Switch Simulation Report

Assignment 2

CS544: Topics in Networks

Group 29

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1. Introduction

Metrics used for performance analysis have been defined below:

Metric	Definition
Average Packet Delay	The number of slots a packet takes starting from the slot it is received into the input buffer of the switch to being transmitted out of an output buffer of the switch. Its value must be **at least 3 slots** as one slot is required for being buffered into the input buffer, the second slot for transfer from the input buffer to its target output buffer, third to transmit out of an output buffer into the medium.
Average Link Utilisation	In one slot in the best case, N packets, one from each input buffer can be transferred to its own output buffer, without any collision. Link utilization is the actual number of packets transmitted from some input to some output port. This definition also holds for KOUQ, if K packets are going to an output port we add K to the numerator.
Drop Packet Ratio	The ratio of packets dropped at any point (buffering, scheduling, etc.) to total packets transmitted or dropped.
KOUQ Drop Probability	The probability per slot that more than K packets were generated for an output port.
Standard Deviation of Packet Delay	Each transmitted packet provides a delay datapoint. We calculate the variance from this series.

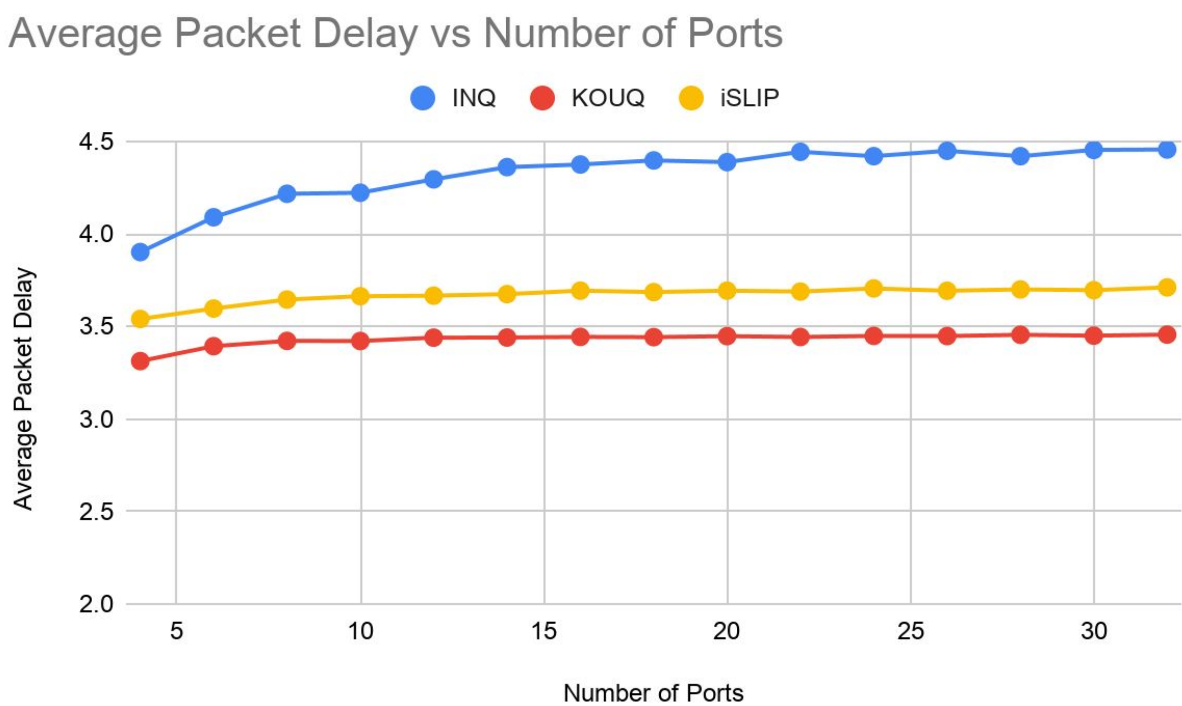
The default values used in the simulation have been listed below:

Parameter	Default Value	Definition
Switch Port Count (N)	8	The number of input ports the same as the number of output ports in our case.
Buffer Size (l)	4	Each port (input/output) has a queue whose maximum size is this buffer size. For INQ and iSLIP only output buffer size 1 is required since at any slot at most one packet can come in an output port. For ISLIP, inside every input port, there are n virtual queues, one for every output port. For these n virtual the buffer size is 4 not 4 * n.
Packet Generation Probability (p)	0.5	The probability that at a given slot, a packet will arrive at an input port.
Knockout Ratio (k) (KOUQ only)	0.6	In one instance of scheduling, a maximum of (k_ratio * n) packets competing for the same output port can all be serviced. This gives enormous flexibility to KOUQ scheduling.
Maximum Time Slots	10,000	The number of slots the simulation runs.

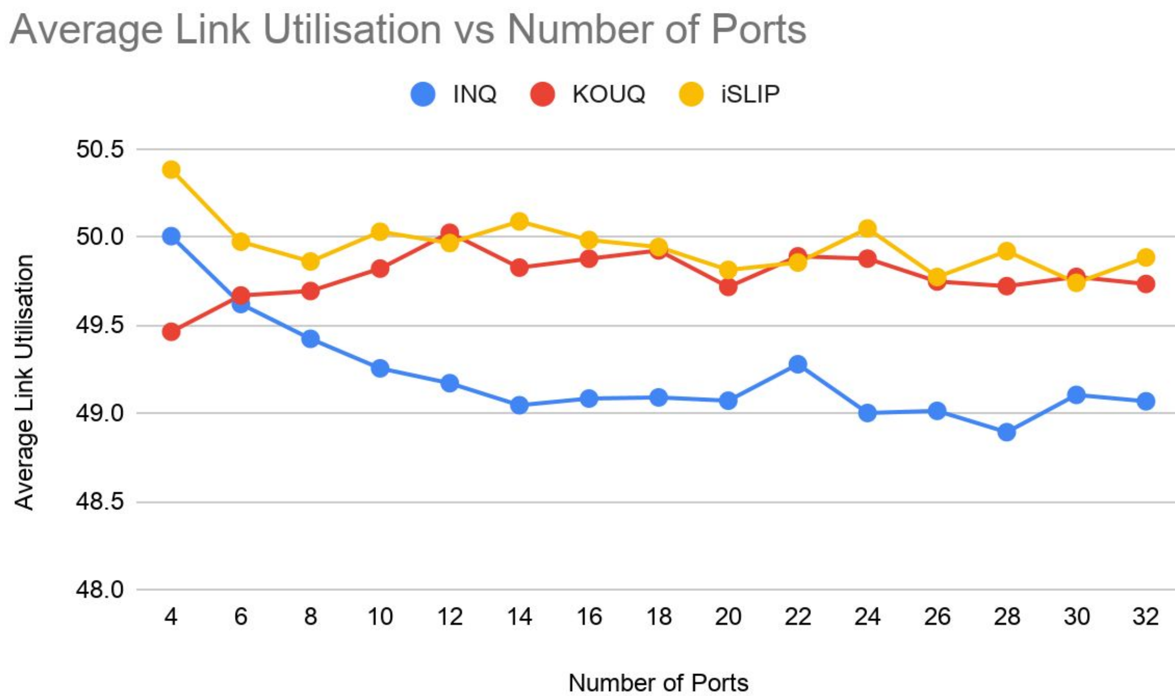
For performance analysis, the following parameters N, l, k, and p have been varied. While varying a parameter, others are kept at their default values to better analyze the impact of that parameter. The following section describes each such change in detail.

2. Varying Number of Ports (N)

N has been varied from 4 to 32 in increments of 2. All other parameters are at their default values as listed in the introduction.



The first graph is for the average packet delay.
KOUQ provides the minimum delay, followed by iSLIP and lastly INQ.
KOUQ scheduling is aggressive in the sense that all packets received in a given time slot either get transmitted to the output port or get dropped instead of being kept in an input buffer to the scheduled slot in the next slot. And since dropped packets do not contribute to the packet delay they cannot increase the delay.
Next is iSLIP in which packets that participate in scheduling can be denied passage for that slot. But, these packets will be considered in the next round and not immediately dropped. Thus they will contribute their increased packet delay, increasing it.
INQ suffers from the most delay since like iSLIP it doesn't drop packets in scheduling. It only gives a valid matching which is not often of the largest size due to HOL blocking.



The observed trend for average link utilization with respect to the number of ports while keeping all other parameters at their default value is given above.

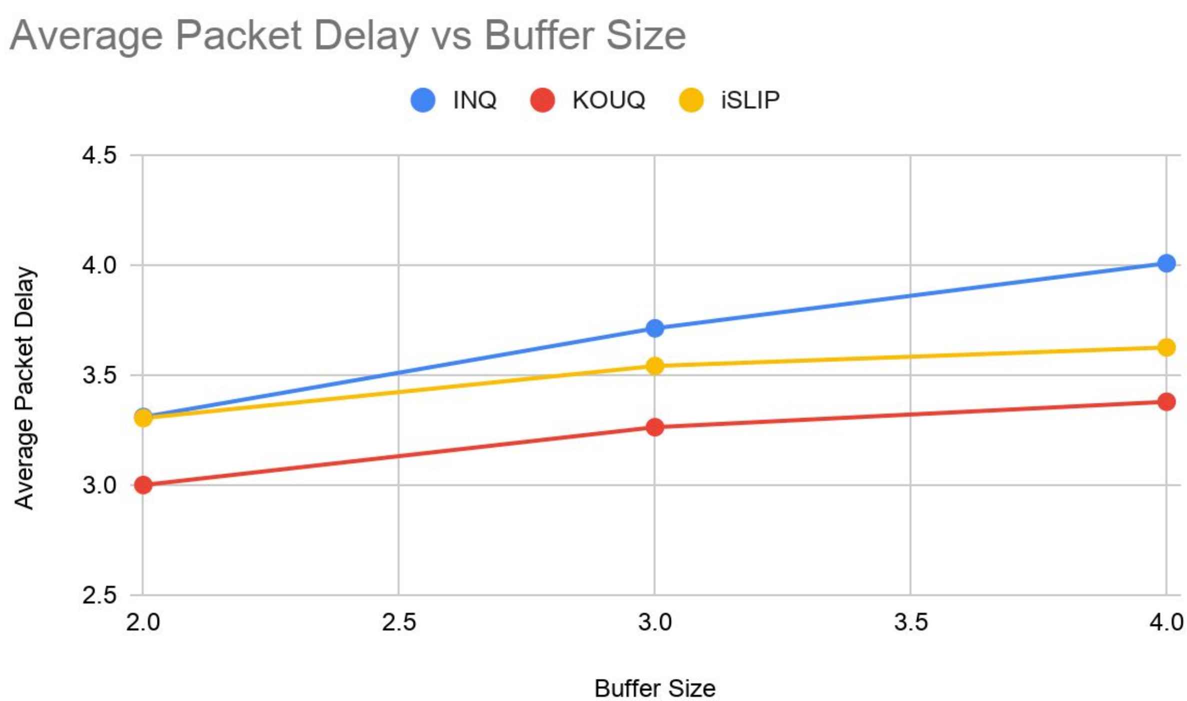
The INQ scheduling suffers from HOL (head of the line) blocking therefore as the number of ports is increased this leads to more packet kept waiting thus the observed trend is decreasing with the least value of link utilization achieved using INQ scheduling.

The KOUQ scheduling in itself is aggressive in nature i.e it either drops the packet or delivers it to the output port, so it is free from HOL blocking, however as the number of ports increases the number of packets that can be delivered to a particular output port increases which are equal to K*n where K is the knockout ratio and n is the number of ports. Therefore we observe there is an increase in link utilization in KOUQ scheduling as the number of ports is increased.

The iSLIP scheduling performs scheduling using a virtual input queue for each output port in every input port, thus it is free of HOL blocking, hence it has the highest link utilization value. However, as the probability of collision increases as the number of packets increases, we observe a slightly decreasing trend of link utilization.

3. Varying Buffer Size (l)

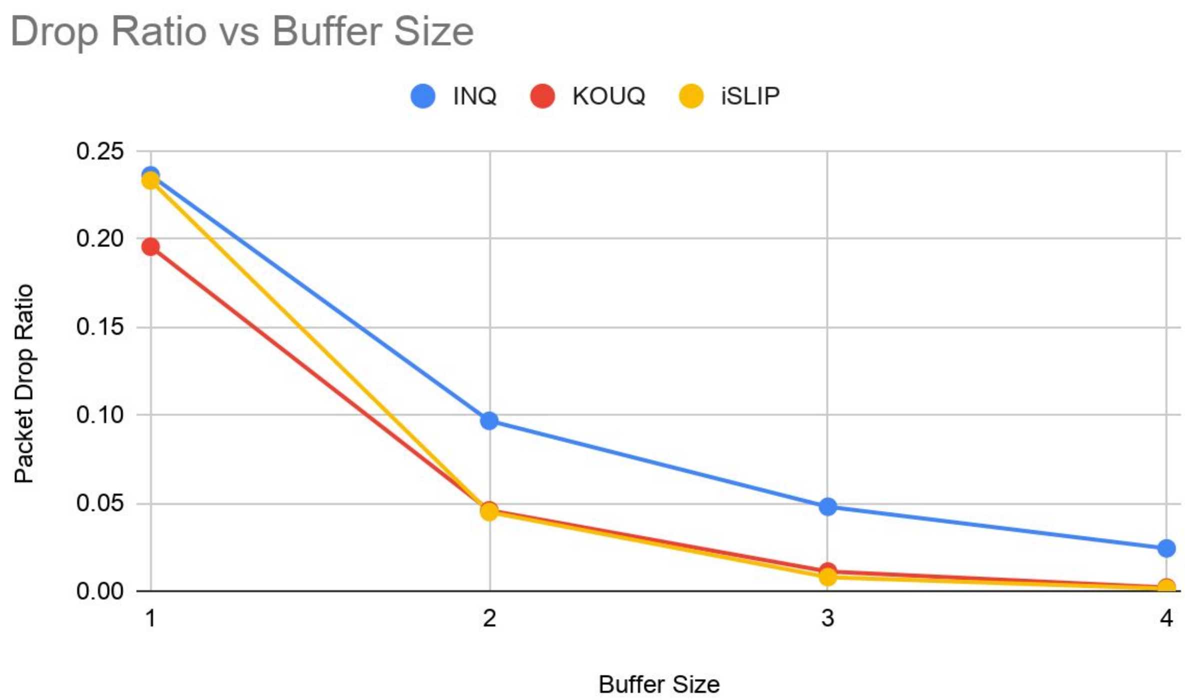
Buffer Size has been varied from 2 to 4 for obtaining results.



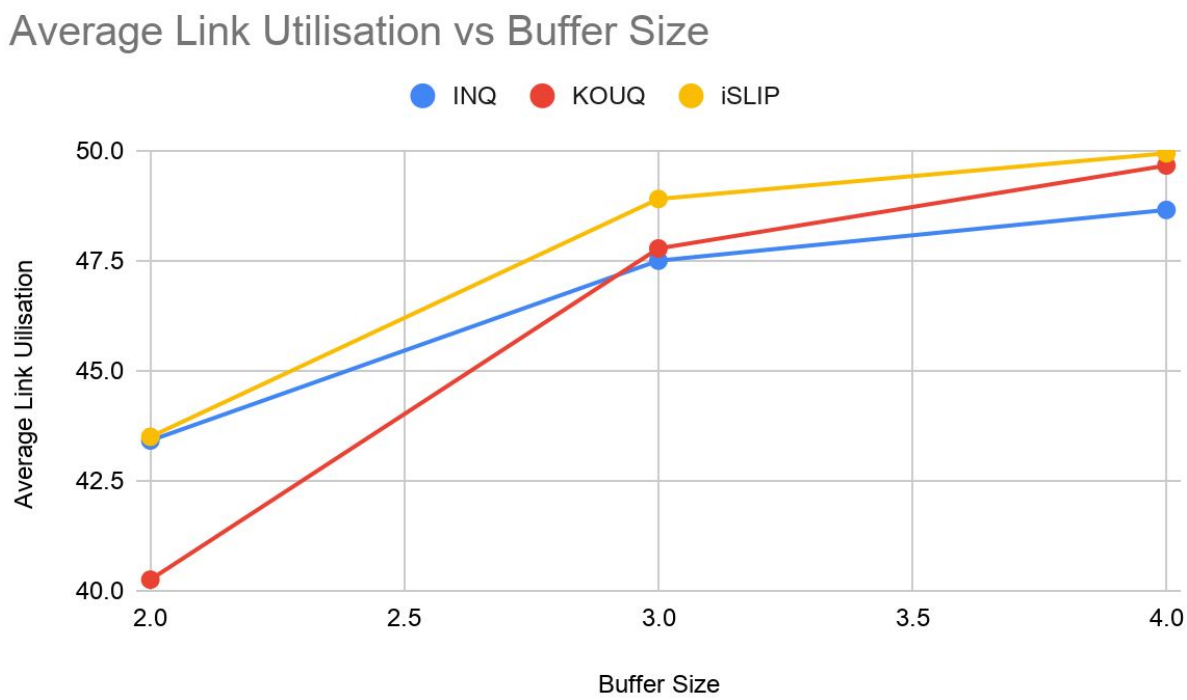
In INQ scheduling as the buffer size is increased the number of packets that are kept waiting for scheduling increases therefore relatively there is more delay in the delivery of packets as can be observed from the observed trend.

In KOUQ scheduling there is no waiting at the input port, however, as the buffer size increases the total number of packets that can be kept waiting in the output queue waiting for transmission increases, therefore, there is an increase in the average delay of packets. Relatively this delay is very less than the HOL blocking which occurs in INQ as well as the collision which leads to delay in iSLIP, hence we observe the average delay is least in KOUQ.

In iSLIP scheduling, a similar argument can be made as to the buffer size increases it means more packets can be accommodated at the input port end and thus this leads to more delay. The delay in iSLIP is comparatively lesser than that of INQ as it does not suffer from HOL blocking.



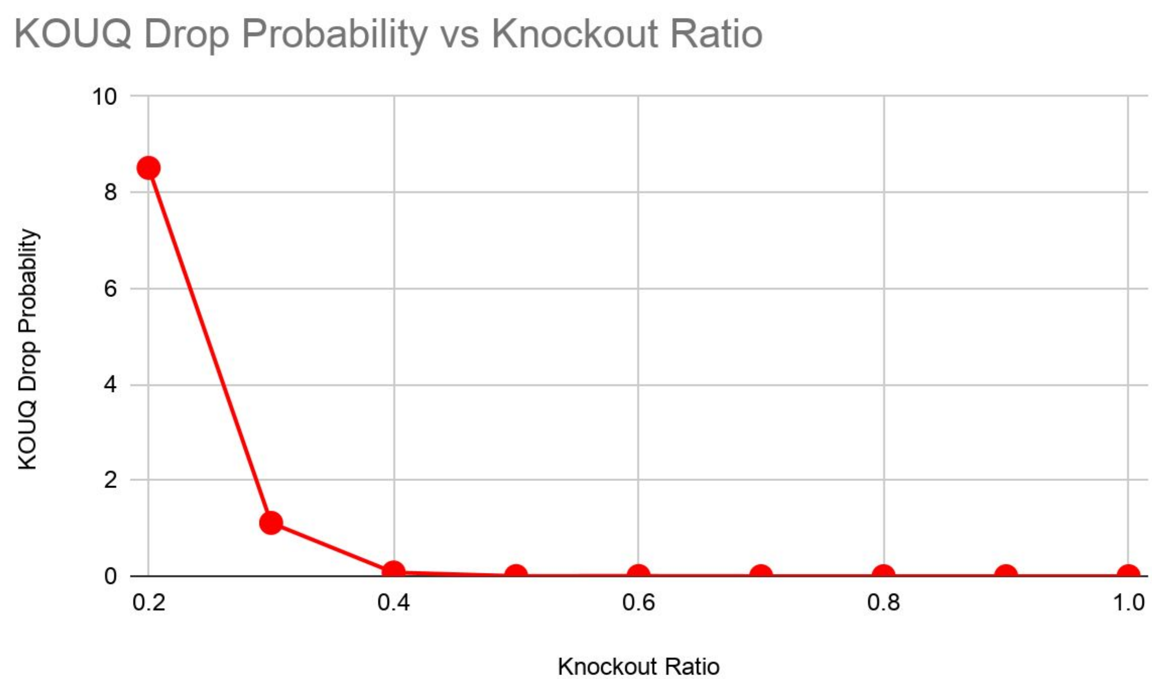
In INQ scheduling as the buffer size increases more packets are able to get accommodated at the input portend which leads to a lesser number of packets getting dropped due to filled input queue, thus we observe a decrease in the drop ratio.
In KOUQ scheduling similarly, as the buffer size increases more packets can be accommodated at the output portend, this leads to a decrease in the drop ratio.
In iSLIP the same scenario as in the INQ occurs however because there is a virtual queue for each output port respectively this leads to a lesser drop ratio value as compared to INQ.



In INQ and iSLIP scheduling an increase in the buffer size increases the probability for packets to be delivered in the latter slots as compared to getting dropped this leads in an increase in the link utilization as the input ports are relatively busier with an increase in the number of packets to be scheduled.
In the case of KOUQ scheduling as buffer size increases the number of packets getting transmitted increases thus link utilization increases. The change in the KOUQ scheduling is much more significant as can be observed from the graph plotted from the simulation.

4. Varying Knockout Ratio (k)

This section is applicable for KOUQ scheduling only. We change the knockout ratio from 0.2 to 1.0 in increments of 0.2. Also, the number of ports is 8. Thus the value of K ranges from minimum 1 (0.2 * 8) to maximum 8 (1.0 * 8).

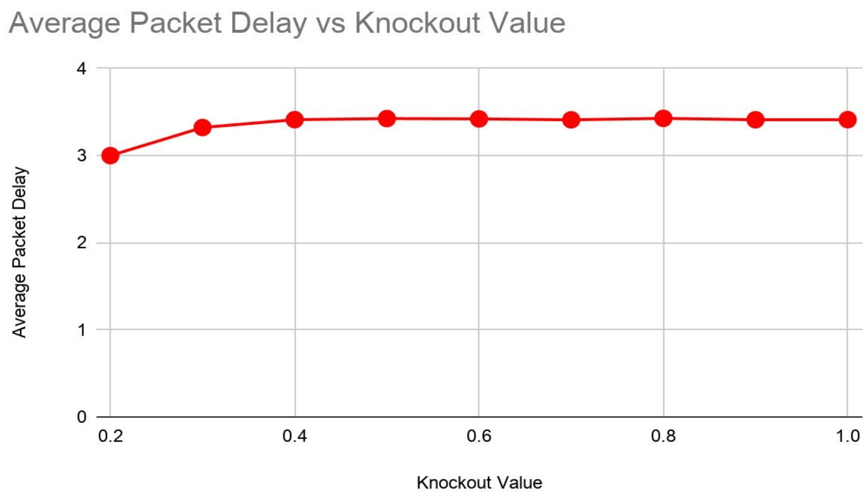


The first graph is of Drop probability vs Knockout Ratio as this is the metric that will be immediately affected. Drop probability measures the output ports which have been targeted by more than (k_ratio * N) packets. Let us calculate the probability for K_value = floor(0.2 * 8) = 1.

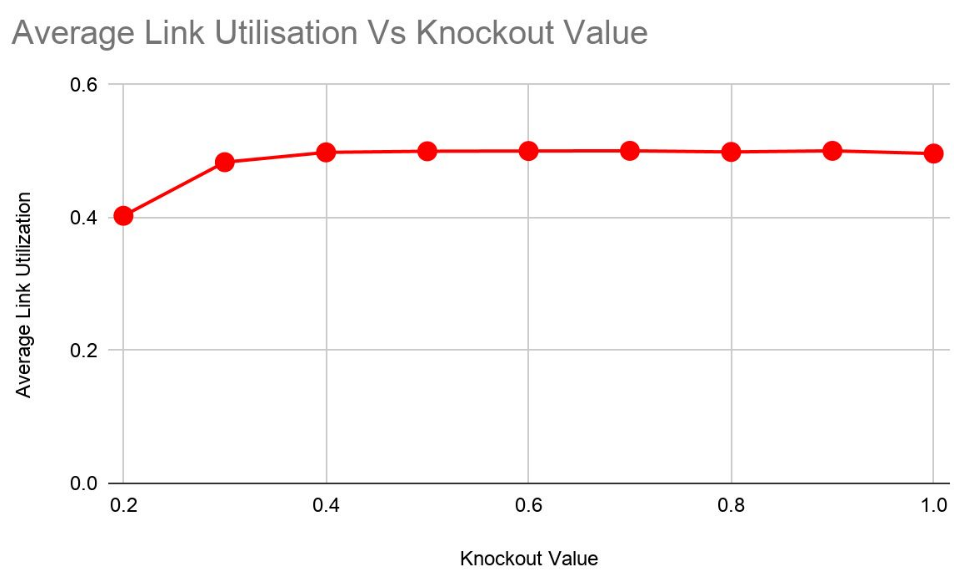
P(A output port gets more than 1 packet) =
1 - P(that port gets no packet) - P(gets exactly 1 packet)
P(gets no packets) = (1 - p/n)^(n)
*P(gets exactly one packet) = n * (p/n) * (1-p/n)^(n-1)*

Putting n = 8, p = 0.5 in the above formula gives drop probability 0.085 (8.5 %) which is also shown by the results. If K is higher, it becomes exponentially unlikely that say half of the packets will be destined for the same output port.

The second graph is for the average packet delay vs knockout ratio. Note that output buffer size is the default 4 in this case. For k_ratio = 0.1, k_value is 1 which means at most one packet will be sent to an output port. And this packet will be immediately transmitted out of the switch in the next slot. Thus, the minimum packet delay is almost 3. As k_ratio increases, more packets will be put in an output buffer after scheduling which will incur delay staying in that buffer. Thus the delay value increases and saturates.

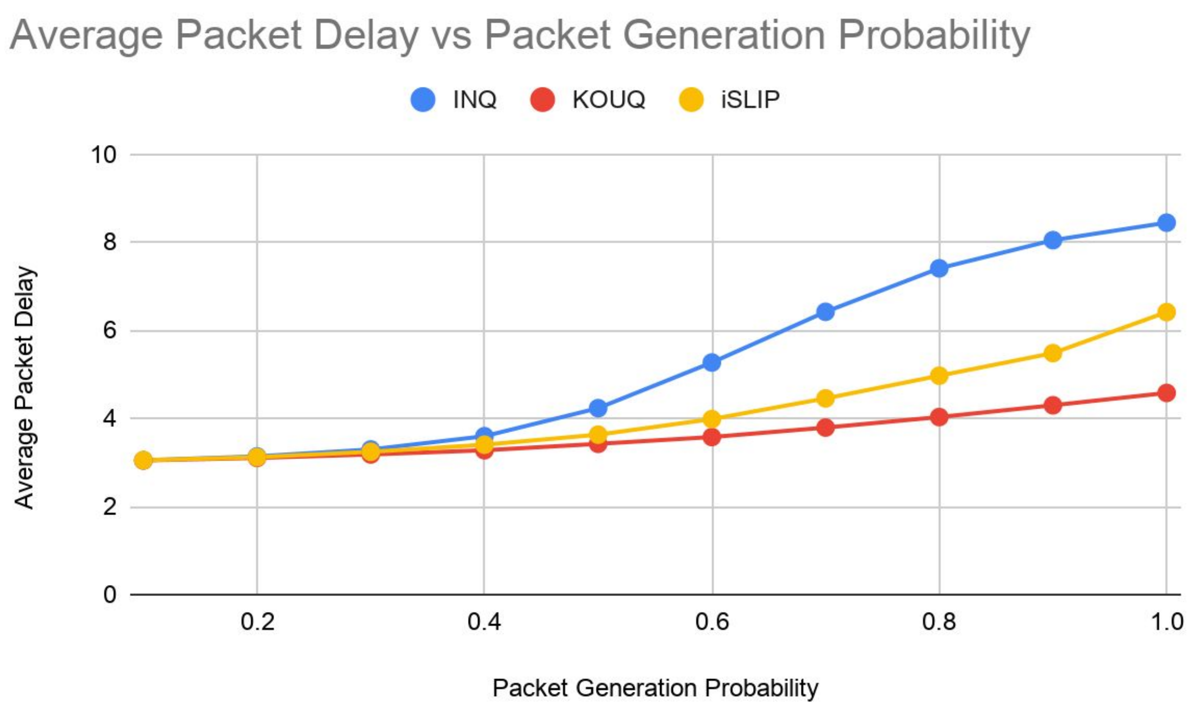


Similarly, link utilization will suffer if k_ratio is very low. since even if two packets compete for the same output port one will get dropped effectively decreasing the link utilization by 1 that slot. The trend, however, saturates quickly because, from k_ratio = 0.4 i.e. k_value = 3, collisions occur rarely to decrease link utilization.



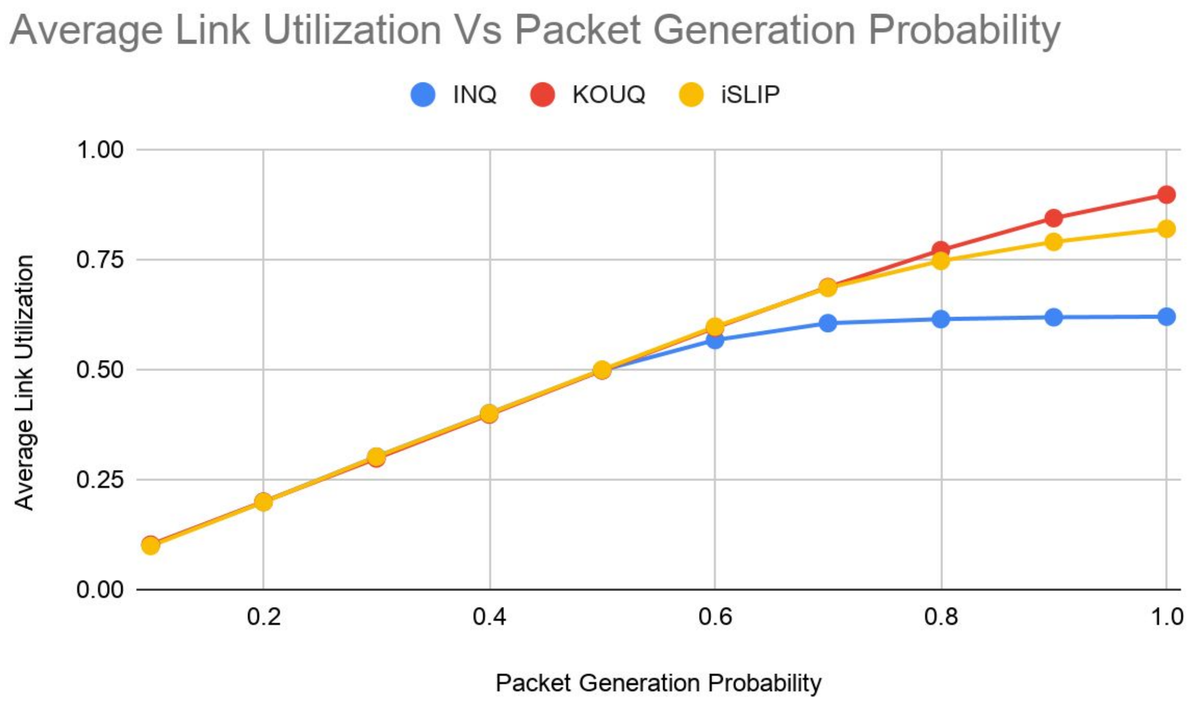
5. Varying Generation Probability (p)

The packet generation probability has been varied from 0.2 to 1.0 to obtain the result.

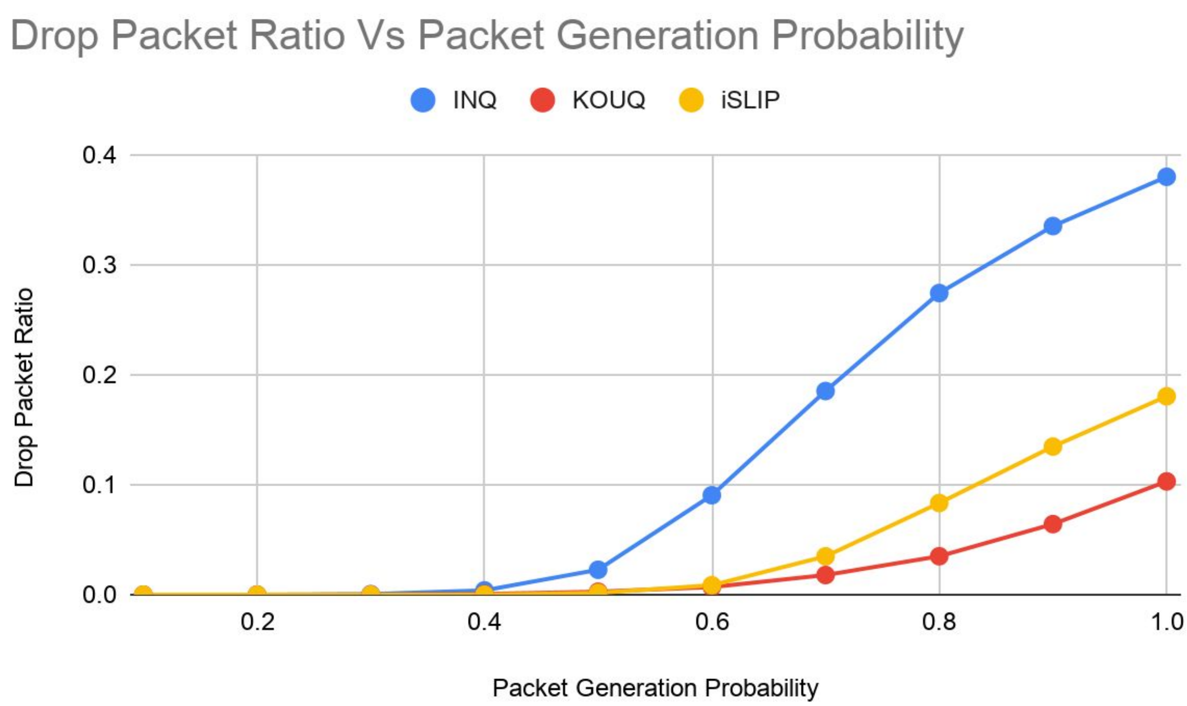


As we increase the packet generation probability more packets are generated at each input port, therefore for all types of scheduling the number of packets the switch has to handle increases considerably.
In the case of INQ scheduling, as more packets keep waiting in the input queue due to HOL, there is a significant increase in the average packet delay as compared to the other variants of scheduling. the more the generation probability the more filled the input queue of the input port is, thus more delay in the delivery.
In the case of KOUQ scheduling, there isn’t a very significant change in the average packet delay value because either the packets are delivered to the output port for transmission or there are dropped as such there is no waiting at input queue. However we do observe a slight increase in the value this can be attributed to the reason that as more packets are being delivered the probability of multiple packets destined for the same output port in a slot increases, thus the output queue is relatively more filled hence more delay occurs till transmission.

In the case of iSLIP scheduling even though there is no HOL more packet generation leads to packets getting accumulated at the input port and waiting to be scheduled thus increasing delay.



In the link utilization graph above till the packet generation probability is less than 0.5, all three scheduling mechanisms give virtually the same utilisations as there are fewer packets, and thus fewer collisions, so there is less scope of optimization. But as p increases (all the way from to 1), we start to see the difference. KOUQ leads as its default knockout ratio is 0.6, i.e. only if more than 60% of the packets are for the same output port, the link utilization will take a hit. This, of course, is a very rare situation, so KOUQ is able to transfer almost all packets. iSLIP comes in second since it uses virtual queueing to combat Head-of-Line blocking and using multiple iterations to give a better matching between input and output port. Since generation probability is also high, there is scope to optimize the size of matching. Lastly, comes INQ as it does and selects a valid matching and makes no effort to combat HoL blocking.



In INQ scheduling as the number of packets generated increases, this leads to the input queue buffer getting filled earlier and the latter packets generated after the buffer is filled getting dropped. The effect of this dropping is much higher due to HOL blocking as if because of one particular port multiple input ports are blocked the packets generated for these ports will start getting dropped, therefore we observe that the drop ratio of INQ scheduling is highest among all the scheduling types.

A similar case is observed in iSLIP scheduling however because there is a virtual queue present for each of the output port the drop ratio is relatively lesser.

In KOUQ scheduling there is no such blocking on the input side however as the number of packet increases so does the number of packets destined for a particular output port, thus if the output buffer size is exceeded this leads to packets drop, although this drop is relatively least among all the scheduling types mentioned as can be observed from the graph obtained from simulation.

6. Conclusion

From the above analysis by observing the obtained graphs we can conclude that:

a. **Average Packet Delay**

For average packet delay, INQ performs the worst, iSLIP in the middle KOUQ (with K ratio 0.6) performs the best.
This can be explained by the fact that INQ suffers from HOL blocking, as such, there are more packets that are remains queued for transmission. Increasing the number of ports, buffer size or the generation probability increases the number of packets that will remain queued and hence we see an increasing trend in the average delay.
For the iSLIP, although there is no HOL blocking the packets are made to wait because of collision hence the average packet delay value is lesser than that of INQ.
The KOUQ scheduling is aggressive in nature either the packets are dropped or they are added in the output queue for transmission, therefore the only delay a packet suffers is while waiting in the output queue for its turn to be transmitted, hence KOUQ has the least average packet delay value.

INQ > iSLIP > KOUQ

b. **Average Link Utilization**

For average link utilization, the general trend is that iSLIP performs the best followed by a close KOUQ whereas the INQ performs the worst. In the case where the probability generation is close to 1.0, we observe that KOUQ starts outperforming iSLIP.
The observed trend for INQ was expected as the probability fo successful utilization drops because of HOL blocking, providing less chance for successful scheduling. The iSLIP using its virtual queue attempts to provide the best possible input-output matching at any given slot, therefore, its performance is best in most of the cases. As mentioned earlier the KOUQ is an aggressive scheduling algorithm h its performance is slightly less than that of iSLIP in usual cases, however, under special circumstances for eg when generation probability is close to 1 or when the knockout ratio is close to 1 we observe that it outperforms iSLIP.

iSLIP >= KOUQ > INQ

c. **Average Packet Drop Ratio**

For the average packet drop ratio, we observe that INQ has the highest value this is because of its input buffer getting filled and all the subsequent packets being dropped.Similar is the case for iSLIP however the presence of the virtual queues allows multiple packets from the input port to contest for the link as compared to INQ hence the drop ratio is comparatively less.In the case of KOUQ as the default knockout ratio is 0.6 this coupled with default generation probability of 0.5 ensures the number of packets getting dropped at output port is comparatively least. If we have used some other value of knockout ratio closer to 0 we observe there is a significant increase in the dropped packet count.

INQ > iSLIP > KOUQ