COMPARISON OF NETWORK PERFORMANCES FOR QUEUING DISCIPLINES IN A MULTIPLE LINK, SHARING A BUFFER AND IMPACT OF ADAPTIVE QUEUING

A. BRIEF DESCRIPTION

This project report explores the performance of different queuing disciplines in a complex networking scenario where multiple links converge to share a common buffer. The study goes beyond traditional queuing analyses by introducing the concept of "adaptive queuing" and compares with the non-adaptive queuing disciplines.

B. MOTIVATION

- In the previous learning period, as part of our assignment, we have proposed a network architecture for a Small Medium Enterprise, keeping in mind about the capacity of the links, and future scaling needs.
- In LAN networks like a Small Medium Enterprise, Multiple department devices share a common network segment like router and switch. These devices generate data traffic that needs to be managed as it moves through the LAN, with an aggregation of data packets from different links fed into the single buffer.
- Thereby, the thought of "Multiple Links Single Buffer" shown in Fig. 1 has emerged from our concept of central router is connecting to multiple departments with the help of links in an SME.

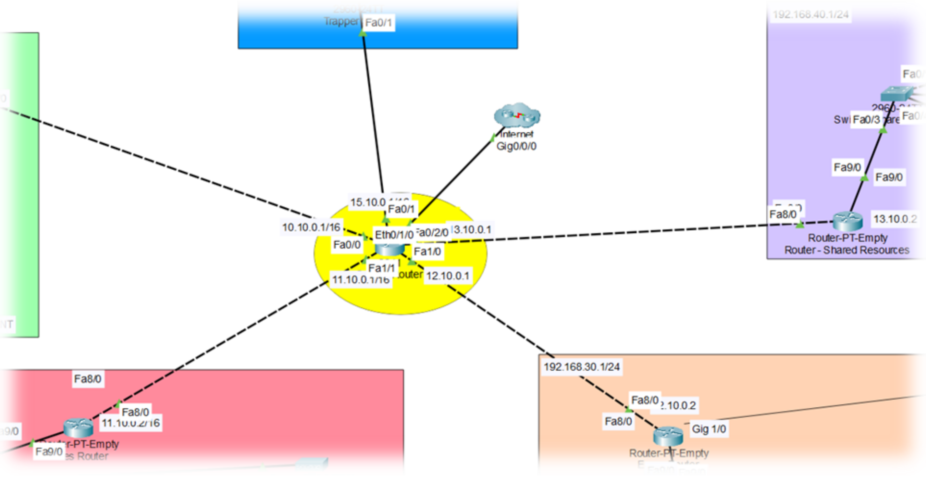


Fig. 1. The Buffer Network Element - central router, connecting different departments in SME.

C. WHAT ARE WE CURIOUS TO FIND, UNDERSTAND AND INVESTIGATE?

- Observation of different points of view i.e., from buffer and links.
- (In either of the network elements – Buffers and Links) Impact of
    - multiple parallel arrival sources with a shared queue.

- Scheduling policies or queuing disciplines in buffers and links.
- Adaptive queuing in different queuing disciplines

- Performance metrics of the above observations.

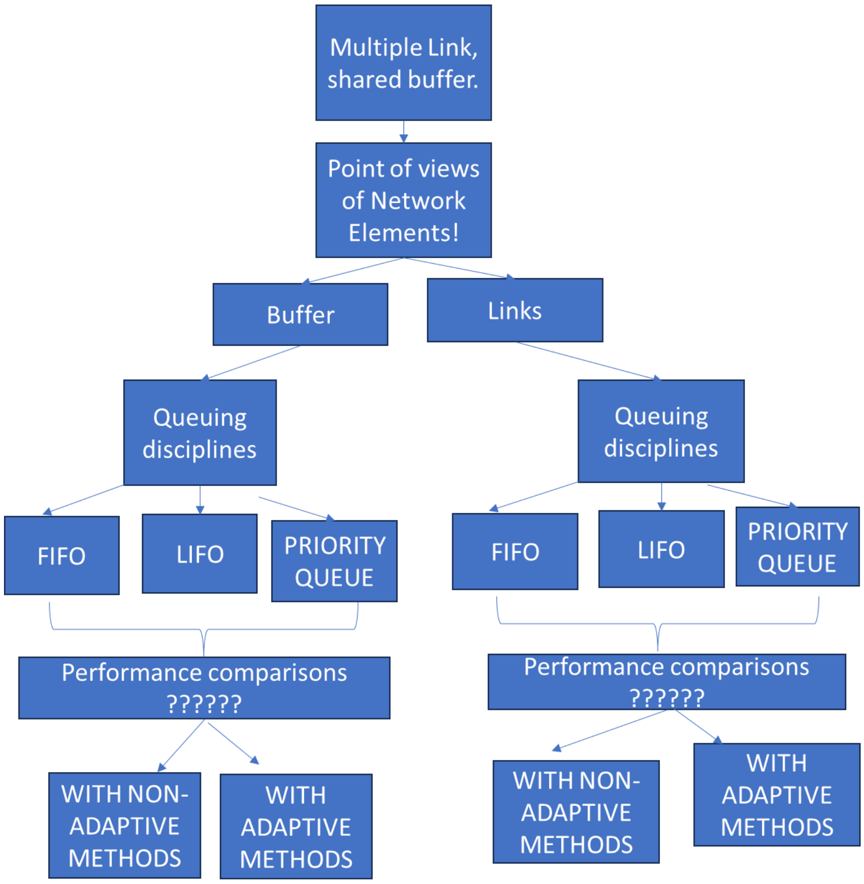


Fig. 2. Brief Flowchart of the project investigations

D. WHAT KIND OF SYSTEM IS OURS? 2 VIEWS!

1) Buffer - Point of view - M/M/1:SP (Scheduling Policy)
2) SP's OBSERVED IN LINKS POINT OF VIEW with M/M/1 buffer.

We considered SP --> Scheduling Policies on links and in the buffer. FIFO, LIFO, Priority.
Kendal's or Erlang Notation:
A/B/S/K: SP where

- A refers to the packet arrival process, i.e., the interarrival time distribution for that process.
- B refers to the packet service process i.e., the interservice time distribution for that process.
- S refers to the number of servers (i.e. transmitters or processors).
- K refers to the total number of packets that can be stored in the queueing system, including those in the buffer and those in service.

1. POINT OF VIEW – BUFFER

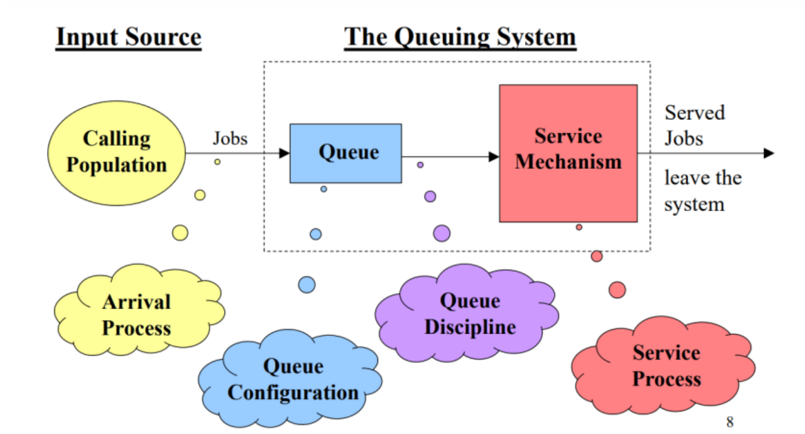


Fig. 3. Queuing system showing queuing mechanisms inside the buffer.

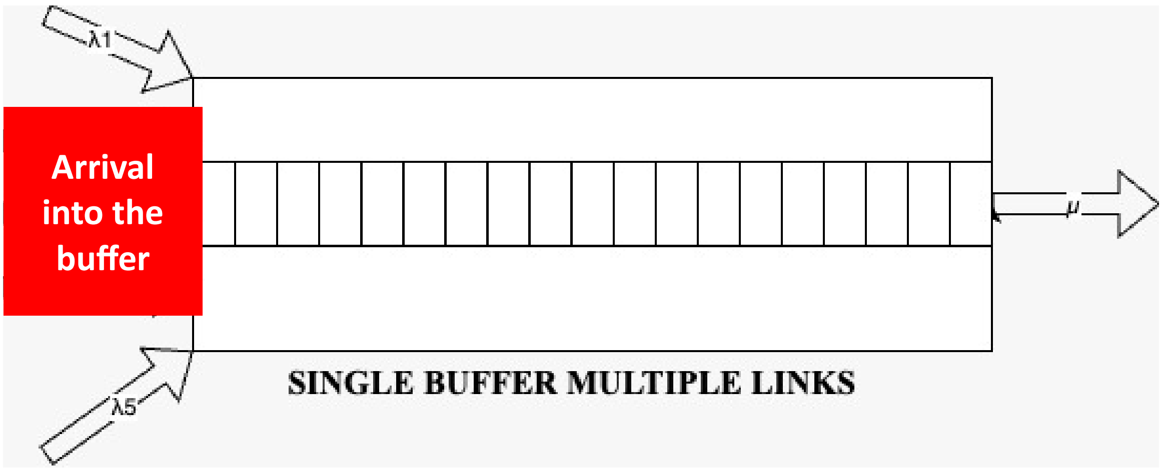


Fig. 4. Another illustration showing arrivals into the buffer with 2 different arrival rates, departing the buffer with a single service rate of "μ"

1.1 FIFO / FCFS – First Come First Serve

During the event of departure, the foremost packet queued is dequeued and the observation of packet delay in such case is plotted w.r.t the 2 links' arrival rates. The mechanism is illustrated in the Fig.5 below.

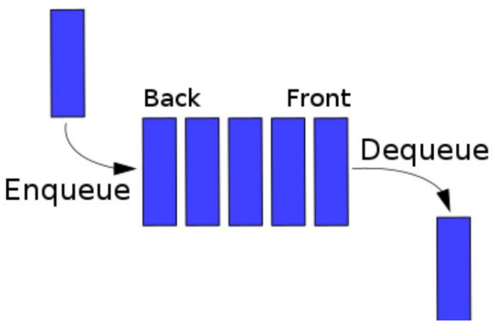


Fig. 5. Mechanism of FCFS

Considering M/M/1 buffer follows FCFS, while dimensioning the different arrival rates from different links, the packet delay is observed as follows, whilst the packet loss was almost neglible.

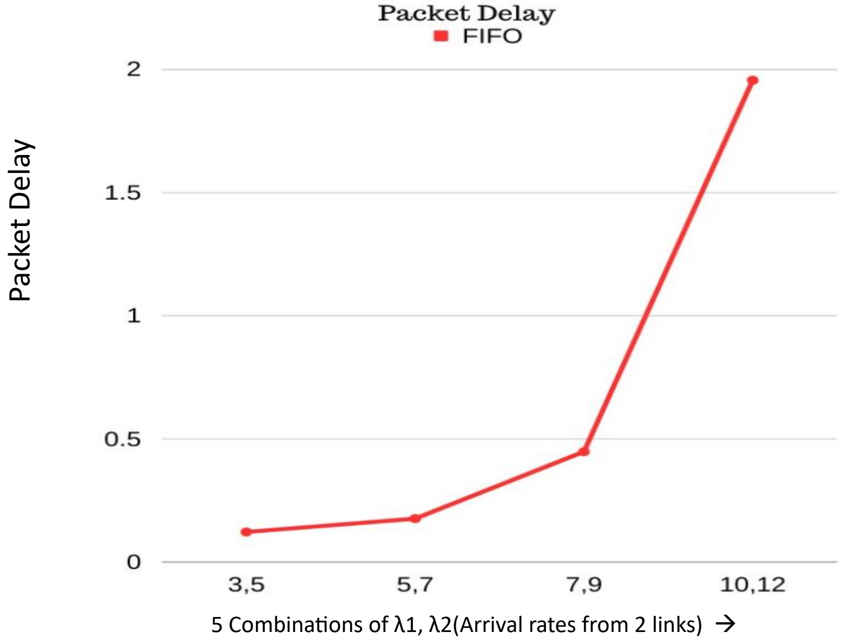


Fig. 6. Packet Delay observed in a buffer with FCFS

From the graph, we can say that as the arrival rate increases there is a significant growth in the packet delay which can be backed by the reasoning that as the arrival rate increases the inter-arrival time decreases with the service rate being constant the load on the system increases there by the packet delay also increases.

1.2. LIFO – Last In First Out

During the event of departure, the latest packet queued is dequeued and the observation of packet delay in such case is plotted w.r.t the 2 links' arrival rates.

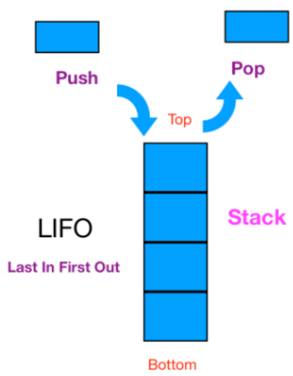


Fig. 7. LIFO Mechanism

Considering M/M/1 buffer follows FCFS, while dimensioning the different arrival rates from different links, the packet delay is observed as follows, whilst the packet loss was almost neglible.

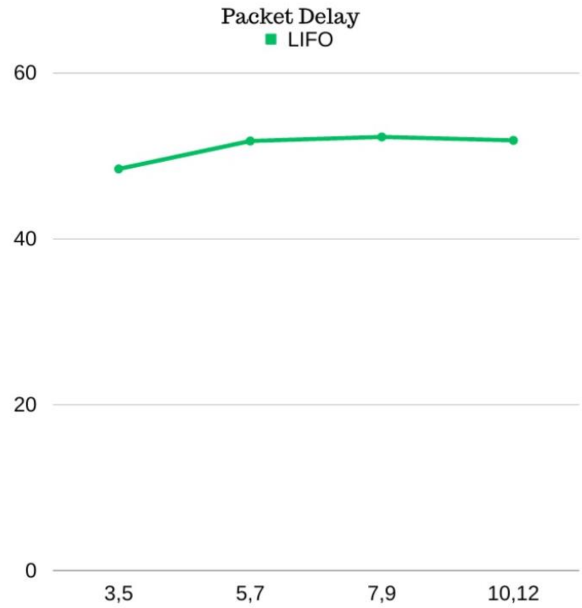


Fig. Packet Delay Observed in a buffer with queuing discipline LIFO

In the LIFO scheduling principle it is observed that the packet delay increases with an increase in arrival rates but another observation here is that even for the lower values of arrival rates the packet delay is high which is due to the scheduling principle which servers the latest packets first.

1.3. PRIORITY BASED

This case is like a VIP customer who has the highest priority which is a packet in our case and is served first, irrespective of time of arrival or position in buffer.

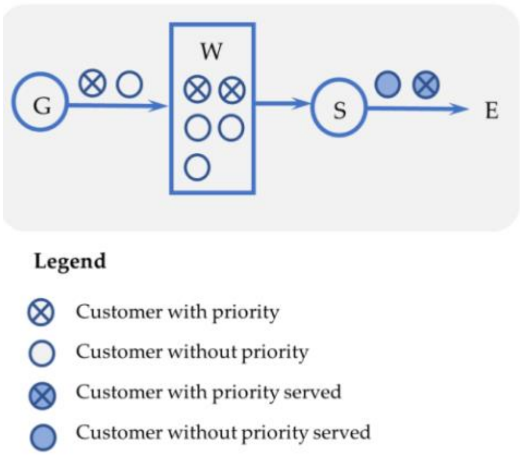


Fig. 8. Priority Based Queuing Mechanism

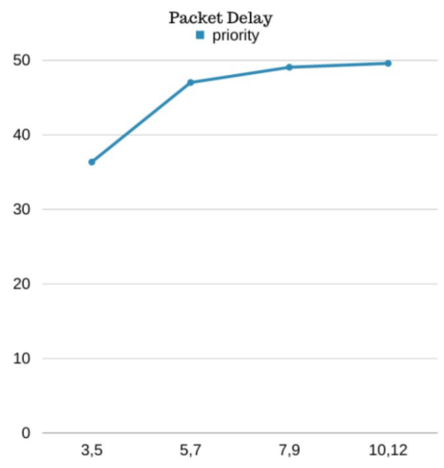


Fig. 9. Packet Delay observed in a buffering implementing Priority Based Queuing

The behaviour of priority-based queuing is observed to be similar to that of LIFO queuing i.e. the packet delay increases as the values of arrival rates increase and the packet delay for the least lambda is also observed to be higher.

1.4. AGGREGATE OBSERVATIONS

Without any adaptive nature, the LIFO makes more packets to wait in the buffer increasing the packet delay. Similarly in the case of priority packets with high priority only are getting served, making the packets in the queue to be in delay. The graph below illustrates our observation along with their means, variances and standard deviations observed.

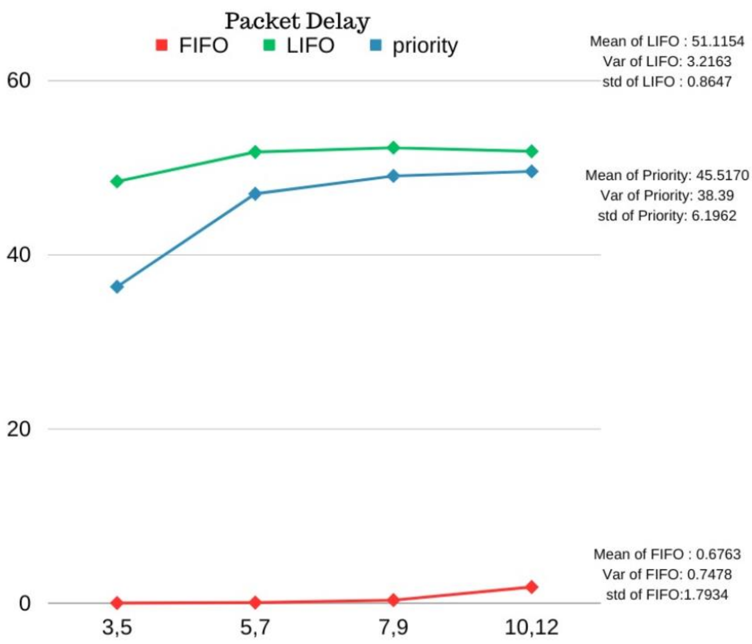


Fig. 10. Aggregate Packet Delays observed in Non - Adaptive Scheduling Polici**es.**

1.5. ADAPTIVE QUEUING - Thresholding

When the system load becomes greater than 1, there is a need for us to keep the system stable, may be by adopting the adaptive techniques.

$$\rho = \frac{\lambda}{\mu}$$

ρ, is dependent on interarrival rate λ and service rate μ. We can reduce ρ by increasing the service rate or reducing the arrival rate. Usually increasing the service is the most commonly used methodology, hence, we have gone for manipulating with the arrival rates of the packets.

For unstable cases of load > 1, we have chosen the method of dynamically changing the arrival rate of packets into the queue, for **a threshold of 0.4 to 0.9 as minimum and maximum utilisation factors**. In this case, if the load > 1, the reduction of arrival rates happens, at the same time if the utilisation factor falls below 0.2, we are increasing the arrival rates of the packets, by not keeping the buffer server to be idle.

It is like, when there are more people or customers to be served in the queue, we would lessen the rate of arrival(Eg. by stopping the customers for a period of time let's say) of the customers to enter into the queue to take the service. Otherwise, if there are less number of customers in the queue but the capacity of the service is 90%, since we do not want the cashier or the service provider to sip a coffee or be idle for a long time, we henceforth, increase the arrival rate of the customers by allowing more of them into the queue to take the service.

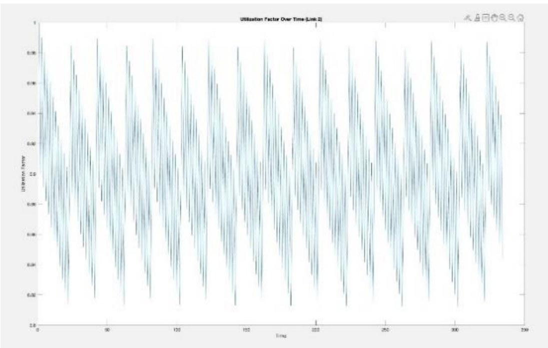


Fig. 11.1 Initial λ value of link = 9

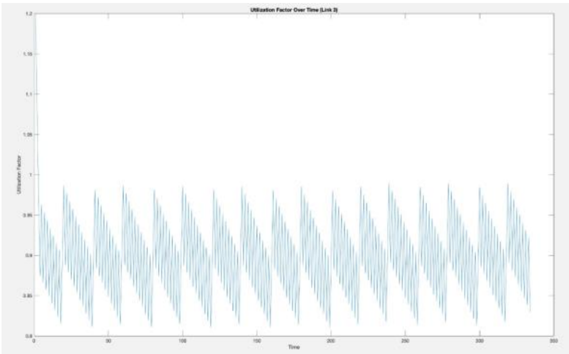


Fig. 11.2 Initial λ value of link = 12

Fig. 11. Figures showing the fluctuations of Utilisation Factor between 0.4 and 0.9 as the dynamic arrival rates of the packets in the adaptive queuing have been used.

DISCIPLINE	FIFO		LIFO		PRIO	
	Packet Loss	Packet Delay	Packet Loss	Packet Delay	Packet Loss	Packet Delay
Adaptive	479	0.5404	1137	55.87847	226	39.7004
Non-Adaptive	899	0.67238	899	52.0677	899	43.83124

Table 1. Comparisons of Adaptive and Non-adaptive Queuing mechanisms in the buffer (Buffer POV)

2. SCHEDULING POLICIES IN THE POINT OF VIEW OF LINKS

Now we consider the case:

- Shared buffer with combined capacity for all links

Instead of the buffer, we are interested in how the links make a difference following the scheduling policies to the buffer and were interested in finding the packet loss and packet delay from the link's point of view.

- Here the arrival rate values are taken as 5,7,9,10 and 12 respectively for each link with a common service rate of 10.

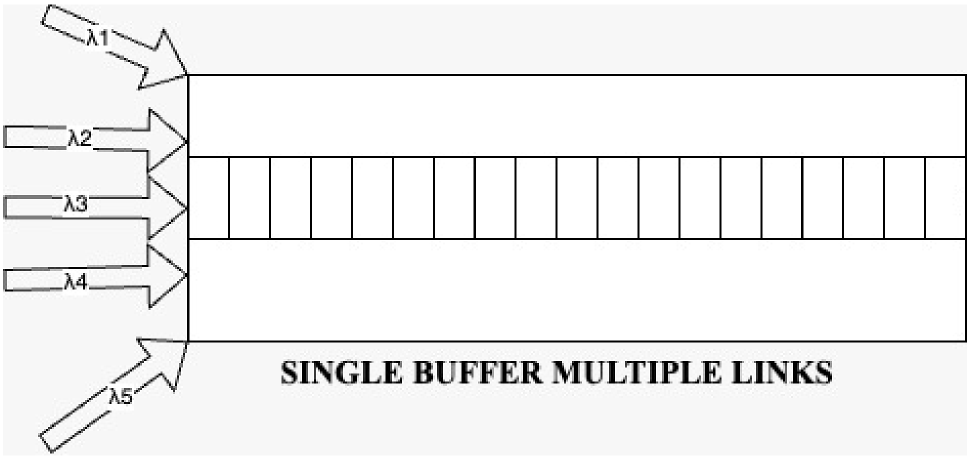


Fig. 12. Five different links following scheduling mechanisms with a shared buffer

2.1. ARRIVALS INTO THE SHARED BUFFER FROM ALL THE LINKS WITH A COMBINED CAPACITY

- Methods simulated for: FIFO, LIFO & Priority (ADAPTIVE & NON-ADAPTIVE)

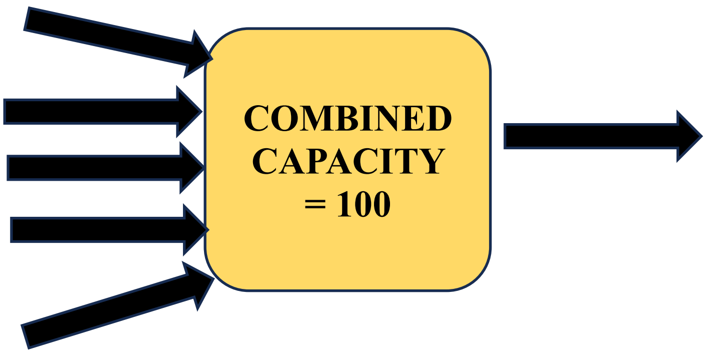


Fig. 13. Different arrival rates from 5 different links with a combined buffer capacity of 100 units.

2.1.1. FIFO – Non-Adaptive

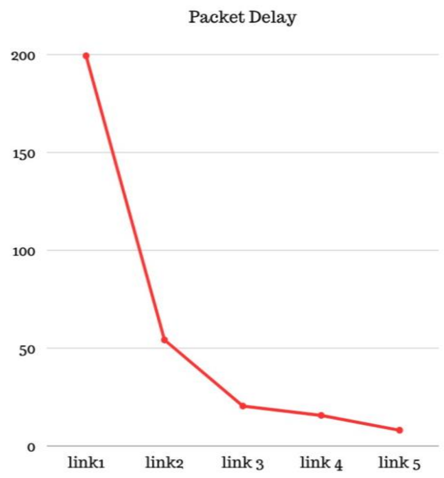


Fig. 14. Packet Delay observed when links had FIFO mechanism

Here the arrival rate values are taken as 5,7,9,10 and 12 respectively for each link with a common service rate of 10.

For 50 iterations, the mean value of the packet delays have been calculated for each link and plotted.

This result is a bit surprising as the arrival rates of the packets increase the Packet delay is decreased but theoretically, it must imply the reverse.

2.1.2. LIFO – Non-Adaptive

Here the arrival rate values are taken as 5,7,9,10 and 12 respectively for each link with a common service rate of 10.

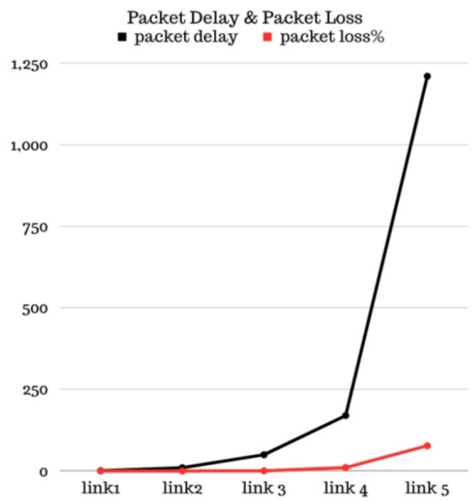


Fig. 15. Packet Delay observed when links had LIFO scheduling policy.

(In the above figure the last two values are scaled by a factor 1/100 to have clarity in the graphs)

The packet loss and packet delay increased for the increased value of lambda of the links. The values plotted are again for the mean values of 50 iterations.

As the arrival rates increase the packet delay and packet loss show a very significant rise and almost go beyond the hand for the unstable case (link 5). This can be backed up conceptually as well.

2.1.3. PRIORITY BASED – Non Adaptive

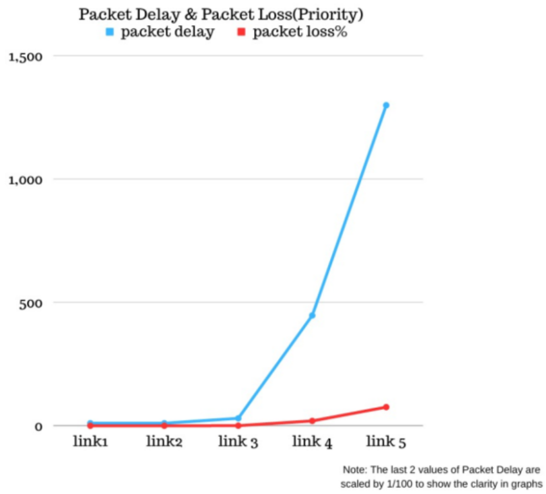


Fig. 15. Packet Delay and Packet loss observation for Non- Adaptive Priority Based.

- Here the arrival rate values are taken as 5,7,9,10 and 12 respectively for each link with a common service rate of 10.

- This case is also very similar to LIFO Non-adaptive queuing as the arrival rates increase the packet delay and packet loss show a very significant rise and almost go beyond the hand for the unstable case (link 5). This can be backed up conceptually as well.

2.1.4. AGGREGATE CONCLUSION FOR NON-ADAPTIVE CASES

- In all the cases of the point of view of Links, the behaviour retained as in the behaviour of buffer point of view, with different scheduling policies except for FIFO(SURPRISING ENOUGH! ☺)
- But the fluctuations of values are evident enough in links POV.

2.2. ADAPTIVE CASE & Comparisons with NON-ADAPTIVE CASE.

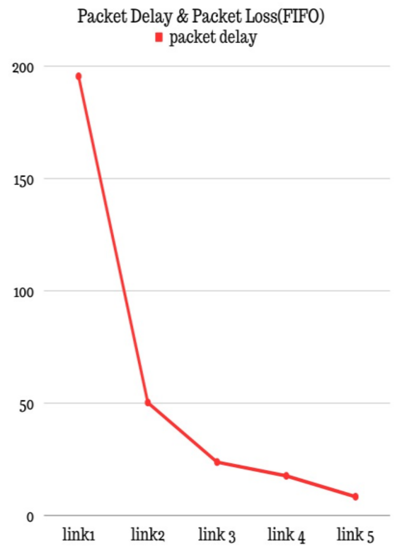


Fig. 16. FIFO – Adaptive (POV: Link)

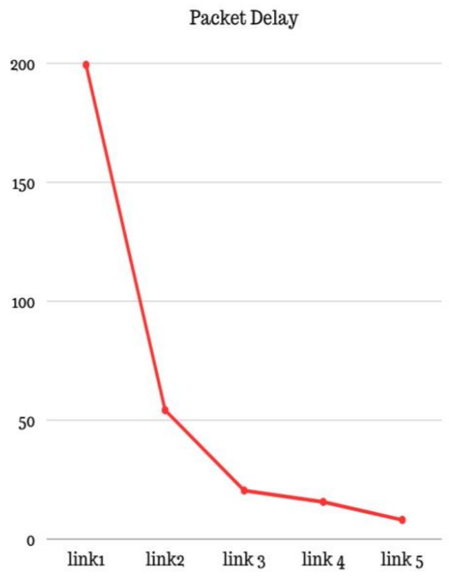


Fig. 17. FIFO – Non -Adaptive.(POV: Link)

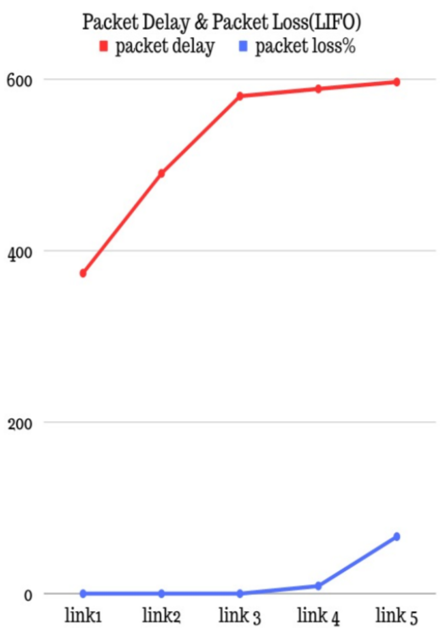


Fig. 18. LIFO – Adaptive(POV: Link)

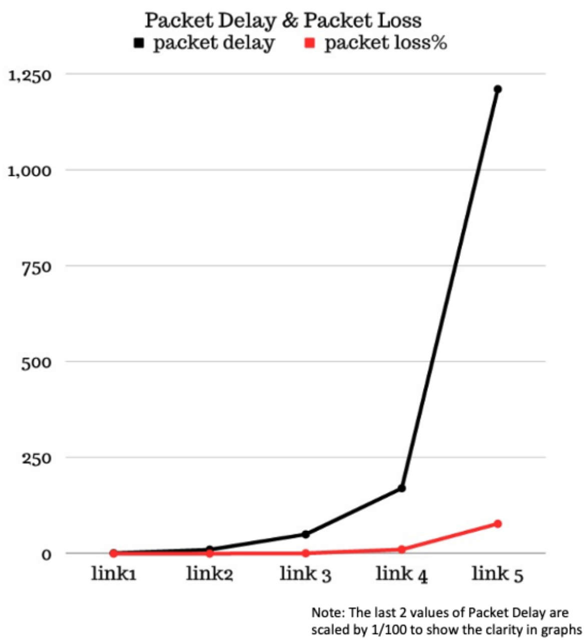
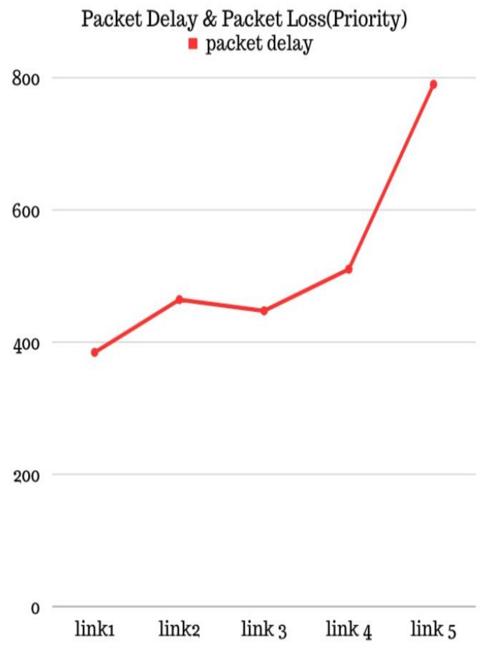


Fig. 19. LIFO – Non Adaptive(POV: Link)



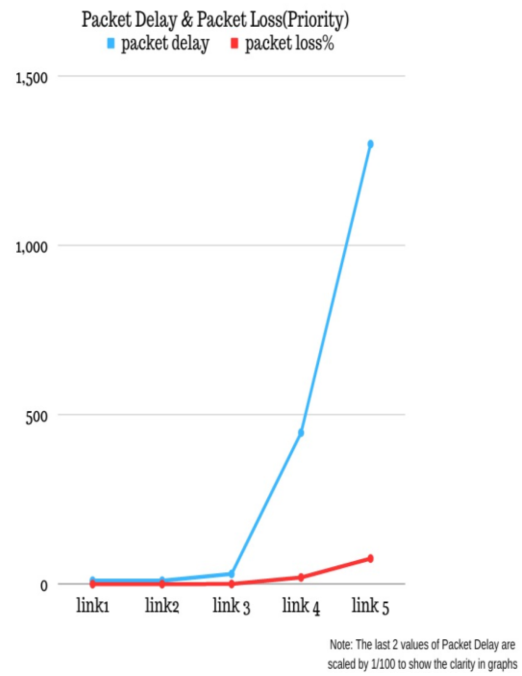


Fig. 20. PRIORITY – Adaptive(POV: Link)   Fig. 21.PRIORITY -Non-Adaptive(POV:Link)

In each and every case of adaptive and non-adaptive, we can clearly conclude that the values of packet delays have decreased and we minimised the packet loss successfully this clearly represents the impact of adaptive queuing as it minimized the packet loss and packet delay.

Through this project, we successfully inferred that in both cases(POV: buffer & Link) adaptive queuing helped in minimizing the packet delay and packet loss given all scheduling policies. Also based on our results of performance metrics i.e. Packet loss and Packet delay we could say FIFO is more efficient than LIFO is more efficient than PRIORITY-based queuing.

References.

1) Queueing Problems with Solutions Collected by: Dr. János Sztrik University of Debrecen, Faculty of Informatics 2021.

2) Analysis of Packet Queueing in Telecommunication Networks.Borris Bellata and Simon Oechsner, Universitat Pompeu Fabra.