



IIT Armour College of Engineering
ILLINOIS INSTITUTE OF TECHNOLOGY

ECE 587
HARDWARE/SOFTWARE CO-DESIGN

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PROJECT REPORT - 2

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Fast Fourier Transform on NoC Architectures

OBJECTIVE:

The main goal of this project is to finish the NoC model actualized in SystemC and to execute and assess a framework that processes 8-point Discrete Fourier Transform (DFT) utilizing Fast Fourier Transform (FFT) from a well-defined design flow.

INTRODUCTION:

Network on Chip engineering is one of the growing field where numerous processor ideas are winning the business sector right now. NoC innovation applies organizing hypothesis and strategies to on-chip correspondence and brings remarkable changes over conventional bus and crossbar interconnections. NoC enhances the versatility of SoCs, and the power efficiency of complex SoCs contrasted with different plans. A Network-on-Chip system comprises of communication links which are used to interconnect the processing elements (PEs) and routers. The packets are generated and devoured by the PEs while the routers are responsible to route the packets from source PEs to destination PEs.

The quantity of routers relies on topology being utilized furthermore number of utilized ports for each rely on their position in the topology. By and large routers or switches are considered to have 5 input and output ports. In which, 4 sets of input/output ports are associated with different switches in the system and fifth one is for the association with PE.

For this project, the topology being considered is a 2-D 3*3 mesh architecture. The topology is shown in below figure 1. From the topology we can infer that there are 9 processing elements (PEs) and 9 routers. Both the location of a router and the address of the PE attached to it are represented by a pair of integers (x, y) denoting the two coordinates within the network. Moreover, as discussed above the 2-D mesh structure requires each router to have four pairs of input/output ports that connect to neighboring routers on the four sides. Adding the pair of input/output ports for the router to communicate with the attached PE, we illustrate the router with these five pairs of ports in figure. 2, and name them as NORTH, SOUTH, EAST, WEST, PE. Note that every PE

should also have a pair of input/output ports such that it can communicate with the router it attaches to. Routing algorithm used in this project is XY routing algorithm.

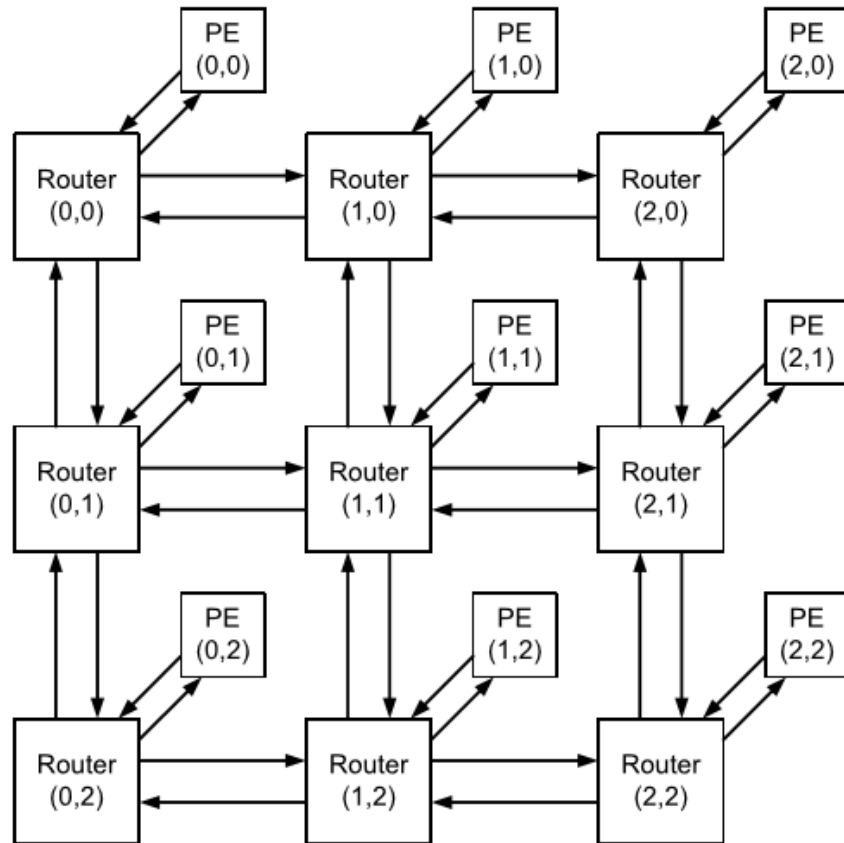


Figure 1: 2-D Mesh NoC Architecture

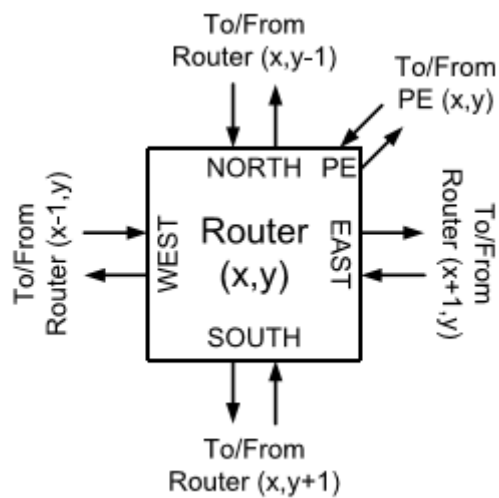


Figure 2: Router

IMPLEMENTATION:

The first step of this project is to create the 2-D 3*3 NoC architecture as shown in above figure 1 and assemble all the components which are the routers, communication links and processing elements (PEs). Once the mesh architecture is implemented and assembled, next step is to complete the routing algorithm for this 2-D mesh architecture. The XY routing algorithm route a packet based on the location of the current router and the destination of the packet. It follows the three stages beneath:

- If the destination is the attached PE, then the packet should be delivered to it.
- If the y coordinate of the destination is the same as the current router, then the packet is delivered to the router either on the west or on the east depending on the x coordinate.
- If the y coordinate of the destination is different from that of the current router, then the packet is delivered to the router on the north or on the south depending on the y coordinate.

When the NoC outline is finished, each of the FFT equation should be mapped to the PEs which are in charge of computation of the inputs got through parcels. FFT implementation includes taking of two inputs, perform a few calculations and afterward send the two yields for the following phase of estimation. This is as shown in the below figure.

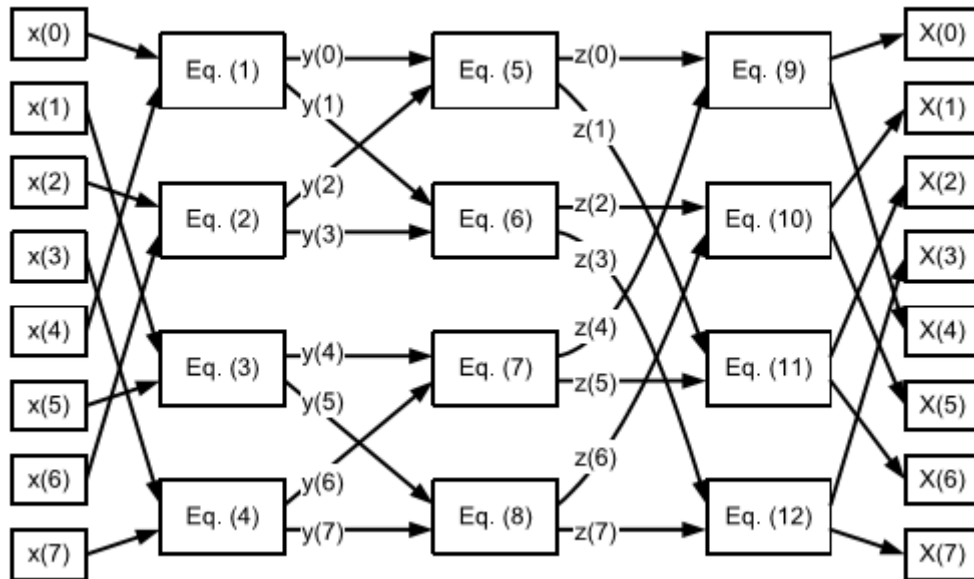


Figure 3: DFG for FFT computation

The inputs are $x(0)$, $x(1)$, $x(2)$, $x(3)$, $x(4)$, $x(5)$, $x(6)$ and $x(7)$ and its corresponding FFT outputs are $X(0)$, $X(1)$, $X(2)$, $X(3)$, $X(4)$, $X(5)$, $X(6)$ and $X(7)$.

SIMULATION:

The inputs given to the NoC architecture is $\{1, 0, 2, 0, 3, 0, 4, 0\}$. The outputs obtained for the given input are $\{10+0j, -2+2j, -2+0j, -2-2j, 10+0j, -2+2j, -2+0j, -2-2j\}$.

The obtained outputs are shown as screenshots in below Appendix.

RESULT:

The main goal of this project which was to implement a 2-D 3×3 NoC architecture which processes an 8-point Discrete Fourier Transform (DFT) utilizing Fast Fourier Transform algorithm was successfully designed and the outputs were obtained.

REFERENCES:

ECE587-prj01.pdf

ECE587-prj02.pdf

https://en.wikipedia.org/wiki/Network_on_a_chip


Appendix – 1 shows the screenshots for the FFT outputs obtained from the given inputs.

Appendix – 2 shows the screenshots for Single input fired over each cycle with different probabilities.

Appendix – 3 shows the screenshots for Multiple inputs fired over different clock cycles with different probabilities.

APPENDIX - 1:


FFT outputs for the inputs {1, 0, 2, 0, 3, 0, 4, 0}.

 saturn.ece.iit.edu - PuTTY

```

PI: send 2.000000 + 0.000000 to (0,1) -- flag:11, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:11, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:11, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:11, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:11, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:11, pkt:7
cycle 23 =====
inc(1,0): send -2.000000 + -2.000000 to (1,1)
inc(1,0): send -2.000000 + -2.000000 to (1,1)
cycle 24 =====
PO: received X[2] = -2.000000 + 0.000000 from (2,1)
cycle 25 =====
inc(2,0): send 10.000000 + 0.000000 to (2,0)
inc(2,0): send -2.000000 + 0.000000 to (2,1)
PO: received X[0] = 10.000000 + 0.000000 from (2,0)
inc(2,1): send 0.000000 + 0.000000 to (2,0)
inc(2,1): send 0.000000 + 0.000000 to (2,1)
cycle 26 =====
PO: received X[3] = -2.000000 + -2.000000 from (1,0)
inc(0,2): send -2.000000 + 2.000000 to (1,1)
inc(0,2): send -2.000000 + 2.000000 to (1,1)
cycle 27 =====
inc(0,0): send 4.000000 + 0.000000 to (2,0)
inc(0,0): send -2.000000 + 0.000000 to (0,2)
inc(1,0): send 0.000000 + 0.000000 to (0,2)
inc(1,0): send 0.000000 + 0.000000 to (1,0)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:12, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:12, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:12, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:12, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:12, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:12, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:12, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:12, pkt:7
PO: received X[6] = -2.000000 + 0.000000 from (2,1)
cycle 28 =====
inc(2,0): send 10.000000 + 0.000000 to (1,1)
inc(2,0): send 10.000000 + 0.000000 to (1,1)
inc(0,1): send 6.000000 + 0.000000 to (2,0)
inc(0,1): send -2.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:13, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:13, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:13, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:13, pkt:3


```

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```

PI: send 2.000000 + 0.000000 to (0,1) -- flag:13, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:13, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:13, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:13, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:13, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:13, pkt:7
PO: received X[7] = -2.000000 + -2.000000 from (1,0)
inc(0,2): send -2.000000 + 2.000000 to (0,2)
inc(0,2): send -2.000000 + -2.000000 to (1,0)
inc(2,2): send 0.000000 + 0.000000 to (2,1)
inc(2,2): send 0.000000 + 0.000000 to (1,0)
cycle 29 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:14, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:14, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:14, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:14, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:14, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:14, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:14, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:14, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:15, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:15, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:15, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:15, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:15, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:15, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:15, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:15, pkt:7
PO: received X[4] = 10.000000 + 0.000000 from (2,0)
inc(2,1): send -2.000000 + 0.000000 to (1,1)
inc(2,1): send -2.000000 + 0.000000 to (1,1)
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 30 =====
PO: received X[1] = -2.000000 + 2.000000 from (0,2)
cycle 31 =====
PO: received X[5] = -2.000000 + 2.000000 from (0,2)
cycle 32 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:16, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:16, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:16, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:16, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:16, pkt:4

```

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```
cycle 992 =====
inc(0,0): send 0.000000 + 0.000000 to (2,0)
inc(0,0): send 0.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:421, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:421, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:421, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:421, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:421, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:421, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:421, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:421, pkt:7
cycle 993 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:422, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:422, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:422, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:422, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:422, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:422, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:422, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:422, pkt:7
inc(2,1): send 0.000000 + 0.000000 to (0,0)
inc(2,1): send 0.000000 + 0.000000 to (0,0)
cycle 994 =====
cycle 995 =====
inc(0,0): send 4.000000 + 0.000000 to (2,0)
inc(0,0): send -2.000000 + 0.000000 to (0,2)
cycle 996 =====
inc(0,1): send 6.000000 + 0.000000 to (2,0)
inc(0,1): send -2.000000 + 0.000000 to (0,2)
inc(2,2): send 0.000000 + 0.000000 to (2,1)
inc(2,2): send 0.000000 + 0.000000 to (1,0)
cycle 997 =====
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 998 =====
cycle 999 =====
Generated outputs is: 5
Number of generated input sets is = 422
Number of cycles is = 1000
Total Throughput obtained is = 0.422000
The minimum latency obtained is = 28
The average latency obtained is = 38
kkanakap@saturn.ece.iit.edu:~%
```


APPENDIX – 2:

Single Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with 30% probability:

```

saturn.ece.iit.edu - PuTTY
inc(0,0): send 4.000000 + 0.000000 to (2,0)
inc(0,0): send -2.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:1476, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1476, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:1476, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1476, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:1476, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1476, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:1476, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1476, pkt:7
cycle 1496 =====
inc(0,1): send 6.000000 + 0.000000 to (2,0)
inc(0,1): send -2.000000 + 0.000000 to (0,2)
inc(2,2): send 0.000000 + 0.000000 to (2,1)
inc(2,2): send 0.000000 + 0.000000 to (1,0)
cycle 1497 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:1477, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1477, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:1477, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1477, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:1477, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1477, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:1477, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1477, pkt:7
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 1498 =====
cycle 1499 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:1478, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1478, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:1478, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1478, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:1478, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:1478, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:1478, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:1478, pkt:7
Generated outputs is: 5
Number of generated input sets is = 1478
Number of cycles is = 5000
Total Throughput obtained is = 0.295600
The minimum latency obtained is = 28
The average latency obtained is = 38
Segmentation fault
kkanakap@saturn.ece.iit.edu:~%

```

Single Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with 50% probability:

```

saturn.ece.iit.edu - PuTTY
inc(0,0): send 4.000000 + 0.000000 to (2,0)
inc(0,0): send -2.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2476, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2476, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2476, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2476, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2476, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2476, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2476, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2476, pkt:7
cycle 4996 =====
inc(0,1): send 6.000000 + 0.000000 to (2,0)
inc(0,1): send -2.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2477, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2477, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2477, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2477, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2477, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2477, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2477, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2477, pkt:7
inc(2,2): send 0.000000 + 0.000000 to (2,1)
inc(2,2): send 0.000000 + 0.000000 to (1,0)
cycle 4997 =====
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 4998 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2478, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2478, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2478, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2478, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2478, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2478, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2478, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2478, pkt:7
cycle 4999 =====
Generated outputs is: 5
Number of generated input sets is = 2478
Number of cycles is = 5000
Total Throughput obtained is = 0.495600
The minimum latency obtained is = 28
The average latency obtained is = 41
Segmentation fault
kkanakap@saturn.ece.iit.edu:~%

```

Single Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with 90% probability:

```

saturn.ece.iit.edu - PuTTY
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4484, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4484, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4484, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4484, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4484, pkt:7
=====
cycle 4997
inc(0,0): send 0.000000 + 0.000000 to (2,0)
inc(0,0): send 0.000000 + 0.000000 to (0,2)
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4485, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4485, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4485, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4485, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4485, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4485, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4485, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4485, pkt:7
=====
cycle 4998
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4486, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4486, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4486, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4486, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4486, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4486, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4486, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4486, pkt:7
inc(2,1): send 0.000000 + 0.000000 to (0,0)
inc(2,1): send 0.000000 + 0.000000 to (0,0)
=====
cycle 4999
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4487, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4487, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4487, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4487, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4487, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4487, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4487, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4487, pkt:7
Generated outputs is: 5
Number of generated input sets is = 4487
Number of cycles is = 5000
Total Throughput obtained is = 0.897400
The minimum latency obtained is = 27
The average latency obtained is = 41
Segmentation fault
kkanakap@saturn.ece.iit.edu:~$

```

APPENDIX – 3:

Multiple Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with a 30% probability:

```

saturn.ece.iit.edu - PuTTY
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 4998 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2103, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2103, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2103, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2103, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2103, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2103, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2103, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2103, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2104, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2104, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2104, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2104, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2104, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2104, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2104, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2104, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2105, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2105, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2105, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2105, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2105, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2105, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2105, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2105, pkt:7
cycle 4999 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:2106, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2106, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:2106, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2106, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:2106, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:2106, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:2106, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:2106, pkt:7
Generated outputs is: 5
Number of generated input sets is = 2106
Number of cycles is = 5000
Total Throughput obtained is = 0.421200
The minimum latency obtained is = 28
The average latency obtained is = 38
Segmentation fault
kkanakap@saturn.ece.iit.edu:~%

```

Multiple Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with a 50% probability:

```

saturn.ece.iit.edu - PuTTY
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4908, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4908, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4908, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4908, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4908, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4909, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4909, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4909, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4909, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4909, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4909, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4909, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4909, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4910, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4910, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4910, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4910, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4910, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4910, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4910, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4910, pkt:7
inc(2,2): send 0.000000 + 0.000000 to (2,1)
inc(2,2): send 0.000000 + 0.000000 to (1,0)
cycle 4997 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:4911, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4911, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:4911, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4911, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:4911, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:4911, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:4911, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:4911, pkt:7
inc(1,2): send 0.000000 + 0.000000 to (2,1)
inc(1,2): send 0.000000 + 0.000000 to (1,0)
cycle 4998 =====
cycle 4999 =====
Generated outputs is: 5
Number of generated input sets is = 4911
Number of cycles is = 5000
Total Throughput obtained is = 0.982200
The minimum latency obtained is = 28
The average latency obtained is = 42
Segmentation fault
kkanakap@saturn.ece.iit.edu:~$

```

Multiple Inputs {1, 0, 2, 0, 3, 0, 4, 0} fired with a 90% probability:

```

saturn.ece.iit.edu - PuTTY
PI: send 1.000000 + 0.000000 to (0,0) -- flag:44823, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44823, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:44823, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44823, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:44823, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44823, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:44823, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44823, pkt:7
cycle 4998 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:44824, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44824, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:44824, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44824, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:44824, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44824, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:44824, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44824, pkt:7
PI: send 1.000000 + 0.000000 to (0,0) -- flag:44825, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44825, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:44825, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44825, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:44825, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44825, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:44825, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44825, pkt:7
inc(2,1): send 0.000000 + 0.000000 to (0,0)
inc(2,1): send 0.000000 + 0.000000 to (0,0)
cycle 4999 =====
PI: send 1.000000 + 0.000000 to (0,0) -- flag:44826, pkt:0
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44826, pkt:1
PI: send 2.000000 + 0.000000 to (0,1) -- flag:44826, pkt:2
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44826, pkt:3
PI: send 3.000000 + 0.000000 to (0,0) -- flag:44826, pkt:4
PI: send 0.000000 + 0.000000 to (2,2) -- flag:44826, pkt:5
PI: send 4.000000 + 0.000000 to (0,1) -- flag:44826, pkt:6
PI: send 0.000000 + 0.000000 to (1,2) -- flag:44826, pkt:7
Generated outputs is: 5
Number of generated input sets is = 44826
Number of cycles is = 5000
Total Throughput obtained is = 8.965200
The minimum latency obtained is = 27
The average latency obtained is = 43
Segmentation fault
kkanakap@saturn.ece.iit.edu:~$

```