International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-2, Issue-6, August 2013

Mesh Topology of NoC Architecture Using Source Routing Algorithm

Vaishali V.Ingle, Mahendra A. Gaikwad

***Abstract— NoC i.e. Network –on- Chip is one of today's emerging technology which has spread very fast to meet today's need of fast communication. Few years back the communication was based on the bus addressing but as the number of components increased to gain and achieve higher improving or modified techniques; System –on-Board (SoB) transformed to System –on-Chip (SoC) which was further transformed to NoC. In this paper, we have used West-First routing algorithm as strategy of Source routing in 2D Mesh Topology of NoC Architecture using NIRGAM* Simulator with Bursty Traffic.**

Keywords - Bursty traffic, Mesh Topology, Network-on-Chip, Source Routing Algorithm, West-First Routing Algorithm.

I. INTRODUCTION

For NoC, Topology and Routing Algorithm is one of the important criteria for achieving a better performance of NoC network communication. Although a large number of routing algorithms have been proposed in various literatures which are distinctly classified as distributed and source routing algorithms. In distributed routing, the header contains destination address only, while the path is computed dynamically by routing the packet as per path available avoiding deadlock. Whereas in case of Source Routing, the information about the whole path from the source to the destination is precompiled and provided in header. Now as the paths are precomputed offline and hence there can be no or less path adaptively in the case of faults & traffic congestion; also it has large overhead to store path information in the header, due to these reasons source routing has not been used for NoCs.[7]

Source Routing is most suitable for static networks like NoC, where network size is fixed and regular network topology like Mesh is used and path information is encoded by the small no of bits. Since it was found that two bits are sufficient to encode every hop in the path using source routing, which results in simplified router design and makes it independent of network size, which ultimately overrides the advantages on its disadvantages.

II. NETWORK TOPOLOGY

The topology of a NoC specifies the physical organization of the interconnection network. It defines how nodes, switches and links are connected to each other. Topology for NoCs can be classified into two broad categories: 1) direct network topologies, in which each node (switch) is connected to at least one core (IP), and 2) indirect network topologies, in which we have a subset of switches (nodes) not connected to any core (IP) and performing only network operation.

2D mesh is most popular topology in which all links have the same length it eases physical design and area grows linearly with the number of nodes. It must be designed in such a way as to avoid traffic accumulating in the center of the mesh. The size of topology can be specified in terms of number of rows and columns.

The Network Topology refers to the static arrangement of channels and nodes in the network. It is good if it allows to satisfy the requirements of the traffic at reasonable costs. In NoCs there are many types of proposed topologies**,** so far, such as Mesh, Torus, Star, Octagon, and SPIN. In this paper, we are using the most commonly used Mesh Topology under Source Routing.

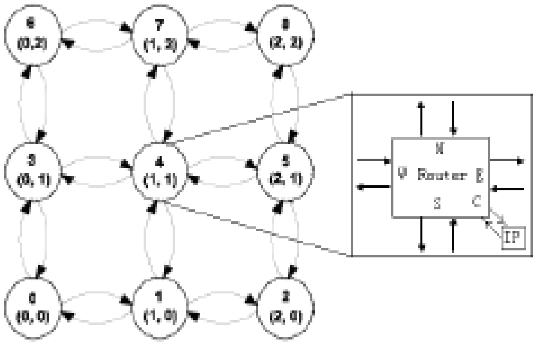

Figure1. A 2-D 3×3 Mesh Topology Network on Chip

In the Fig. 1, each circle represents a tile in the network. Each tile consists of an IP core connected to a router by a bidirectional core channel (C). A tile is connected to neighbor tiles by four bidirectional channels (N, E, S and W). Each tile is identified by a unique integer ID. Also, each tile can be identified by a pair x-coordinate and y-coordinate. Our 2-Dimesion 3X3 mesh topology NoC is designed using wormhole switching mechanism, in which packets are divided into flits. A packet consists of 3 types of flits, which are head flit, data flit and tail flit. All the routing algorithms such as XY routing algorithm, OE routing algorithm and West-First routing algorithms are based on these characteristics.

III. ROUTING ALGORITHM

Routing algorithms significantly affect the performance of a NoC. Most of the existing NoC architectural proposals advocate distributed routing algorithms for building NoC platforms. Although source routing offers many advantages, researchers avoided it due to its apparent disadvantage of larger header size requirement that results in lower bandwidth utilization. In this paper we make a strong case for the use of source routing for NoCs, especially for platforms with small sizes and regular topologies like Mesh.

Manuscript received on August, 2013.
Vaishali V. Ingle, P.G Department of Electronics, B.D College of Engineering , Sevagram,Wardha.India.
Dr. Mahendra A. Gaikwad, P.G Department of Electronics, B.D College of Engineering, Sevagram, Wardha India.

Communication performance of a NoC depends heavily on the routing algorithm used. According to where routing decisions are taken, it is possible to classify the routing as source and distributed routing [10].

A. Routing Algorithms For Source Routing

Routing algorithm which uniformly distributes the traffic shows better performance. We can use any existing distributed routing algorithm for computing paths for source routing. Both deterministic and partially adaptive routing algorithm can be evaluated for this purpose.

In source routing as in NIRGAM, it was only for deterministic routing, therefore we have carried out some modifications in the simulator and used it for partial adaptive routing algorithm that is West-First routing algorithm. The results of West-First routing algorithm proves to give better latency per packet.

B. *XY Routing Algorithm*

The XY routing algorithm is one kind of distributed deterministic routing algorithms. For a 2-Dimesion mesh topology NoC, each router can be identified by its coordinate (x, y) (Fig. 1). The XY routing algorithm compares the current router address (Cx, Cy) to the destination router address (Dx, Dy) of the packet, stored in the header flit. Flits must be routed to the core port of the router when the (Cx, Cy) address of the current router is equal to the (Dx, Dy) address. If this is not the case, the Dx address is firstly compared to the Cx (horizontal) address. Flits will be routed to the East port when Cx<Dx, to West when Cx>Dx and if Cx=Dx the header flit is already horizontally aligned. If this last condition is true, the Dy (vertical) address is compared to the Cy address. Flits will be routed to South when CY<Dy, to North when Cy>Dy. If the chosen port is busy, the header flit as well as all subsequent flits of this packet will be blocked. The routing request for this packet will remain active until a connection is established in some future execution of the procedure in this router.

The implementing of XY routing algorithm is simple. However, it is deterministic routing algorithm, which means that, this routing algorithm only provides a routing path for a pair of source and destination. Moreover, XY routing algorithm cannot avoid from deadlock appearance.

C. OE Routing Algorithm

OE routing algorithm is a distributed adaptive routing algorithm which is based on odd-even turn model. It exerts some restrictions, for avoiding and preventing from deadlock appearance. Odd-even turn model facilitates deadlock-free routing in two-dimensional (2D) meshes with no virtual channels. Explaining some definitions are necessary in order to represent this algorithm. In a two-dimension mesh with dimensions X*Y each node is identified by its coordinate (x, y). In this model, a column is called even if its x dimension element is even numerical column. Also, a column is called odd if its x dimension element is an odd number. A turn involves a 90-degree change of traveling direction. A turn is a 90-degree turn in the following description. There are eight types of turns, according to the traveling directions of the associated channels. A turn is called an ES turn if it involves a change of direction from East to South. Similarly, we can define the other seven types of turns, namely EN, WS, WN, SE, SW, NE, and NW turns, where E, W, S, and N indicate East, West, South, and North, respectively. As a whole, there are two main theorems in odd-even algorithm:

Theorem1: NO packet is permitted to do EN turn in each node which is located on an even column. Also, No packet is permitted to do NW turn in each node that is located on an odd column.

Theorem 2: NO packet is permitted to do ES turn in each node that is in an even column. Also, no packet is permitted to do SW turn in each node this is in an odd column.

OE routing algorithm is more complex than XY routing algorithm. However, it is one kind of adaptive routing algorithm. For a pair of source and destination, it can provide a group of routing paths and it can prevent from dead lock appearance [22].

D. West-First Routing Algorithm

West-First routing algorithm is one of the partially adaptive routing algorithms. It restricts at least half of the source destination communication to one minimal path while rest of the pairs can communicate with full adaptivity.

Thus, it is found, West-First routing algorithm provides less even degree of adaptiveness compared to odd-even routing algorithm. Also, it provides all possible shortest paths for the communication. If we use N, E, W ,S to represent the North, East, West and South direction. The West-First algorithm allows WS, SE, WN, NE, ES, EN turns and prohibits SW and NW turns.

For a 2-D Mesh topology, we can use (x, y) coordinates to identify each node. The Source and Destination addresses are represented as (S_{x0}, S_{y0}) ,$(D_{x0,}D_{y0})$ respectively and current address as(C_{x0},C_{y0}).

- When the source address and destination address are equal, then the packets are sent to local node.
- When the source address and destination address are not equal , the value of C_{x0} and D_{x0} must be compared i.e. when $\mathbf{C_{x0} > D_{x0}}$, the packets are sent to West channel; When $\mathbf{C_{x0} < D_{x0}}$,the packets are sent to East channel ; then if $\mathbf{C_{x0} = D_{x0}}$ compare the y coordinates;

When $\mathbf{C_{y0} > D_{y0}}$, packets are sent to North channel . When $\mathbf{C_{y0} < D_{y0}}$ **,** packets are sent to South channel but if the current coordinates are not equal to destination. coordinates , then the packet moves from **WN/WS**, to **NE/SE** ,if the current coordinates are not equal to destination coordinates , then the packet moves to **ES/EN**, but not in **SW/NW** ;hence it shows that the priority is to West direction then to East and then to North/South.

The following Fig.1. clears the idea of West-First routing algorithm.

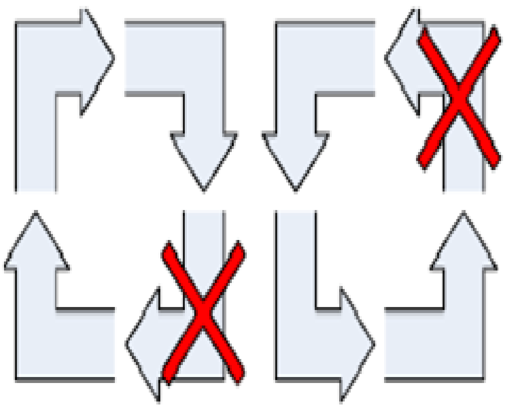

Figure 2. Allowed Turns in West-First

IV. EXPERIMENTAL RESULTS

Performance analysis of West-First routing on various network sizes i.e. 3×3,4×4 and 5×5 we have carried out , also by varying the Packet-Size and then comparing the results of three different routing algorithm i.e. XY,OE and WF.

The results we found are as follows.

Table 1 Comparison of 3×3 WF Routing Algorithm

Parameters	Latency/Flit (clock cycles)	Latency/Pkt (clock cycles)	Throughput (Gbps)	Total N/W Power
3×3	3.74272	11.22	10.4	0.189718
4×4	3.52501	10.575	11.58	0.410221
5×5	2.85674	8.57022	8.028	0.754427

The following figures gives the simulation result of WF routing algorithm of 3×3 network size, which is followed by the graphical representation of Table 1.
The simulation result of Fig. 3. represents latency/flit, Fig.4. represents latency/packet,whileFig.5 represents Throughput Fig.6. Represents total network Power.

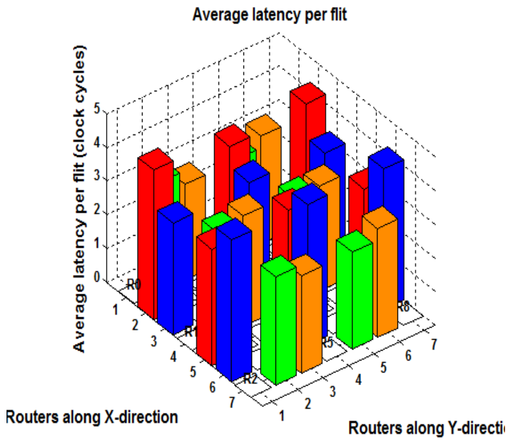

Figure 3. Latency/flit of 3×3 WF Routing Algorithm

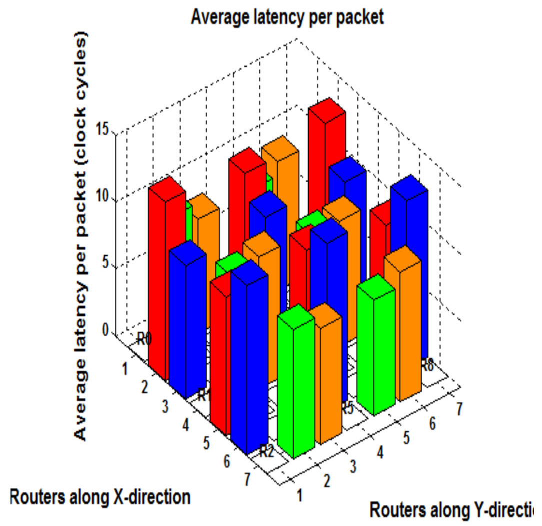

Figure 4. Latency/packet of 3×3 WF Routing Algorithm

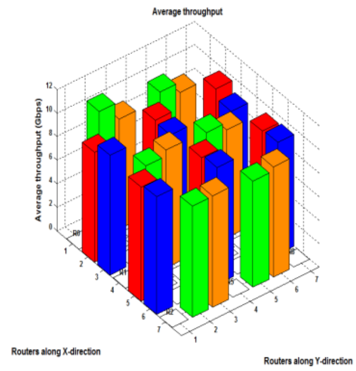

Figure 5. Average Throughput of WF 3×3 Routing Algorithm

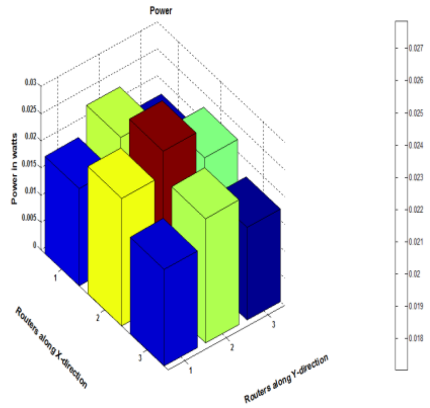

Figure 6. Total N/W Power of WF 3×3 Routing Algorithm

The graphical representation of Table1. is shown below

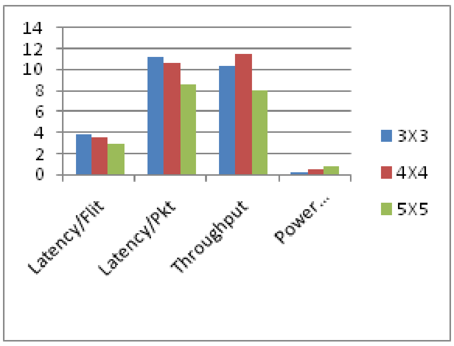

Figure 7. Graphical representation of WF Routing Algorithm of different network sizes.

From the above figure it is clear that as network size increase Latency/flit, Latency /packet and Throughput decreases.

Table 2 WF routing algorithm for different packet sizes.

Pkt size	Latency/ Flit	Latency/ Pkt	Through put
8	3.74	11.228	10.4
16	5.04539	25.227	10.57
32	3.72	33.528	9.387
64	2.80728	47.7237	8.6
128	1.44	47.7006	7.9275

The table 2 shows that as the packet-size increases Latency/Packet increases while as the number of flits increases with Packet-size, it causes the reduction in Latency/flit and that increase the time interval of the packets reaching the destination which causes reduction in Throughput.

The Fig. 8 shows the graphical representation of the Table 2.

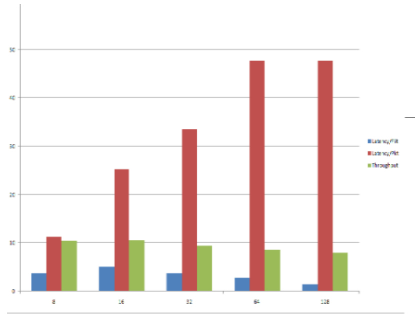

Figure 8. Graphical representation of WF Routing Algorithm of different Packet-size.

The table 3 below shows the comparison of three different routing algorithms in terms of Latency/flit, Latency/packet, Throughput and Total n/w Power.

Table 3 Comparison of XY, OE and WF Routing Algorithm for 3×3 N/W size

Routing Algorithm	Latency/ Flit	Latency/ Pkt	Throughput	Power consumption
XY	3.7262	11.1786	10.22	0.186509
OE	3.91182	11.73	11.51	0.210628
WF	3.74272	11.22	10.4	0.189718

V. CONCLUSION

The paper represents the performance of West-First Routing Algorithm with variation of packet-size and of different network sizes. It has been observed that as network size increases, Latency/flit decreases with a factor of 0.2 to 0.9. Latency /packet decreases by 0.65 to 2.65 and Throughput also decreases nearly by a factor of 2.

With the increase in Packet-size, Latency/Packet increases by factor of 11, whereas, Latency/flit decreases with a factor of 0.9 and Throughput decreases nearly by 0.7 to 0.9.

The comparison results in Table 3 show that in context to Latency/flit and Latency /packet West-First proves to be best compared to XY by 0.7 and 2.21 respectively and OE by 2.79 and 8.09 respectively. Whereas, in case of Throughput XY proves to be the best by 0.7 as compared to West-First routing Algorithm.

References:

[1] Mikael Milberg et.al, Priority Based Forced Requeue to Reduce Worst-Case Latencies for Bursty Traffic Proceedings of the Conference on Design, Automation and Test in Europe 2009 Pages 1070-1075

[2] Wang Zhang et.al, Comparison Research between XY and Odd-Even Routing Algorithm of a 2-Dimension 3x3 mesh Topology Network –on –Chip" 2009 IEEE computer society

[3] Naveen Choudhary, *Bursty Communication Performance Analysis of Network-on-Chip with Diverse Traffic Permutations*" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012

[4] Jan Ho Bahn et.al, On Design and Analysis of a Feasible Network-on -Chip(NoC) Architecture 2007 International Conference on Digital Object Identifier

[5] Chuggani R et.al, Traffic Model for Concurrent Core Task in Network on Chip" IEEE 2011.pages:205-210

[6] NIRGAM Manual: A Simulator for NoC Interconnect Routing and application Modeling Version 1.1

[7] Saad Mubeen, *Evaluation of source routing for mesh topology network on chip platforms, Master of Science Thesis, 2009.*

[8] Dally W.J et.al, "Route packets, not wires: on-chip interconnection networks, in Design Automation. Conference, Las Vegas, Nevada, USA, 2001, pp. 684-689.

[9] Dally W.J. and Towles B., Principles and Practices of Interconnection Networks", Morgan Kaufmann Publishers an Imprint of Elsevier Inc, 2004.

[10] Lalit Kishore Arora, et.al. *Simulation and Analysis of Packet loss in Mesh Interconnection Networks*, IJARCSSE Proceedings on (DRISTI 2012), DRISTI (1):35 - 38, April 2012. ISB

[11] Axel Jantsch et.al, *Networks on Chip, Kluwer Academic Publishers*. 2003.

[12] Kavaldjiev N et. Al, *Routing of guaranteed throughput traffic in a network-on-chip".* Available at: http://doc.utwente.nl/54538/.

[13] Mubeen S., et.al, Designing Efficient Source Routing for Mesh Topology Network on Chip Platforms IEEE 2010Page(s): 181 - 188

[14] Paliwal, K.K.; et.al, Performance Analysis of Guaranteed Throughput and Best Effort Traffic in Network-on-Chip under Different Traffic Scenario, IEEE 2009, Page(s): 74 - 78

[15] Wang Zhang The Buffer Depth Analysis of 2-Dimension Mesh Topology Network-on-Chip with Odd-Even Routing Algorithm. IEEE 2009 Page(s): 1 - 4

[16] A.Hemani, et.al, Network on a chip: architecture for billion transistor era, Proc. IEEE NorChip, 2000.

[17] Lalit Kishore Arora, et.al, *Performance Evaluation of mesh with source routing for Packet Loss.*" IJ ARCSSET Volume-1, Issue-5, August 2012

[18] Benini L., Micheli G.D., Networks on chips: a new SoC paradigm , IEEE Computer Society, 2002.

[19] Pan Hao, et.al, Comparison of 2D MESH Routing Algorithm in NoC, IEEE 2011

[20] Parag Parandkar, et.al, *Performance Comparison of XY, OE and DY Ad Routing Algorithm by Load Variation Analysis of 2-Dimensional Mesh Topology Based Network-on-Chip."*BVICAM's International Journal of Informatiom Technology ©Jan2012

[21] Saad Mubeen, et.al, "*On Source Routing for Mesh Topology Network on Chip.* 9th Swedish SoC Conference, Swedish Chapter of IEEE SSCS

[22] Mirza-Aghatabar, et.al ,An Empirical Investigation of Mesh and Torus NoC Topologies Under Different Routing Algorithms and Traffic Models, IEEE 2007,Pages: 19-26.