IITM-CS6040 : Router Architectures and Algorithms | Release Date: -
Assignment 3 | Due Date : Oct 6, 2024

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References/sources:

1. Notations:
    - *N*: Number of input and output ports on the switch. N X N switch.
    - *B*: The buffer size of the queue at each input port
    - *p*: The probability that a packet will arrive at a given port
    - *q*: The type of Queue supported by switch.
        - *NOQ*: No buffers at the input or output.
        - *INQ*: Buffers only at the input port.
        - *CIOQ*: Buffers at input and output both.
    - *K*: The backplane is K times faster than line rate.
    - *L*: The number of packets to consider in CIOQ.
    - *T*: The max time for which the switch runs.
2. NOQ:
    - In *NOQ*, since there are no queues on the input or the output, no packets will be buffered in the switch.
    - Performing probabilistic analysis for a buffer less switch, we obtain the following expression for *Mean Port Utilization* of the switch:

$$U = 1 - \left(1 - \frac{p}{N}\right)^N \tag{1}$$

    - For equation 1, as $N \to \infty$, we obtain the following theoretical limits on *Mean Port Utilization*:
        - for $p = 1$, we obtain a 63% limit
        - for $p = 0.8$, we obtain a 55% limit
        - for $p = 0.6$, we obtain a 45% limit
        - for $p = 0.4$, we obtain a 32% limit
    - Comparing this with Fig. 1 obtained from simulation, we can observe that as *N* increases, the *Mean Port Utilization* converges to the theoretically obtained values.

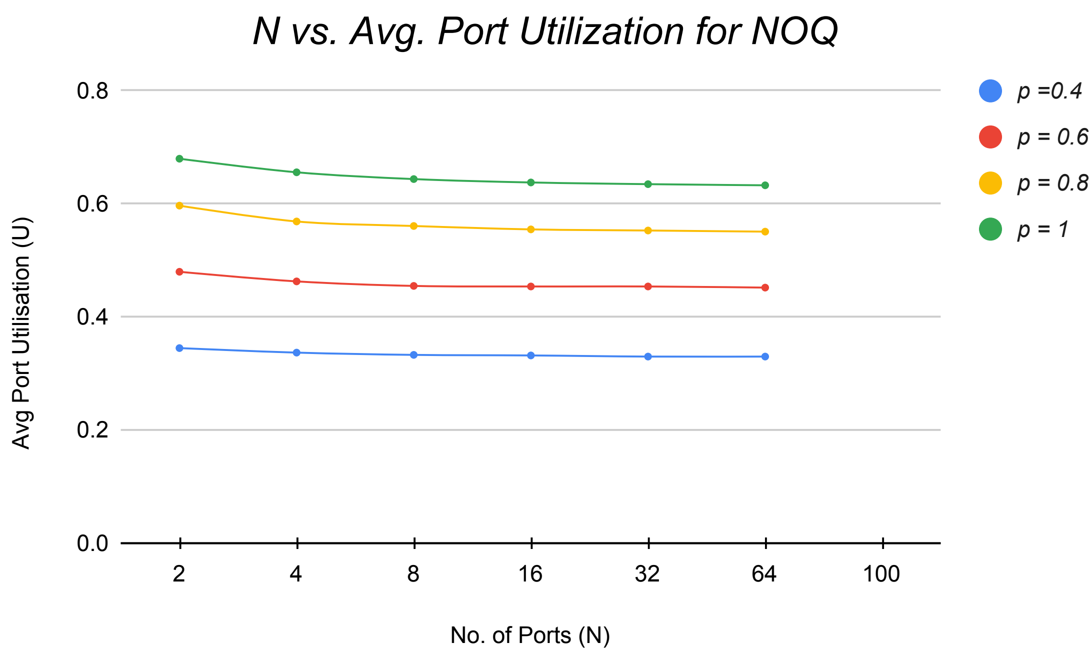

Figure 1: Mean Port Utilization for NOQ

- *Packet delay* is defined as *"the difference between transmission completion time and the packet arrival time"*. Since it takes 1 slot for a packet to finish transmission, for NOQ, the packet delay for any packet is 1 slot. We can confirm this by observing Fig. 2. Also, since no packet is buffered, *mean packet delay* stays 1. In this case, changing the value of *N* or *p* does not have any effect on the *mean packet delay* as no packet is queued.

3. INQ:

- In *INQ*, there are queues on the input, thus packets will be buffered at input of the switch.
- The theoretical limit for Mean Port Utilization of an *INQ* switch is 58% as $\mathrm{N} \rightarrow \infty$.
- Observing with figure 3 obtained from simulation, we can observe that as *N* increase, the *Mean Port Utilization* converges to the theoretical values.
- For smaller of values of *p*, the *Mean Port Utilization* is reduced since less packets are generated at the input.
- *Packet delay* is defined as *"the difference between transmission completion time and the packet arrival time"*. Thus, for *INQ*, the packet delay for any packet is sum of *packet transmission time* (1 slot) and *wait time*. We observe in figure 4, for a particular *N*, as *p* increases, the *mean packet delay* increases. Since, more packets are generated at the input, there is higher contention and thus packets are queued at the input. Also, for a given value of *p*, as *N* increases, the *mean packet delay* increases as more packets may be generated for same output port.

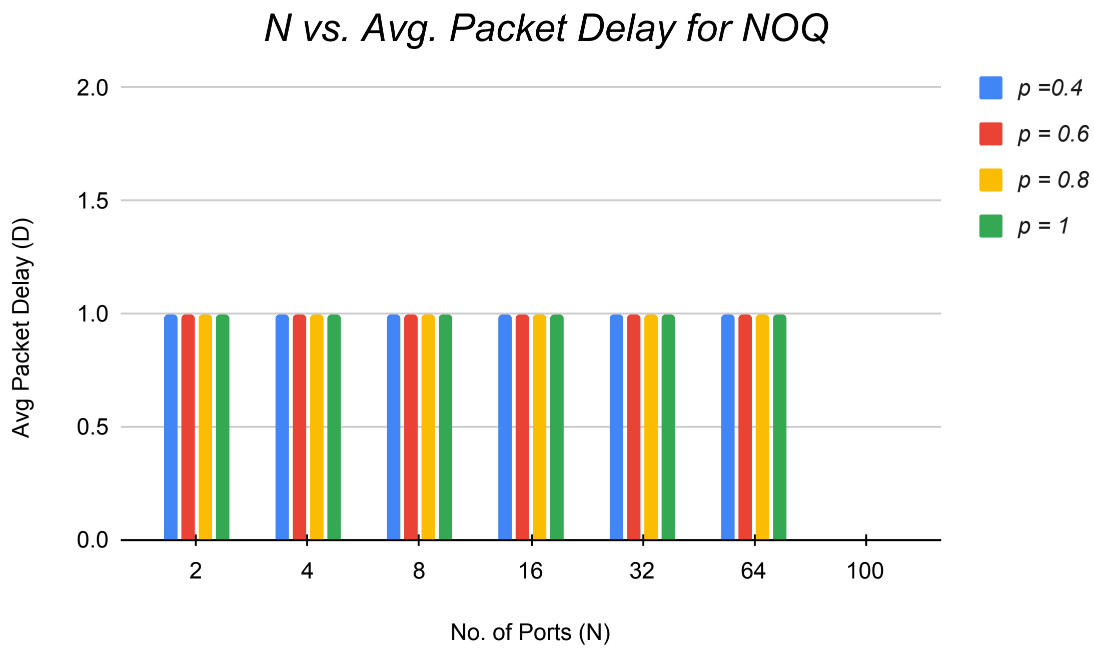

Figure 2: Mean Packet Delay for NOQ

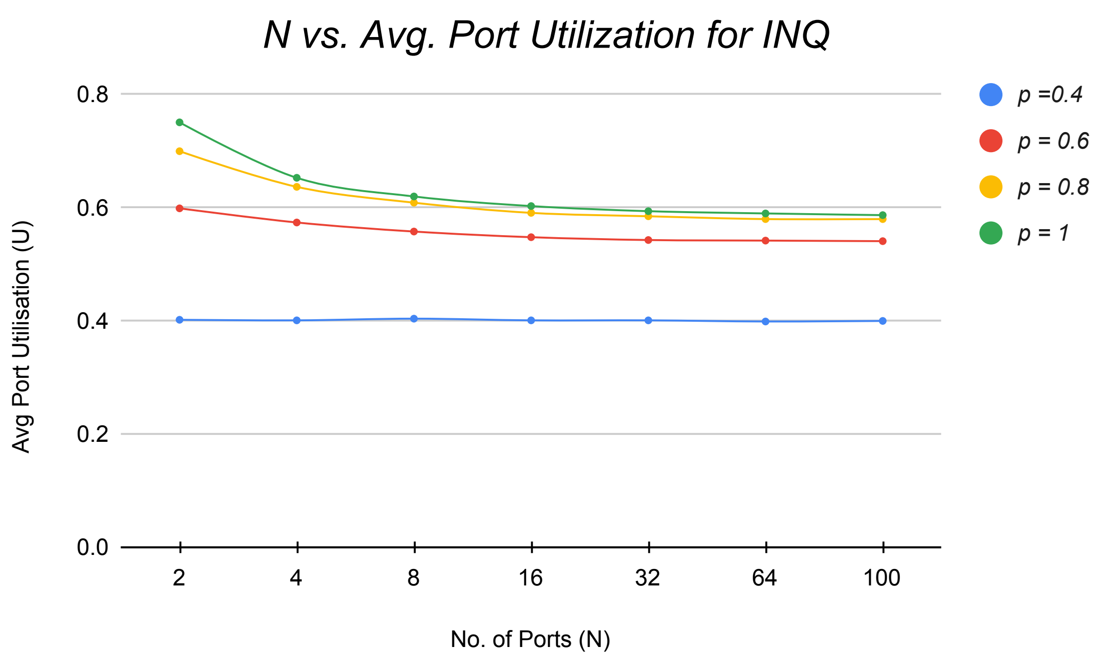

Figure 3: Mean Port Utilization for INQ

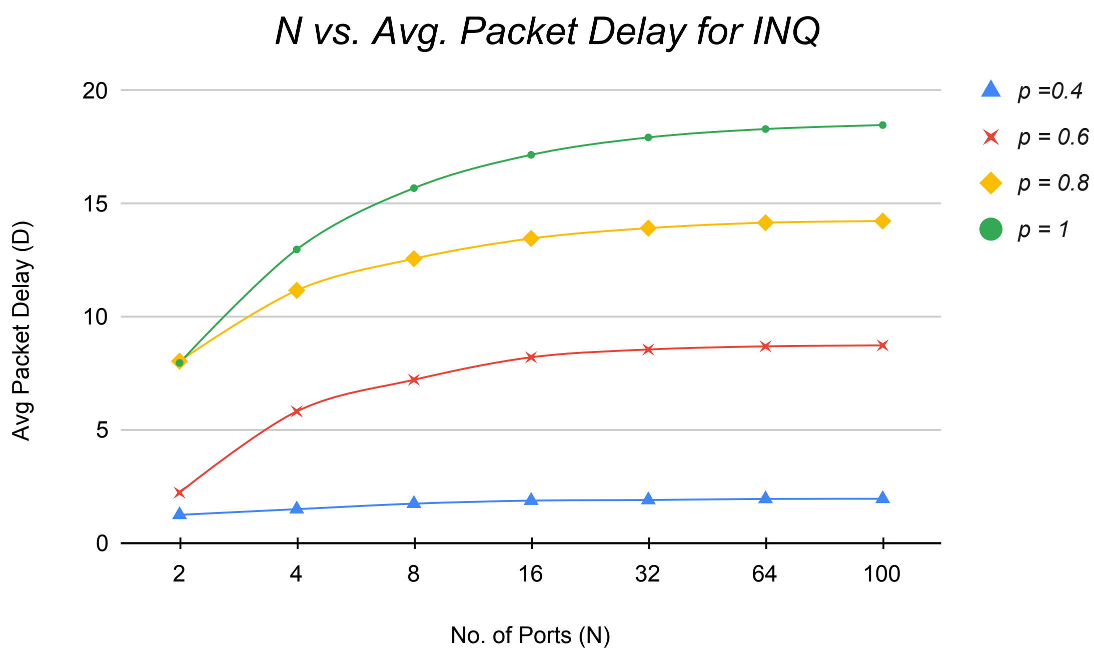

Figure 4: Mean Packet Delay for INQ

4. CIOQ:

- In *CIOQ*, there are queues on the input as well as the output, thus packets will be buffered at input and output of the switch.
- The algorithm for scheduling in CIOQ switch is given in algorithm 1. The approximate time taken by the scheduling algorithm is O(N) i.e. Linear.

  The first for loop iterates over all input ports. If there are packets at the input queue, one packet from L HOL packets is chosen and put into a temporary queue. The chosen packet is then removed from the input queue.

  The second for loop iterates over all output ports. If there are packets in the temporary queue, K packets are chosen to be sent to the output port. All other packets are then dropped.
- Observing with figure 5 obtained from simulation, we can observe that as *Port Utilization* is above 98% across all combinations of *K* and *L*.
- For *CIOQ*, the packet delay for any packet is sum of *packet transmission time* (1 slot), *input wait time* and *output wait time*. We observe in figure 6, as *p* increases, the *Mean packet delay* increases. *N* has little to no effect on the packet delay.
- From the simulation, it is observed that the Mean Drop probability for the above scheduling algorithm is 0 across values of $\mathrm{N} \in 32, 64$ and $\mathrm{p} \in 0.4, 0.6, 0.8, 1$. This is because, since N is large, the values of L and K are large as well. Thus almost no packets are dropped since queues remain

Algorithm 1 Scheduling algorithm for CIOQ

Require: N, q, curr_slot, L, K, B

$\mathtt{temp\_queues} \leftarrow \{0 : [], ..., \mathsf{N} : []\}$
for Every input port **do**
    if There are packets in the queue **then**
        $\mathtt{pkt} \leftarrow$ Randomly chosen pkt from top L packets in the queue
        $\mathtt{temp\_queues}[\mathtt{pkt.outport}] \leftarrow \mathtt{pkt}$
        Remove $\mathtt{pkt}$ from the $\mathtt{input\_queue}$
    end if
end for
for Every output port **do**
    if There is a packet in the temporary queue **then**
        $\mathtt{packets} \leftarrow$ K random packets from the temporary queue
        if length($\mathtt{output\_queue}$) $<$ B **then**
            Insert only $\mathsf{B} - \mathtt{len}(\mathtt{output\_queue})$ packets from the selected K packets
        end if
    end if
end for

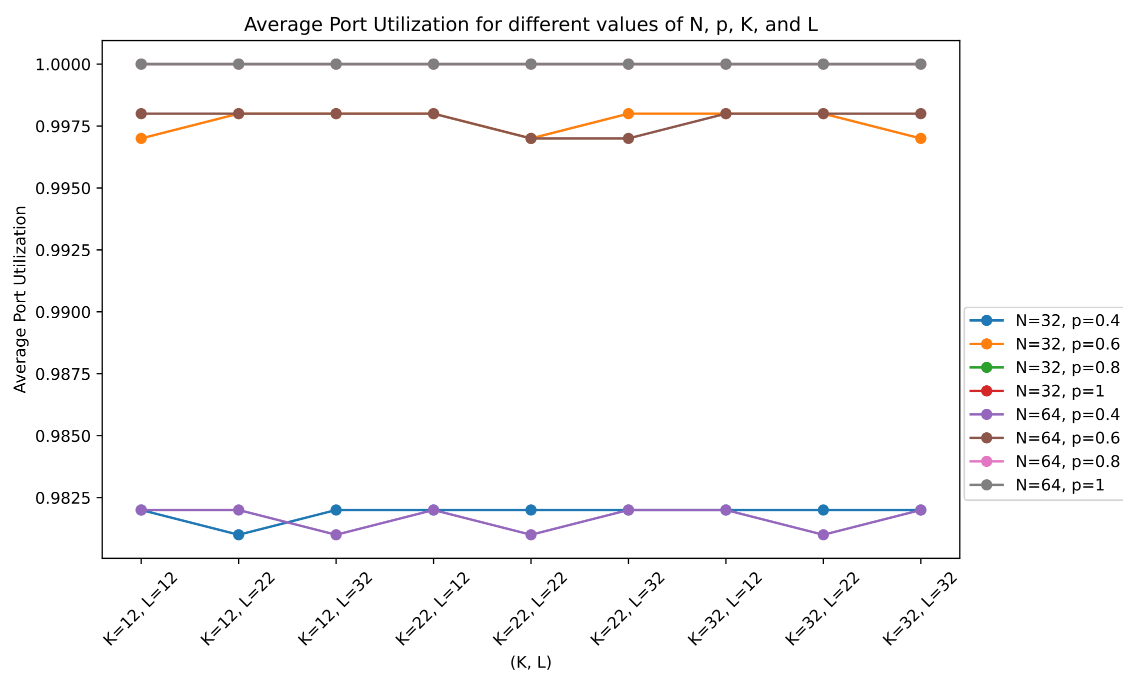

Figure 5: Mean Port Utilization for CIOQ for different combinations of K, L

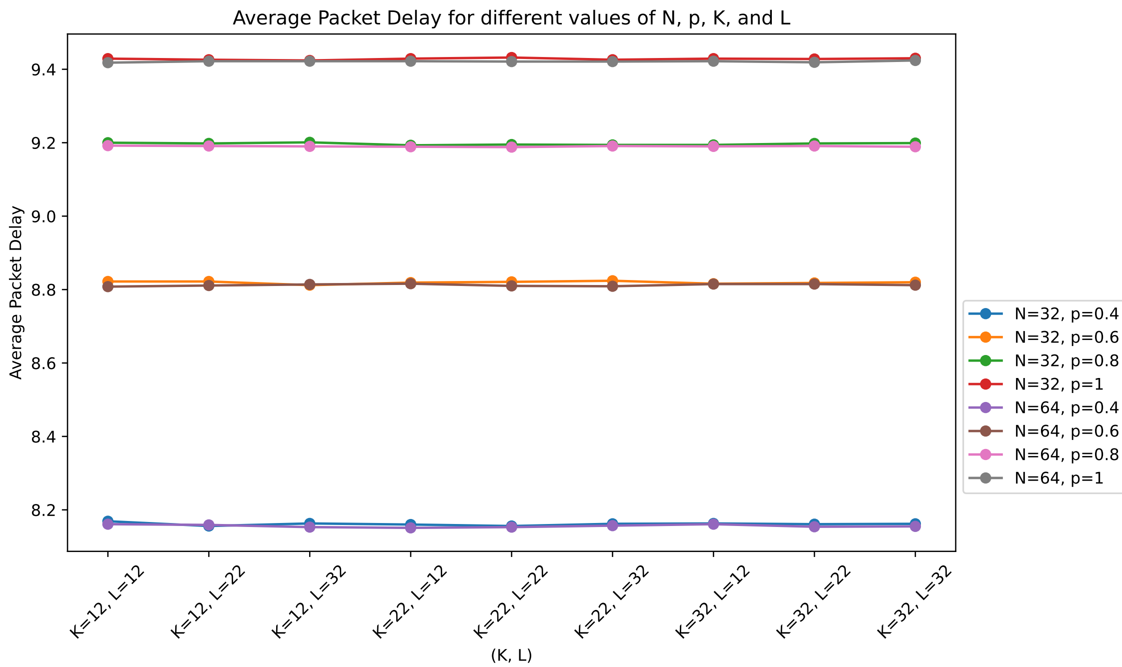

Figure 6: Mean Packet Delay for CIOQ for different combinations of K, L

empty most of the times.