Performance Analysis of NoC Routing Algorithms Using Noxim Simulator

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Abstract –

The primary method that is used for examining and testing novel ideas in the Network-on- Chip design space can be evaluated by using simulation. The NOXIM Simulator is used to perform the analysis of Network-on-Chip by using the different characteristics of NoC. The Noxim Simulator is a System-C developed open, extendible, customizable, cycle – accurate NoC Simulator that enables the analysis of the performance and power statistics for both established wired NoC and new WiNoC designs. In the Noxim Simulator, the user can modify the size of the network, size of the Packets, Routing algorithm, Switching Strategy.

In this paper, the Mesh configuration has been evaluated and analyzed using the different Routing Algorithms of Network-on-Chip. The Network Sizes of 4x4, 8x8, 16x16, 32x32, 64x64 Mesh are analyzed for various Routing Algorithms and its results are investigated. The Network throughput is best for XY and Odd – Even Algorithm, and Network throughput is high for 64x64 Network Size by using the XY and Odd - Even Algorithm. The Network Throughput (flits/cycle) has been evaluated, with XY Routing Algorithm the Network Throughput is 59%. The Network Throughput is more among all the Routing Algorithms, the XY Routing Algorithm is best with Network size 64x64. The Network throughput for the XY and West – First Algorithms is more at high PIR (Packet Injection Rate). The Packet Injection Rate is high as the Network Size increases, the PIR of 0.4 has the highest Throughput for the XY Algorithm, with 60% more among all the Routing Algorithms.

Keywords: Noxim, NoC, Network Throughput

I. INTRODUCTION

The Network-on-Chip is used to scale down the Largenetworks and apply them to the System-on-Chip(SoC).The traditional NoC [1] is used as both for the wired and wireless NoC.

The NoC are used for the On-Chip Communication Fabrics for the Multiprocessor System-on-Chips(MPSoC). The NoC uses Packets to route data from Source to the destination by using the Network fabric which consists of Switches (Routers) and interconnected links (wires).

The Fig-1 shows the NoC architecture of Mesh type topology is interconnected, and it consists of several processing elements are connected together by routers and interconnected wires.

A PE is also referred as node, the processing element can be any component such as microprocessor, ASIC block or memory and thecombination of components connected together.

A Network Interface (NI) at the boundary of each PE isused to packetize the data generated by the PE. TheRouter consists of buffer, a crossbar switch and arbiter. The building block of NoC is router, it directs therouting algorithm to the desired host. It is used in PC,Graphics Processing Unit (GPU) etc. As the rate of increase in the design complexity increases the processtechnology is also advanced. The (e.g: IBM Cell [2]) The key characteristics of Network-on-Chip are Network Topology, Switching Startegies, Routing Algorithms, Flow control Schemes, Clocking Schemeand Quality of Service.

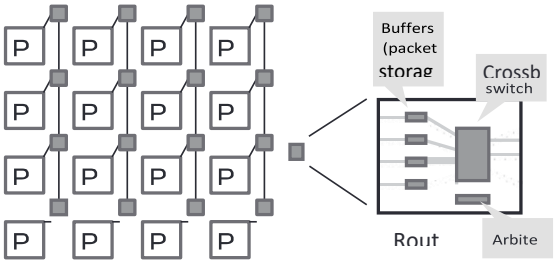


Fig - 1 : Mesh type NoC interconnection Fabric

II. METHODOLOGY

The Tool used to design the NoC[3] is NOXIM Simulator. There are several different evaluation tools and methodologies to facilitate research on NoC. Each tool is developed to achieve the goals of the design space like configuration of nodes, and the Configuration of NoC[4] are Topology, Routing algorithm, Switching strategy and others. The various Simulators are used to build for the evaluation and to design the NoC. Cristinel Ababei [5] and Achballah [6]explored the list of NoC Simulator tools and to simulate the analyze the different types of NoC. The NoC Simulator used is an Open Source Simulator.

The NOXIM [7] Simulator is developed using the SystemC. The NoC components are parameterized by using the command line interface.

In the NOXIM [8]Simulator, we can customize the Network Size, Routing Algorithm[9] and Switching Strategy and Traffic patterns. NOXIM Simulator Supports the Mesh Topology with Wormhole routers. The Evaluation ofNoC is done by producing results in terms of networkthroughput, Delay and Energy. The Detailed evaluationof results can be analyzed by total Packet or Flits sentor received, global average throughput, maximum and minimum global delay, total energy consumption etc. In this paper, I have designed Mesh using different network size 4*4, 8*8, 16*16, 32*32, 64*64 and Routing Algorithm of XY, West first, North last, Negative first and Odd even.

III. NOXIM SIMULATOR

The Noxim, Network-on-Chip Simulator is developed by the University of Catania (Italy) and is developed bySystem C. It is an open source and command line interface for defining the several parameters of the Network-on-Chip. The user can customize the network size, buffer size, Routing Algorithm, Switching Strategy and Trafficdistribution.

The Noxim is categorized into different classes: Topology and Structure, Workload, Dynamic Behaviorand Simulation. It supports various configuration.

The Noxim divides the nodes into tile nodes and hub nodes. The First node consist of computing and storage node. The secondly consist to simulate the gateway it combines the tiles to the network.

There are three distinct connectivity kinds that may becreated. There are three types of connections are possible for the nodes to the connectivity. The Tile- to-Tile is defined as the point to point connection of wiredNetwork The distribution is done between the tile nodes. In the Tile-to-Hub connection is given via wire between the Tile element and a hub element. The Hub- to-Hub connection is a linkage between the two Hub components. These connections can be both wired and wireless. The communication in the Noxim is performed by the splitting of packet in the small parts are known as Flits.

The Noxim Simulator is a readable file and is configured in the YAML format. The Noxim Simulator is configured in three ways and they are wired, wireless and Simulation parameters. The wired configuration deals with the dimension of mesh, routing algorithms and the output directions.

The wireless configuration sets the wireless hub , data rate , the medium of control access and the bit error rate. The simulation parametercan set the clock time, packet size, traffic distribution. The Noxim Simulator is updated and Evaluated by theseveral authors. It supports the Mesh Topology [18] , the author represented the performance evaluation of NoC topologies for the Enhanced Noxim Simulator. In this paper Examined the different Routing Algorithms and Switching Startegies for various Network Sizes.

IV. ROUTING ALGORITHM

(a).XY Algorithm:

The XY Algorithm is the most popular routing algorithm is proposed by Wang Zhang

and Ligang Hou [10]. In the XY Routing Algorithm, the Packet have header flit, tail flit and data flit. The header flit consists of destination node address, for implementing the Mesh topology and wormhole switching mechanism are used.

Each router have the co-ordinates (x,y), the Source address for the routing(S_x,S_y) is compared with the destination address (D_x,D_y) of packet by the comparisons output routing algorithm the router routes the packets. If (D_x>S_x)the head flit moves to East else to West D_x= S_x called horizontal alignment. Now (D_y<S_y) the packets header flit towards the South else North (D_y = S_y).

(b).West-First Algorithm:

The West-first Algorithm is a turn routing. The Dimension order routing [11], the algorithm follows the turn model for Adaptive routing. In the Routing Algorithm, we can limit the possible turns and it also result in deadlock free algorithm.

In the West-first Algorithm[12] the (D_x< S_x) the packets are routed deterministically as in the XY Algorithm. If(D_x>S_x) the packets are routed in East, North or South. This Algorithm includes any 90- degree bend towards the west. The packets are distributed from the west. It is used for routing the packet from the first west.

(c). North-last Algorithm :

The North-last Algorithm[13] is adaptive routingalgorithm in which 90-degree turns are allowed. The packets are routed in the north direction from the last. Itallows totally 6 turns than in the XY algorithm. This algorithm allows turns at any node from north to west and north to east.

In this paper Examined the different Routing Algorithms and Switching Startegies for various Network Sizes.

(d). Negative-First Algorithm :

The Negative-first Algorithm [14] the packets are routed in the negative direction, the packet have to travel in the negative direction.

The packets are routed from the North to West directions.

The packets are deterministically routed. The forbidden turns are two from positive to negative direction.

(e). Odd-Even Algorithm :

The Odd-Even Algorithm[15] is an adaptive routing algorithm based on the turn model, it is free from Deadlock. In the turn model, if x-coordinate is even the column is even and if x-coordinate is odd then odd. The turn model turns are in 90-degree.

It travels in eight directions in the channels(row or column) in EN, WS, WN, SE, SW, NE, and NW((where East, West, North and South).The Odd- Even[16] Algorithm is defined in two theorems.

The Algorithm, the no packet is permitted to take EN turn in each node which is located in an even column. And also, no packet is permitted to take NW turn in each node that is located on an odd column.

The Algorithm, the no packet is permitted to take ES turn in each node that is an even column. Also, no packet is permitted to take SW turn in node which is anodd column.

The Fundamental requirement of Noxim[17] Simulator is extensibility and scalable performance for supportingthe cycle-accurate simulation.

V. RESULTS

1. XY Algorithm :

A. The impact of Energy for different Network Size:The Static and Dynamic Energy compared with different Network Size as shown in Fig-2a. The Static and Dynamic Energy are linearly increased as the Network Size increases.

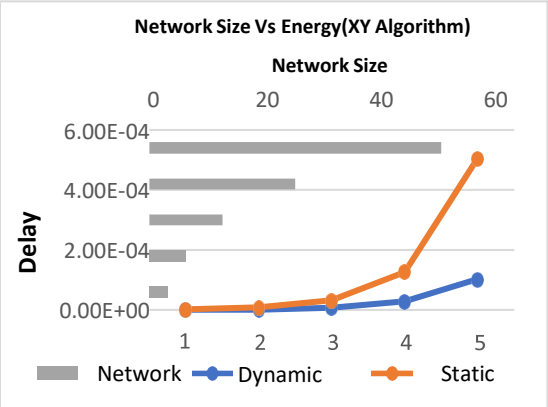


Fig -2a : Network Size Vs Energy (XY Algorithm)

B. The Analysis of Network Throughput Vs Packet & Flit /Cycle :

The several factors are included in the packet andnetwork. The Packet and Flit loss and the network congestion has the impact on the Network Throughput. For the Different Network size the values are taken and observed the analysis using different parameters. The Network Throughput Vs Packet & Flit/cycle as theNetwork Size Increases the no. of Received Flits areincreased. The Network Throughput also increased as thenetwork size increased as shown in Fig-2b.

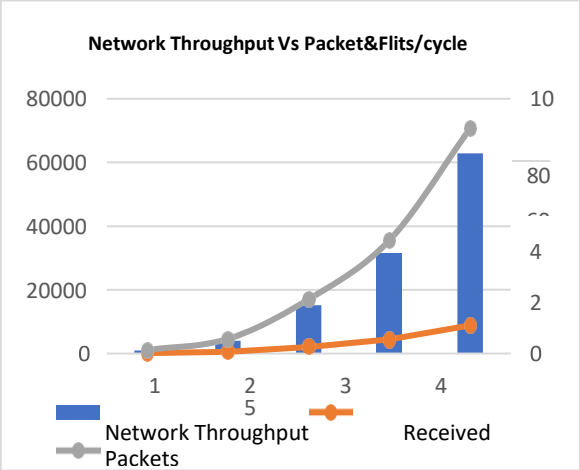


Fig -2b : Network Throughput Vs Packet & Flit /Cycle

C. The Impact of Delay for the different Network Size:

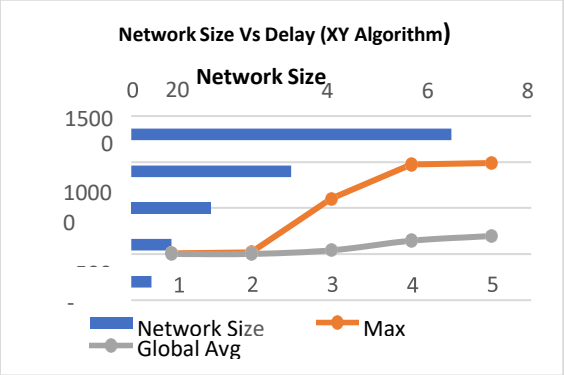


Fig – 2c : Network Size Vs Delay (XY Algorithm)

2. West – First Algorithm :

The Delay compared for various Network Size as shown in Fig-2c. As the Network Size Increased the Delay is very less and later it is more as the network size is increased.

A. The impact of Energy for different Network Size:

The Static and Dynamic Energy compared with different Network Size as shown in Fig-3a. The Static and Dynamic Energy are linearly increased as the Network Size increases.

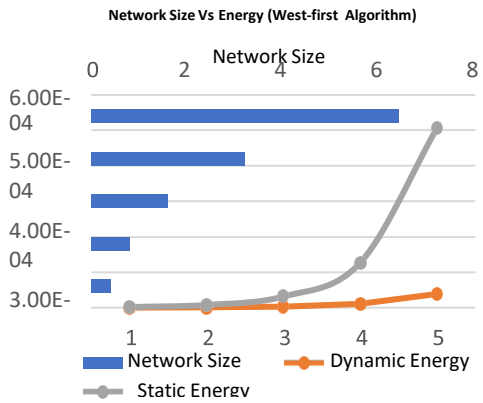


Fig -3a : Network Size Vs Energy (West- First Algorithm)

B. The Analysis of Network Throughput Vs Packet &Flit/cycle:

The several factors are included in the packet andnetwork. The Packet and Flit loss and the networkcongestion has the impact on the Network Throughput. For the Different Network size the values are taken andobserved the analysis using different parameters. The Network Throughput Vs Packet & Flit/cycle as the Network Size Increases the no. of Received Flits are increased. The Network Throughput also increased as thenetwork size increased as shown in Fig-3b.

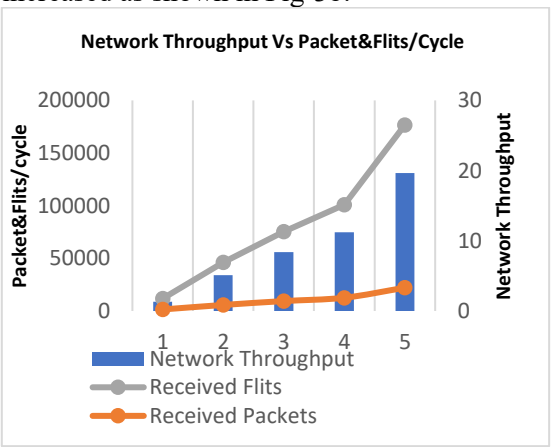


Fig -3b : Network Throughput Vs Packet & Flit /Cycle(West -First Algorithm)

C. The Impact of Delay for the different Network Size:

The Delay compared for various Network Size as shown in Fig-3c. As the Network Size Increased the Delay isvery less and later it is more as the network size is increased.

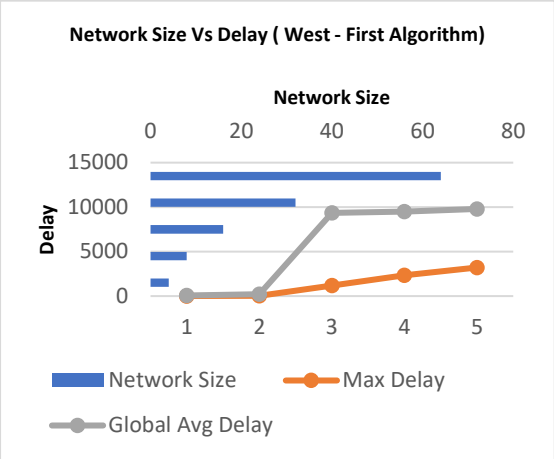


Fig – 3c : Network Size Vs Delay (West -First Algorithm)

3. North – Last Algorithm :

A. The impact of Energy for different Network Size:

The Static and Dynamic Energy compared with different Network Size as shown in Fig-4a. The Static and Dynamic Energy are linearly increased as the Network Size increases.

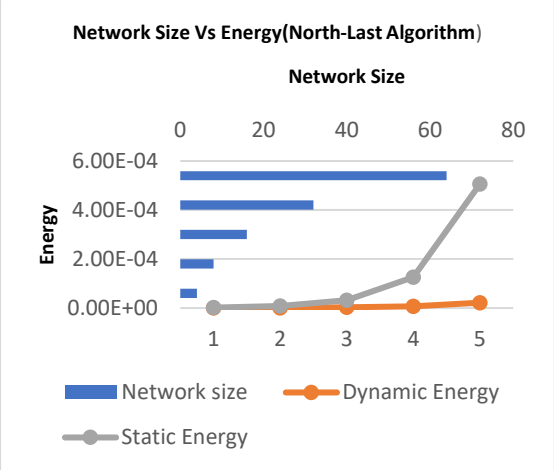


Fig -4a : Network Size Vs Energy (North-Last Algorithm)

B. The Analysis of Network Throughput Vs Packet &Flit/cycle:

The several factors are included in the packet andnetwork. The Packet and Flit loss and the networkcongestion has the impact on the Network Throughput. For the Different Network size the values are taken andobserved the analysis using different parameters. The Network Throughput Vs Packet & Flit/cycle as theNetwork Size Increases the no. of Received Flits are increased. The Network Throughput also increased as thenetwork size increased as shown in Fig-4b.

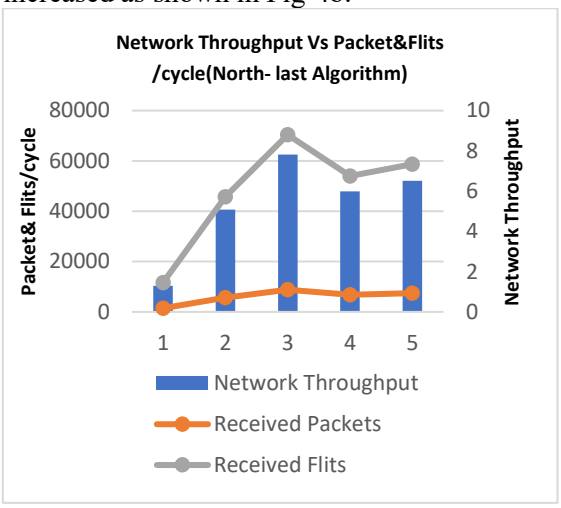


Fig -4b : Network Throughput Vs Packet & Flit /Cycle(North - Last Algorithm)

C. The Impact of Delay for the different Network Size:

The Delay compared for various Network Size as shown in Fig-4c. As the Network Size Increased the Delay isvery less and later it is more as the network size is increased.

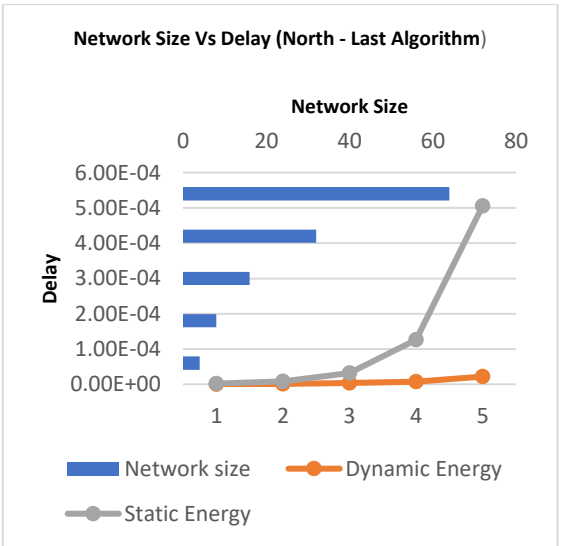


Fig – 4c : Network Size Vs Delay (West -First Algorithm)

4. Negative – First Algorithm :

A. The impact of Energy for different Network Size:

The Static and Dynamic Energy compared with different Network Size as shown in Fig - 5a. The Static and Dynamic Energy are linearly increased as the Network Size increases.

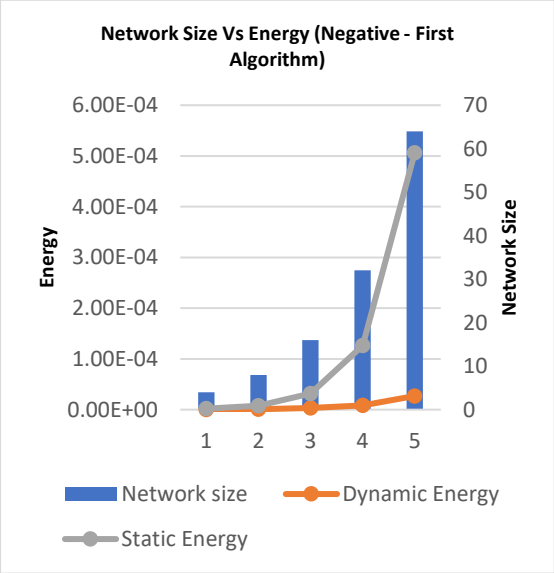


Fig – 5a : Network Size Vs Energy (Negative-First Algorithm)

B. The Analysis of Network Throughput Vs Packet &Flit/cycle:

The several factors are included in the packet andnetwork. The Packet and Flit loss and the network congestion has the impact on the Network Throughput. For the Different Network size the values are taken and observed the analysis using different parameters.

The Network Throughput increased as Network Size increases as shown in Fig – 5b.

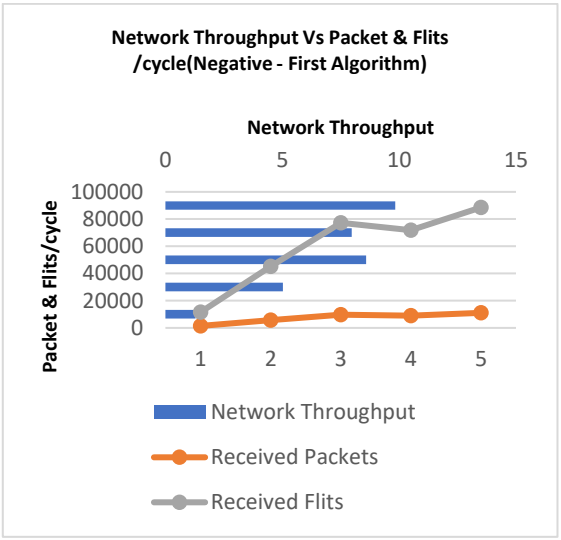


Fig – 5b : Network Throughput Vs Packet &Flit (Negative – First Algorithm)

C. The Impact of Delay for the different Network Size :

The Delay compared for various Network Size as shown in Fig - 5c. As the Network Size Increased the Delay isvery less and later it is more as the network size is increased.

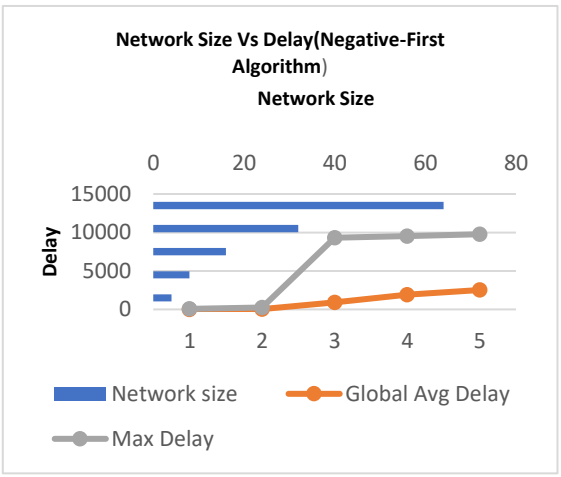


Fig – 5c : Network Size Vs Delay (Negative-First Algorithm)

5. Odd – Even Algorithm :

A. The impact of Energy for different Network Size:

The Static and Dynamic Energy compared with different Network Size as shown in Fig - 6a. The Static and Dynamic Energy are linearly increased as the Network Size increases.

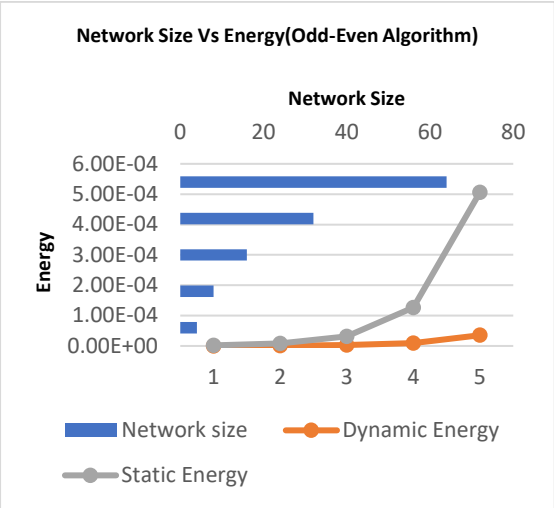


Fig – 6a : Network Size Vs Energy (Odd – Even Algorithm)

B. The Analysis of Network Throughput Vs Packet &Flit/cycle:

The several factors are included in the packet andnetwork. The Packet and Flit loss and the network congestion has the impact on the Network Throughput. For the Different Network size the values are taken and observed the analysis using different parameters.

The Network Throughput increased as Network Size increases as shown in Fig – 6b.

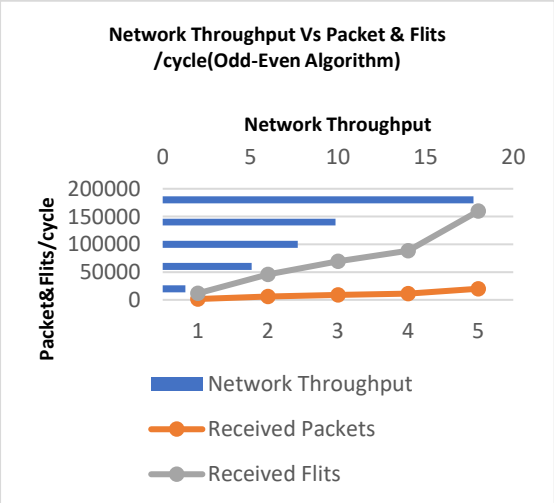


Fig – 6b : Network Throughput Vs Packet & Flit/cycle (Odd – Even Algorithm)

C. The Impact of Delay for the different Network Size :

The Delay compared for various Network Size as shown in Fig - 6c. As the Network Size Increased the Delay isvery less and later it is more as the network size is increased.

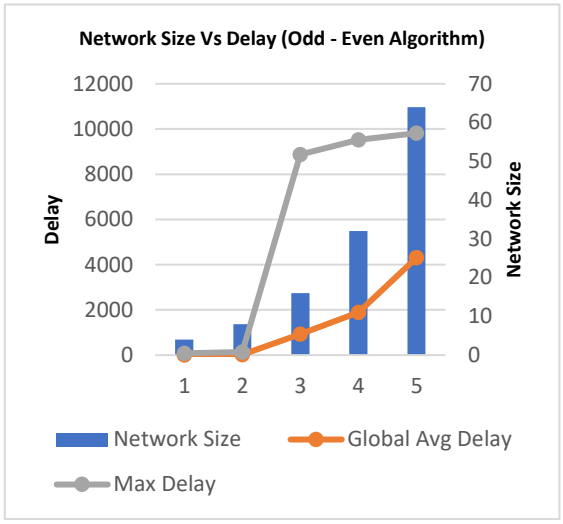


Fig – 6c : Network Size Vs Delay (Odd - Even Algorithm)

In this paper, examine the effects of five different Routing Algorithms (XY, West-first, North-last, Negative-first, Odd-Even)for the different Network Size (4x4, 8x8, 16x16, 32x32, 64x64). The various parameters like Received Packets & Flits/cycle, Network Throughput and Energy and Delay the performance of Various Routing Algorithms. As the Network Size increases the maximum delay and the global average delay is best for the XY and the West-first Routing Algorithm.

The Static Energy and Dynamic Energy for different network size the variation is slight difference the high energy is occurred at the 32x32 network size for the Static energy in the XY and Negative – First Algorithm.

The Network throughput is high for 64*64 packet size XYand west first algorithm, and odd even algorithm compared with the Received Packets & Flits per cycle. As the Network Size is increased for the west first and odd even algorithms is strong at high Max Delay.

The Static Energy and Dynamic Energy for different network size the variation is slight difference the high energy is occurred at the 32x32 network size for the Static energy in the XY and Negative-First Algorithm.

6. Network Size Vs Network Throughput :

A. The Network Throughput is higher, in the Network size 64x64 is increased. The highest

Network Throughput is achieved, by using the XY Routing Algorithm. In the West – First , as the Network Size increases the Network Throughput is increased. As shown in Fig – 7(a).

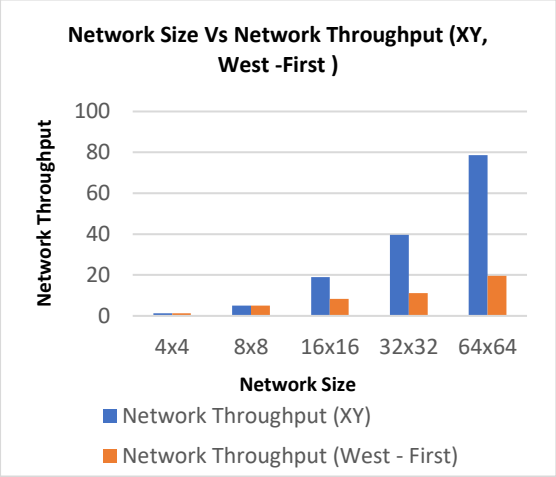


Fig – 7a : Network Size Vs Network Throughput (XY, West - First)

The Network Throughput is higher, in the Network size 64x64 is increased. The highest Network Throughput is achieved, by using the Odd – Even Routing Algorithm. As shown in Fig – 7(b).

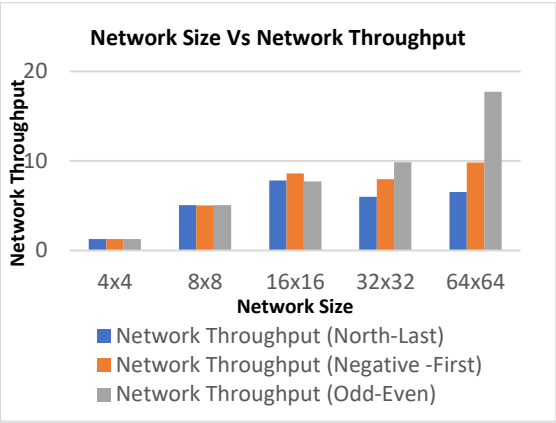
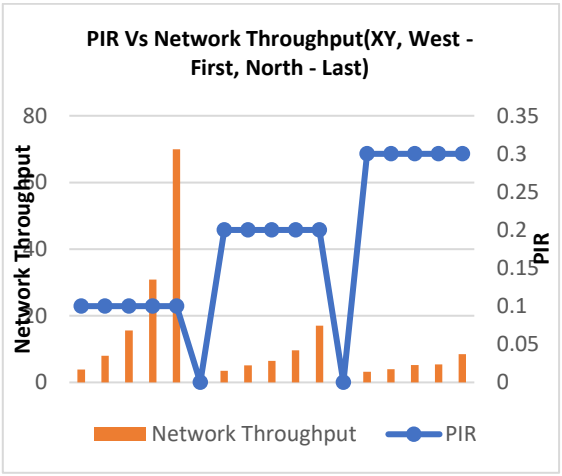


Fig – 7.6(b) : Network Size Vs Network Throughput (North – Last, Negative – First, Odd – Even Algorithm)

B. The Node's rate of injecting packets into the network is commonly referred to as its packet injection rate. The network throughput comparison of various PIR (0.1, 0.2, 0.3, 0.4)as shown in Fig - 7 (c) & 7(d).
As the PIR is increased, the network throughput increases. The Network with a higher throughput will have a more efficient system. The PIR of 0.1 and 0.2 has the highest Network Throughput.



Fig– 7(c) : PIR Vs Network Throughput (XY, West – First Algorithm, North - Last)

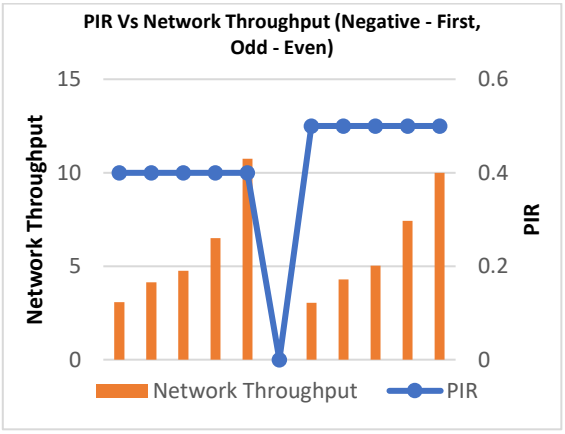


Fig – 7(d) : PIR Vs Network Throughput (Negative – First, Odd – Even Algorithm)

VI. CONCLUSION

The Simulation is one of the main tool used for the analysis of new proposals in the Network-on-Chip. The Noxim Simulator is the more accurate and near to real system. In this paper, the performance analysis of various Routing Algorithms and their effects on different Network Size (Mesh Topology).The Performance of the Various RoutingAlgorithms Parameters like Energies(Static and Dynamic Energy),Packet and Flits per cycle and Delay

(Max and Global Average Delay) for different Network Size.

The Analysis of the NoC, this Mesh type of architecture gives the best performance. The performance of NoC is evaluated by the Routing Algorithms are XY, West-first, North – Last, Negative – First and Odd – Even Algorithms.

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