around 17 seconds for single queue and 15 seconds for priority queue. Parameters like '**average out of order rate'** is almost same for both the models.

<u>Graph: Plotted between Number of packets and Average delay(in seconds)</u>



Here, we have prepared a graph for **data visualization**, average packet delay is defined as sum of the end-to-end delay of all packets divided by the total number of packets. From graph, we can clearly depict that the **average delay**(end to end delay) that a packet experienced during transmission is quite less in the model with priority queue than the model with single FIFO queue. The orange spikes on the above graph represents the delay values for the single queue model and the blue spikes in the above graph represents the delay values for priority queue model.

<u>Bar Graph: Plotted between the Average drop rate & Number of packets</u>



Here, we have prepared this bar graph for data visualization, **average packet loss rate** is defined as the ratio of total number of packets dropped by the router over the total number of packets. From graph, we can clearly depict that the average number of packets lost during overall transmission is quite less in the model with priority queue than the model with single FIFO queue. The orange bar on the above graph represents the average drop rate for the single queue model and the blue bar in the above graph represents the drop rate for priority queue model.

VII. CONFIDENCE INTERVALS

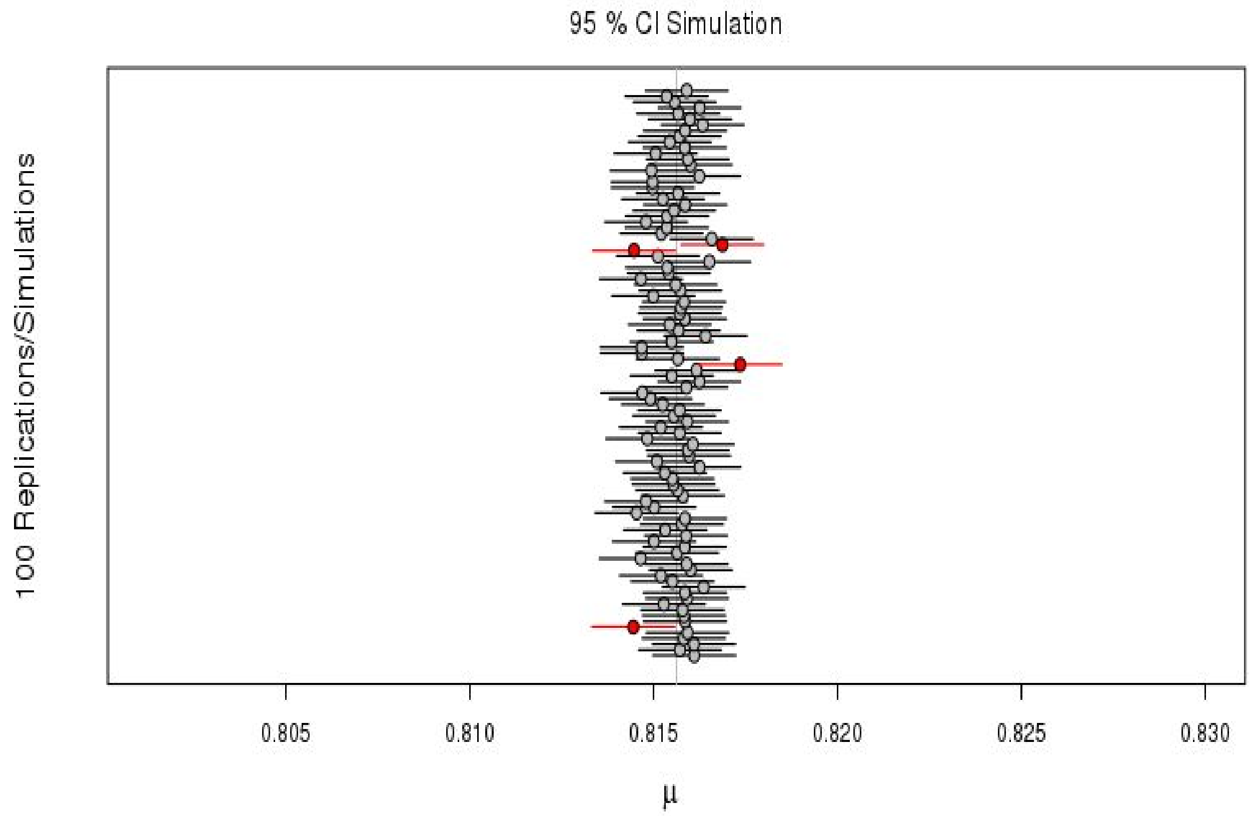
Statistical inference is the process of analysing sample data to gain insight into the population from which the data was collected and to investigate differences between data samples. In data analysis, we are often interested in the characteristics of some large population but collecting data on the entire population may be infeasible. For example, leading up to U.S. presidential elections it could be very useful to know the political leanings of every single eligible voter, but surveying every voter is not feasible.

Instead, we could poll some subset of the population, such as a thousand registered voters, and use that data to make inferences about the population as a whole.

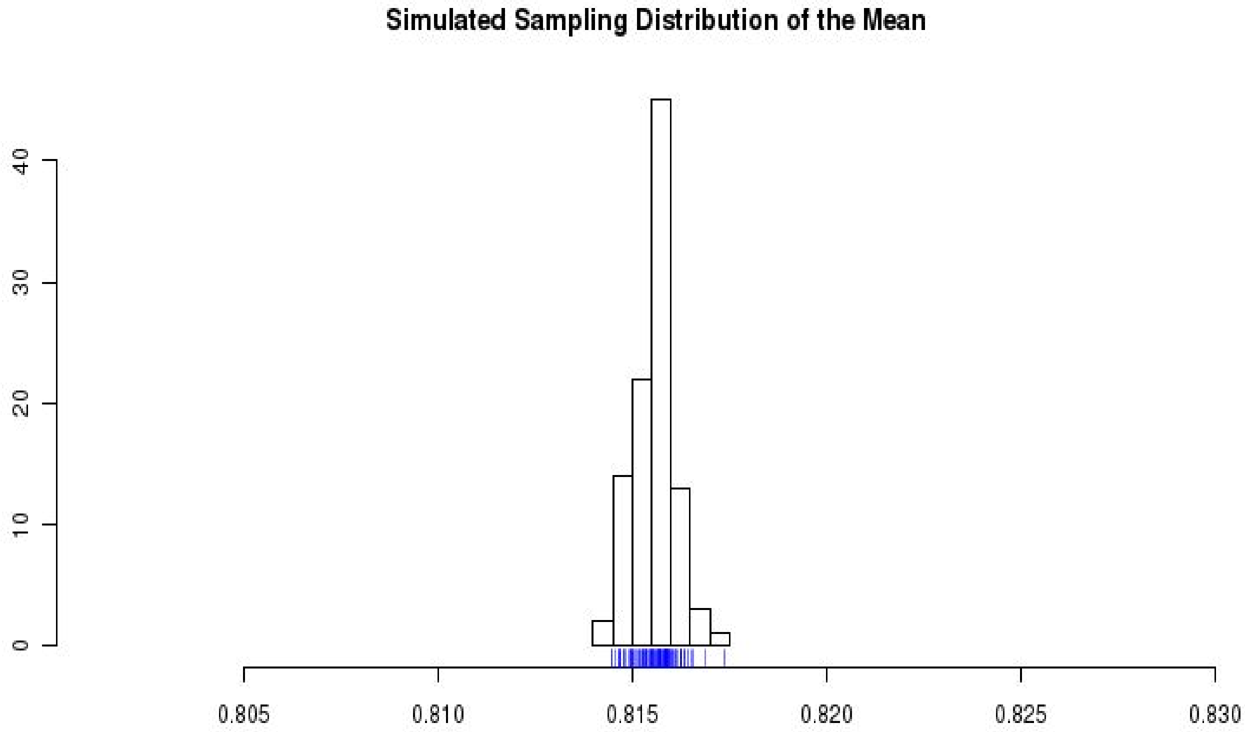
Average out of order rate per interval

interval	seed = 9439	seeed=6500	seed=7853	seed=1234	seed=3432
1	0.81929841	0.81175492	0.81699962	0.81395135	0.817878
2	0.81935484	0.81476122	0.81909594	0.80969212	0.815107
3	0.81383473	0.81293175	0.8145851	0.82011478	0.818766
4	0.81486274	0.82007049	0.81929727	0.81332206	0.814839
5	0.81254052	0.81400376	0.81384644	0.81676903	0.813005

We can be 95% confident that the population mean (μ) falls between **0.81442168** and **0.81683232.**



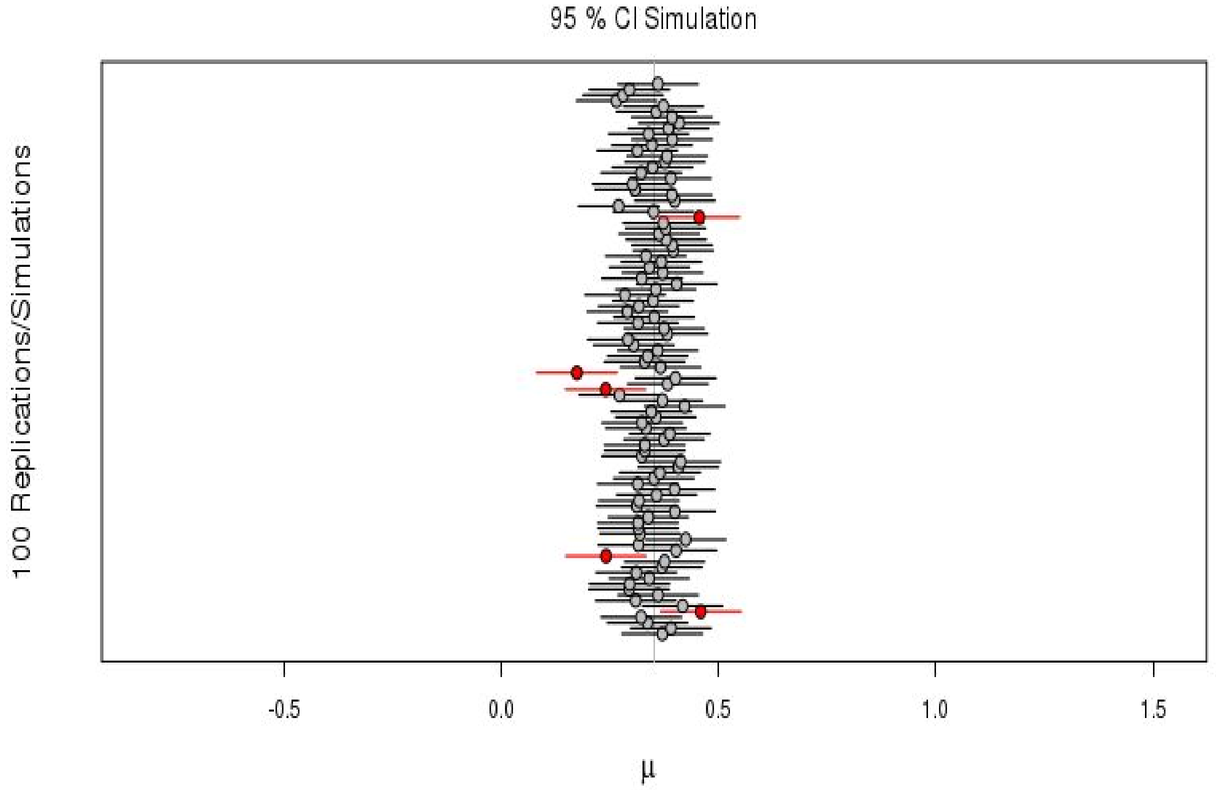
We are 95% confident that the population mean (μ) falls between **0.25540763** and **0.44966837**.

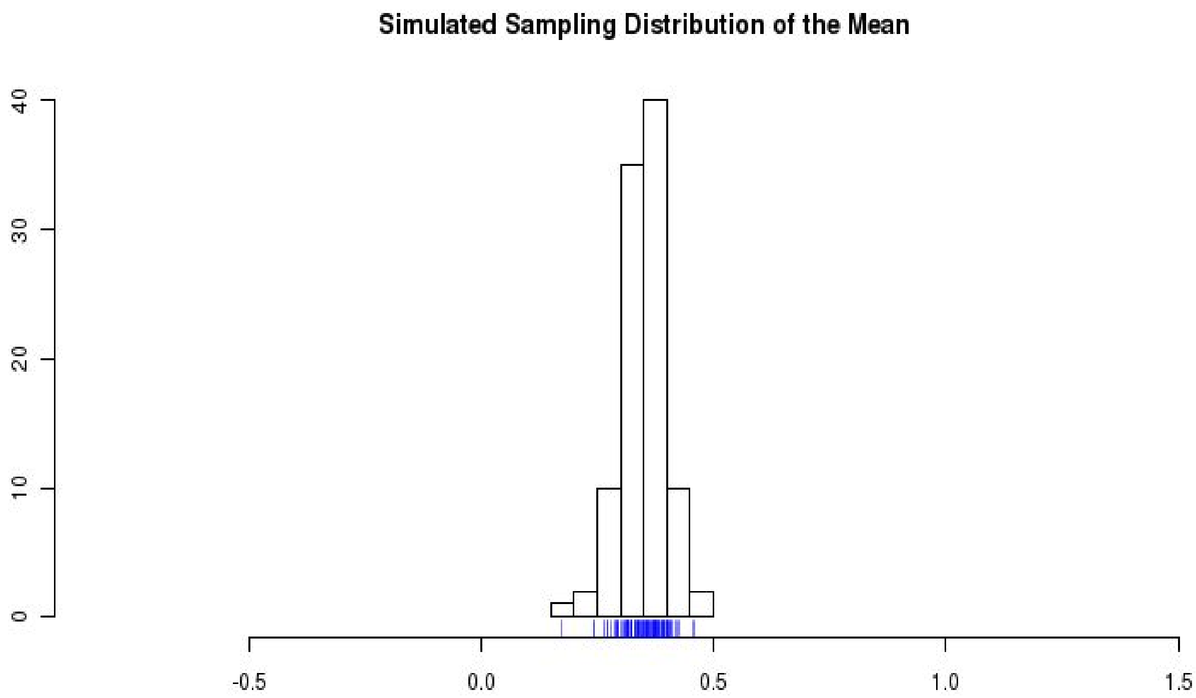


Average drop rate per interval

interval	seed = 9439	seeed=6500	seed=7853	seed=1234	seed=3432
1	0	0	0	0	0
2	0.1564977	0.16217438	0.14345018	0.14687006	0.155926
3	0.53528319	0.53661232	0.53265671	0.5378681	0.539228
4	0.53757279	0.54182897	0.54043503	0.53147313	0.536261
5	0.53468556	0.53505639	0.53765421	0.53759538	0.534324

We are 95% confident that the population mean (μ) falls between **0.25540763** and **0.44966837**.


95 % CI Simulation
100 Replications/Simulations
-0.5
0.0
0.5
1.0
1.5
μ


Simulated Sampling Distribution of the Mean
0
10
20
30
40
-0.5
0.0
0.5
1.0
1.5

VIII. CONCLUSION

We can conclude from the above analysis and calculations that there is a benefit of using priority queueing in the intermediate routers to alleviate the packet re-ordering problem. It can be noticed that there is a significant difference in the average drop rate or packet loss rate between single queue model and priority queue model, suggesting that the priority queue model has a upper hand over single queue model. Also, if we consider other parameter like ‘average delay’ then we can clearly observe that the priority queue is performing better than the single FIFO queue in terms of the delay each packet experienced during the transmission. Though parameters like ‘average out of order rate’ and ‘server utilization’ are same for both the models. We can clearly state that the use of priority queue in the intermediate router can solve the packet re-ordering problem and is definitely better than the model with router having a only FIFO queue.