Performance Evaluation of Turn Model based Routing using LBDR

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ABSTRACT
On single silicon chip, the growing availability of number of resources is enforcing the designers to come up with mechanisms for effective and efficient management of these resources on a chip. Network-on-Chip (NoC) is used for high-speed inter-node communication inside a System-on-Chip (SoC). The routing algorithm is one of the key components in NOC architecture that decides the performance of the network. The routing algorithm is used to find the path taken by a packet between the source and the destination.

In this paper, we have compared the turn model based routing algorithms (West-First, Negative First, North last and Odd-Even routing) using Logic Based Distributed Routing (LBDR) technique in 2D Mesh Topology. Performance comparison is done using NIRGAM Simulator with CBR Traffic with different packet size.

Keywords
West-First Routing, Negative-First Routing, North-Last Routing, Odd-Even Routing, LBDR, Network-on-Chip.

1. INTRODUCTION
As per Moore's Law, the packing density of deep sub-micron technology doubles in every 18 months, leading to increased research interests in the field of network-on-chip (NoC) interconnection paradigm that provides scalability, suitability and flexibility in designing efficient SoCs. NoC is new communication mechanism inside the SoC [7]. Single core architectures replace with the multi core architecture has been introduced in industries for designing high performance systems. According to the International Technology Roadmap for Semiconductors (ITRS) [1], we will be entering the era of a billion transistors on a single chip before the end of this decade. Increase the processing elements (PE) integration on single chip routing algorithm is tedious task. Routing algorithm is a key factor for achieving a better performance of network communication of the NoC. Different types of routing methodologies such as distributed routing and source routing [8] are available for both regular and irregular NoC topologies. In distributed routing each router receives a packet and decides the output direction to send it, while source routing decided the whole path at the source router and store all information in header.

According to how a path is computed to transmit packets, routing can be classified as adaptive or deterministic. Deterministic routing algorithm always selects the same pathway between a pair of nodes. Adaptive routing algorithm to make routing decision uses information about the network's state. Some routing algorithm uses the turn restrictions for packet route for nodes. Glass and Ni [3] proposed the turn model based adaptive routing. Prohibiting the turns to break all of the cycles produces routing algorithms that are deadlock free. Three partially adaptive routings are West-First, Negative First and North Last.

In this paper, we have performance evaluation of turn model based routing using LBDR in the research literature of NOC domain. The rest of paper is organized as follows: section II shows Logic based Distributed Routing (LBDR), a routing implementation in NoC. Section III briefly presents the turn model based routings. Experimental results and analysis describe in section IV, in section V we conclude.

2. LBDR: A BACKGROUND
All Logic based distributed routing (LBDR) [2] is recently proposed as an alternative solution for routing implementation in NoC. LBDR is a simple methodology of routing that enables the removal of the routing tables at every switch and uses only a small set of bits per switch to enable efficient routing. It is provide a simple, flexible and compact way to represent the topology, and deadlock free routing. In this routing scheme, 12 bits for each router. In 12 bits, 4 bits are used for connectivity bits for neighboring nodes and remaining bits are used for routing restriction (each direction used two restriction bits). LBDR mechanism divided in two parts. First part computes the relative position of destination corresponding to source or current node using two comparators. The output of this first part computation one or two signals may be active. The second part consists of four logic units. One logic unit for each output port. Each one can be implemented with only four AND gates, one OR gate and two inverters. Surveys different variations of efficient LBDR proposed in [11]. In this paper LBDR technique used for turn model based West-First (WF), Negative First (NF), North-Last (NL) and Odd-Even (OE) routing algorithms.

3. TURN MODEL BASED ROUTING ALGORITHMS
Effective routing algorithms are required to enhance the communication performance of NoC architecture. A lot of distributed routing algorithms for NoC have been proposed in literature [4][5][6].In this section we emphasize on turn restriction based algorithms which are used in 2D Mesh topology. Turn restriction in topology means few turn are restricted for communication between source to destination and prevent from deadlock. All turn model based routing algorithms are deadlock free and turns are shown in Figure 1(a). Turn model based West First (WF), Negative First (NF), North Last (NL) and Odd-Even (OE) routing algorithms are discussed in the following subsections

3.1 XY Routing Algorithm
XY routing algorithm is one of the simplest, deterministic and most commonly used routing algorithms used in NoC. In XY routing four turns are restricted out of eight in Mesh topology.

In this algorithm a packet routed first in X axis or horizontal of mesh and then routed along with Y axis or vertical and towards the destination resource. Four restricted turns are north to east, north to west, south to east and south to west. All restricted turns in XY routing algorithm are shown with cross (see Figure 1(b)). Routing restriction in LBDR technique are Rnw, Rne, Rse and Rsw are set to zero and remaining turn sets to one.

3.2 West First Routing Algorithm

West-First routing (WF), route a packet first west (if necessary) and then adaptively south, east and north. It is one of the partially adaptive routing algorithms. In this routing algorithm restricts North-West or South-West turn at any node in mesh topology. Figure 1(c) shows one way to prohibit two turns [3] in a 2D-mesh. Routing restriction in LBDR technique is Rnw and Rsw are restricted. West-First routing algorithm provides less even degree of adaptiveness compared to odd-even routing algorithm.

For a 2-D Mesh topology, we can use (x, y) coordinates to identify each node. The Source and Destination addresses are represented as (Xsrc, Ysrc), (Xdest,Ydest) respectively and current address as(Xcu,Ycu).

1. If the source and destination address are equal then packet are sent to core node(C).
2. If both address are not equal Xcu and Xdest must be compare, if Xcu>Xdest then packets are sent to West (W) channel else, the packets are send to East (E) channel.

If (Xcu==Xdest) then if Ycu>Ydest, packets are send to North (N) else packets are send to South (S) channel..

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3.3 Odd Even Routing Algorithm

Chiu [5] proposed routing algorithm, in which nodes in odd columns and even columns restrict different sets of turns. It is a partially adaptive routing algorithm. Figure 1(f) shows a restricted turns in odd columns and Figure 1(g) shows a restricted turns in even columns. Odd-Even routing (OE) restricts the turns from north to west and south to west at any node in an odd column. It also restricts the turns from east to north and east to south at any node in an even column. Routing choice of the OE turn model better than those of the original turn model proposed by Glass and Ni [3].

3.4 Negative First Routing Algorithm

Negative First routing (NF) is a partially adaptive routing algorithm. The restricted turns are the two from a positive direction to a negative direction. It restricts East-South or North-West turn at any node in the mesh topology. Negative-First routing [3] defined as travel a packet first adaptively west and south, and then adaptively east and north. Restrictions in Negative First routing algorithm are shown below (see Figure 1(e)).

3.5 North Last Routing Algorithm

It is partially adaptive routing algorithm. The restricted turns are the two when travelling North Channel. Therefore, a packet should only travel north when that is the last direction it needs to reach at destination node. It restricted North-East or North-West turns at any node in the mesh topology. Restrictions in North Last Routing Algorithm [3] are shown in Figure 1(d).

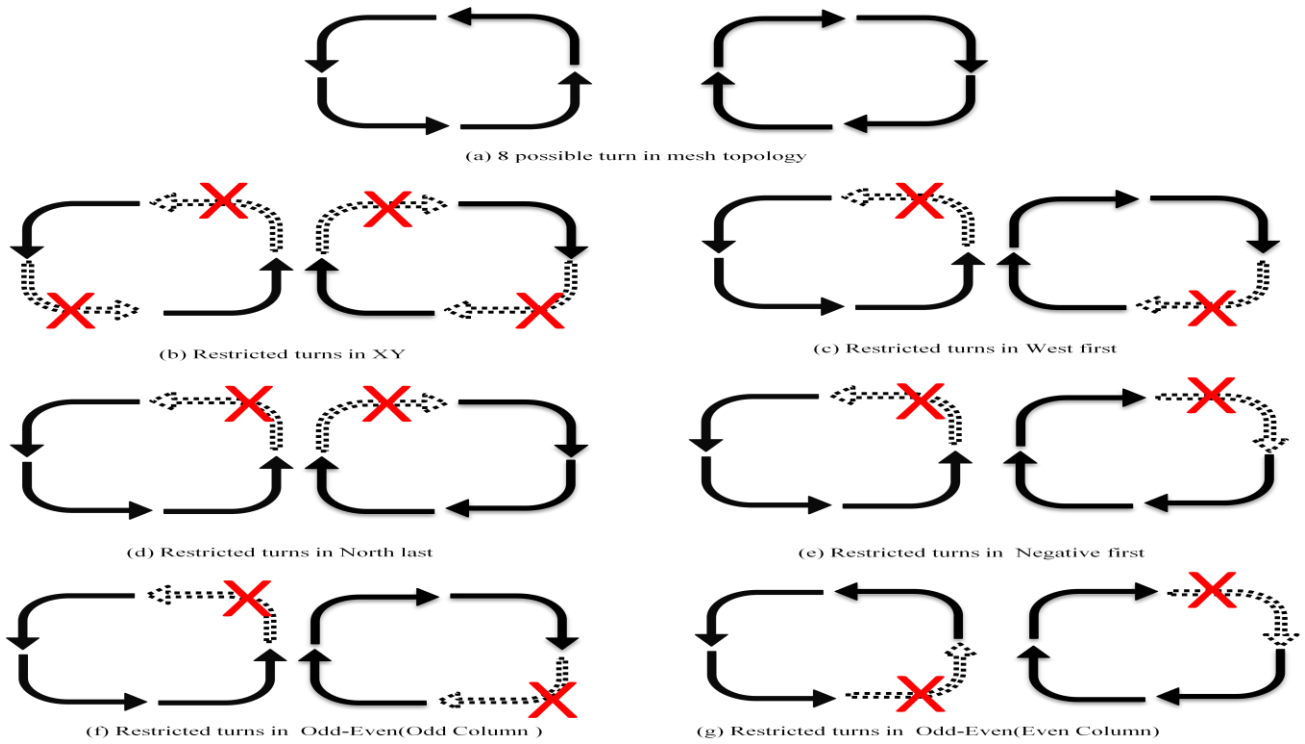

Fig 1: Restrictions in Turn Model Based Routings in Mesh topology (dotted Arrows with cross)

4. EXPERIMENTAL RESULTS

All the simulations are done using the NIRGAM [9][10] simulator with CBR fixed traffic. Performance analysis of Turn model based routing on network sizes i.e. 4×4 we have carried out, also by varying the Packet-Size and then comparing the results of five different routing algorithms i.e. XY, WF, OE, NL and NF.

The results we found are as follows

Table 1. Comparison of XY, WF, OE, NL and NF Routing Algorithm for packet size 8

Routing	latency per channel (cycles/flit)	latency per channel (cycles/ packet)	Network Power (In Watt)
XY	3.14602	9.43806	0.229456
WF	3.14602	9.43806	0.229456
NL	3.14602	9.43806	0.229456
NF	5.42051	16.2615	0.189448
OE	4.91958	14.7587	0.180172

The following figures 2 gives the simulation result of all five turn model based routing algorithm of 4×4 network with 16 packets fixed traffic using LBDR mechanism. Routing algorithms such as XY, WF and NL are depicts same results, because WF and NL are following the same turns that are restricted in XY routing. NF and OE use more latency compare to rest three routings. Figure 2 shows the graphical representation of Table 1.

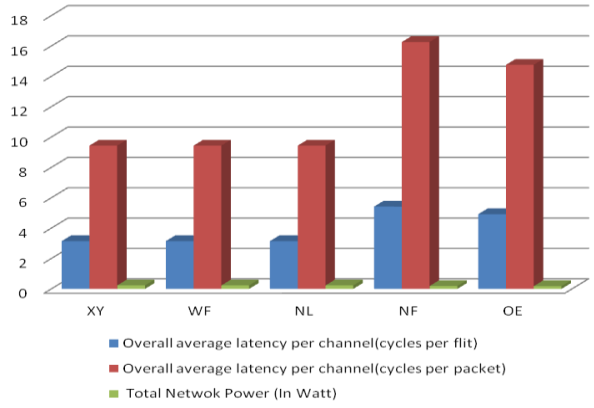

Fig 2: Performance, power consumption of XY, WF, OE, NL and NF Routing Algorithm for packet size 8

Table 2. Comparison of XY, WF, OE, NL and NF Routing Algorithm for packet size 16

Routing	latency per channel (cycles/flit)	latency per channel (cycles/ packet)	Network Power (In Watt)
XY	1.69304	8.46521	0.268464
WF	1.69304	8.46521	0.268464
NL	1.69304	8.46521	0.268464
NF	2.84136	14.2068	0.210057
OE	2.49053	12.4526	0.212679

The following figures 3 gives the simulation result of all five turn model based routing algorithm of 4×4 network with 16 packets fixed traffic using LBDR mechanism. NF and OE use more latency compare to rest three routings. Figure 3 shows the graphical representation of Table 2.

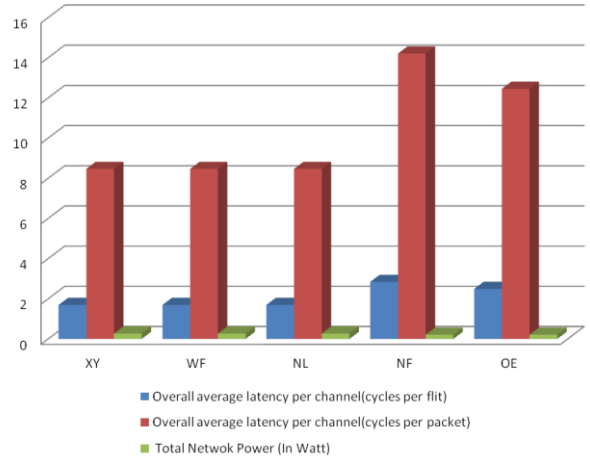

Fig 3: Performance, power consumption of XY, WF, OE, NL and NF Routing Algorithm for packet size 16

5. CONCLUSION

This paper represents the performance evaluation of turn model based routing algorithm with variation of packet-size. The comparison results in Table 1 and Table 2 show that in terms of Latency/flit, Latency/packet and Network Power in West-First, XY and North Last are less than the Odd-Even and Negative–First.

6. ACKNOWLEDGMENTS

It is matter of great pleasure for me to submit this paper on "Performance Evaluation of Turn Model Based Routing using LBDR", as a part of my thesis work for the award of degree of "Master of Technology". I am thankful to Dr. Naveen Choudhary, H.O.D. CSE Department, for his constant encouragement and guidance. I take this opportunity to express my deep sense of gratitude towards Ms. Shalini Dutt, who has helped me in various ways.

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