Review of Odd Even Routing Algorithm for 2D Mesh Topology of Network-on-Chip Architecture for Bursty Traffic

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ABSTRACT
Network-on-chip (NoC) has been introduced as a new paradigm to solve System on chip (SOC) design challenges. The Network-on-Chip (NoC) architecture as a viable solution to the complex on-chip communication problems. Communication performance of NOC's is heavily depends on routing algorithm. The architecture of NOC is based on topology, routing algorithm and switching techniques. The routing algorithm is one of key ingredient in NOC architecture. A routing algorithm determines how the data is routed from sender to receiver The routing algorithm are Source, deterministic XY routing algorithm, adaptive Odd-Even (OE) routing algorithm with deadlock-free ability. This paper presents review of Odd-Even (OE) routing algorithm on 2D Mesh topology of NOC architecture for bursty traffic.

Keywords
Network-on-chip; OE routing algorithm; 2D Mesh Topology, Bursty Traffic, Nirgam Simulator.

1. INTRODUCTION
The growing interest in network-on-chip can be explained by looking IC technology and at the ever increasing demands of Electronic system design. The progress in the VLSI design technology and the large number of transistors obtainable on a single chip permit designers to fabricate complex SoCs with hundreds of IP blocks. The IP's can be CPU or DSP cores, memory blocks, or ASICs. Network on Chip (NoC) is a new paradigm for System on Chip (SoC) design. Increasing integration produces a situation where bus structure, which is commonly used in SoC, becomes blocked and increased capacitance poses physical problems.In NoC architecture traditional bus structure is replaced with a network which is a lot similar to the Internet. Data communications between segments of chip are packetized and transferred through the network. The network consists of wires and routers. Processors, memories and other IP-blocks (Intellectual Property) are connected to routers. A routing algorithm plays a significant role on network's operation. Routers make the routing decisions based on the routing algorithm. Intellectual Property (IPs) in a NoC are connected by switches/routers and network channels, and information over the NoC is communicated in the form of packets. W.J.Dally and B.towels authors discusses in that paper on-chip interconnection networks said "Routes are packets,not wires"[1] Figure 1. gives a 4x4 2D Mesh topology . Each router is connected with an IP core. Except the outside edge node, each node is connected with four nodes.

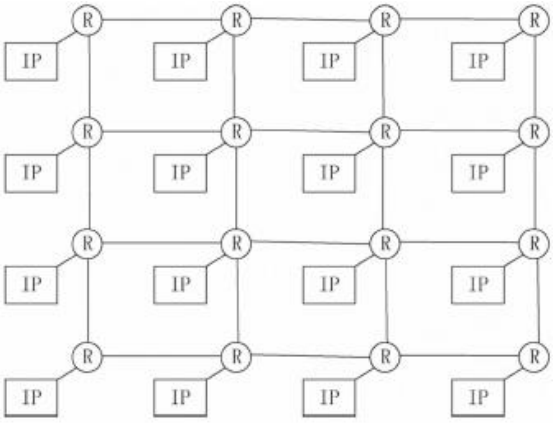

Figure 1. 4×4 of 2D Mesh Topology

To determine NOC topology structure, the means of communication between IP cores will greatly impact network performance. The routing algorithm is key factor which affects NOC network communication. In this paper OE routing algorithm is used which gives limits on the possible shift position of packets to avoid the happening of deadlock.

2. OVERVIEW OF NOC DESIGN APPROACH
The design of a NoC based on Switching technique, topology, Routing algorithm and traffic.

2.1 Switching Technique
There are two major switching techniques: circuit switching and packet switching. Circuit switching establishes a link between source and destination node either virtually or physically before a message is being transferred. Major advantages of circuit switching are that there is no contention delay during message transmission and its behavior is more predictable. In packet switching, messages are divided into packets at the source node and then sent into a network. Packets move along a route determined by the routing algorithm and traverse through a series of network nodes and finally arrive at the destination node. Packet switching is utilized in most of NoC platforms because of its potential for providing simultaneous data communication between many source-destination pairs. Packet switched networks can further be classified as Wormhole, Store and Forward (S&F), and Virtual Cut Through Switching (VCT) networks. In Wormhole switching networks, only the header flit experiences latency. Other flits belonging to the same packet simply follow the path taken by the header flit. If the header flit is blocked then the entire packet is blocked. It does not require any buffering of the packet. Therefore, the size of the chip drastically reduces.

2.2. Mesh Topology

Topology defines how nodes are placed and connected, affecting the bandwidth and latency of a network. Many different topologies have been proposed [8], such as mesh ,torus, mixed and custom topology. Some researchers have proposed the application-specific topology that can offer superior performance while minimizing area and energy consumption [9].

A mesh-shaped network consists of m columns and n rows. The routers are situated in the intersections of two wires and the computational resources are near routers. Addresses of routers and resources can be easily defined as x-y coordinates in mesh. Mesh topology is easy to implement as all nodes are in equally distance as shown in Figure 2.

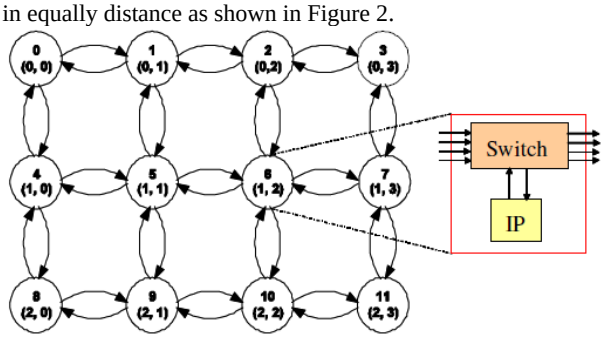

Figure 2. Mesh Topology

[3] Researcher using simulation evaluate the performance of adaptive routing algorithm to deterministic routing strategy respected to throughput, power consumption and latency. The simulation environment is 2D-mesh based NoC topology including different kinds of mapping video object plane decoder (VOPD) application onto this architecture. The experiment results prove the adaptive routing performance under network congestion occurrence

2.3. Routing Algorithm

Routing algorithms are used to determine the sequence of channels a message packet traverses from the source to the destination. Routing algorithm is a key factor which affects the efficiency of the communication of NoC. According to where routing decisions are taken, it is possible to classify the routing in source and distributed routing [4]. In source routing, the whole path is decided at the source router, while in distributed routing each router receives a packet and decides the direction to send it. According to how a path is defined to transmit packets, routing can be classified as deterministic or adaptive. The routing algorithms can be classified based on their adaptability, fault-tolerant capability, a centralized controller controls the data flow in a system and depends on the number of destination. XY Routing algorithm is simple, distributed deterministic routing algorithm. OE routing algorithm is a distributed adaptive routing algorithm which is based on odd-even turn model [10].

2.3.1. Odd-Even Routing Algorithm

OE routing algorithm is Adaptive routing algorithm based on odd-even turn model, so that its free from Deadlock. OE algorithm is shortest path routing Algorithm. In odd-even turn model, column is even if its x-coordinate is even and similarly for odd if its x-coordinate is odd. According to Odd-even turn model, In a two-dimension mesh with dimensions X*Y each node is identified by its coordinate (x, y) [10]. 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. Turn is a 90-degree turn. There are eight types of turns, according to the traveling directions of associated channels (row or column).EN, WS, WN,SE, SW, NE, and NW turns, where E, W, S, and N indicate East, West, South, and North. There are two main theorems in odd-even algorithm:

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

Theorem 2: No packet is permitted to take ES turn in each node that is in an even column. Also, no packet is permitted to take SW turn in each node which is in an odd column.

3. BURSTY TRAFFIC

Bursty traffic is represented by alternating on and off periods. During on period, packets are generated in fixed intervals. During off period, no packets are generated. Traffic is characterized by the following exponentially distributed variables[16]:

- Burst length - Number of packets in a burst (on period)
- Off time - Interval between two bursts

Configurable parameters for Bursty traffic are as follows:

- Packet size (in bytes)
- Load percentage (percentage of channel bandwidth to be used)
- Destination - User can specify a fixed destination or randomly chosen destination
- Inter-flit interval (in clock cycles)
- Average burst length (in number of packets)
- Average off time (in number of clock cycles)

Different authors performed simulation using Odd-even routing algorithm for 2d mesh topology of network-on-chip architecture. Following is review of presented papers

Su Hu has developed[4] a Symmetric Odd-Even Routing Model in Network-on-Chip in which he present an improved OE model called Symmetric Odd-Even Model provides higher level of adaptiveness and uses central deadlock buffers to avoid deadlock Simulation results shows performance improvement in terms of network saturation throughput and package latency by 18 and 25 percent.

Wang Zhang has proposed [5] network on chip architecture with 2-demention mesh topology, odd-even routing algorithm, wormhole switching technique and only input buffers. NOC architecture is evaluated based on metrics of latency and throughput per channel under Constant Bit Rate (CBR) and Bursty traffic. Evaluation results reveal that the average latency of whole network channels is 1.97 cycles under CBR traffic and 1.92 cycles under Bursty traffic. The average throughput of whole network channels is 8.8555 Gbps under CBR traffic and 8.8212 Gbps under Bursty traffic..

Wang Zhang has [6] analyses the buffer depth of 2-dimension mesh topology NoC with odd-even routing algorithm based on NoC interconnect routing and application modeling (NIRGAM) simulator. The analysis results reveal that the optimized input first-in-fist-out (FIFO) buffer depth of virtual channel has not relationship with network scale for 2-dimension mesh topology NoC at constant bit rate (CBR) traffic condition.

Marjan Morvarid, Reza Berangi, Mahmood[7] In this paper,author present a multipath routing scheme which is called DPOE (Dual Path Odd-Even). Author had chosen OE turn model as base algorithm. Multipath routing allows the establishment of multiple paths between a single source and single destination node. It is typically proposed in order to provide load balancing. In this paper, using allowed defined

rotations in Odd-Even adaptive algorithm. packets are sent through two different paths and by employing a new selection policy, which is specifically for multi-path methods, they provided load balancing and improve efficiency of the network. For implementing algorithm author used open source simulator called NOXIM which is System C simulator of mesh based NOC. Simulation carried out on 8×8 mesh NOC. By comparing simulation results, it will be observed that this method, under transpose and random traffic patterns, will significantly perform better than other methods Performance measured in terms of Avg. Packet delay(cycles) and avg Throughput(flit/cycle) over Packet injection rate(packets/cycle).DPOE completely prevents deadlocks by using OE admissible turn and there will be no need of other deadlock prevention methods.

Ge-Ming Chiu[10],The objective of this paper to present the odd-even turn model for designing partially adaptive wormhole routing algorithms without adding virtual channels. The model restricts the locations where some turns can be taken so that deadlock is avoided. Simulation carried for xy algorithm, west-first algorithm, negative-first algorithm, even odd algorithm. Performance of the algorithms measured for avg. communication Latency and Throughput.

Naveen Choudhary[11] ,in this paper author analyzed the performance of standard 2D mesh NOC is for bursty communication traffic for various traffic or topology mapping patterns such as butterfly, transpose etc over a NOC simulation framework. The routing for the NoC is assumed to be XY and OE. It is observed that the communication performance of the 2D-mesh based NoC for bursty traffic is deeply affected by the varying traffic permutation for the used routing function Which basically helps us conclude that if appropriate traffic permutation are chosen for the bursty traffic in accordance to the routing function may lead to major gain in communication performance of the NoC.

Minghua Tang[13] conducts case study of the Odd-Even Turn model which is an adaptive routing algorithm for the NoC. Simulation results show that congestion happens in a local region more seriously.

Table. 1 .comparison of the main simulation performance parameters between XY and OE routing algorithm
Source : Pan Hao,Hong QiI,Du Jiaqin,Pan Pan," Comparison of 2D MESH Routing Algorithm in NOC"

	A maximum value of though channels	A minimum value of through channels	Network average value of XY routing algorithm	Network average value of OE routing algorithm
Packet delay(clock cycle)	6.5	5	5.4667	5.4118
Flits delay (clock cycle)	2.1667	1.6667	1.8222	1.8039
Throughput (Gbps)	20.1342	10.2041	11.549	13.7230

Some authors made comparison between different routing algorithms to observe which routing algorithms is better.

Pan Hao,Hong QiI,Du Jiaqin,Pan Pan[14] .In this paper author purposed NOC is to solve the choke point in communication and the clock problem from architecture. Each in NOC includes some routers, and it takes a few clock periods by passing a router. When the network is in congestion , the package transmission will produce much more time delay. So adopting a appropriate routing algorithm to get the balance between the time delay and throughput rate becomes the key problem. Researcher done some research on XY and OE algorithms based on the 4x4 mesh topology by using NIRGAM emulator. The result shows that the ratio of throughput rate and package time delay is 2.5358 in OE routing algorithm, which is larger than 2. 1126 in XY routing algorithm, and it proves that the OE routing algorithm is better to Mesh topology than XY routing algorithm[13].

Wang Zhang, Ligang Hou, Jinhui Wang, Shuqin Geng, Wuchen Wu" In this paper, researcher demonstrated the two routing algorithms in details at first. XY routing algorithm and OE routing algorithm are then simulated and compared based on a 3X3 mesh topology NoC with NIRGAM simulator.The simulation results show that OE routing algorithm, P= Average Throughput of Network/ Average Latency per packet of Network whose P parameter equals to 1.09, increases P parameter greatly as compared to XY routing algorithm, whose P parameter equals to 0.86, in a 2-dimension 3X3 mesh topology NoC, with Constant Bit Rate (CBR) traffic condition of each tail. If value of parameter P is larger, the performance will be better. P(XY)= 0.86 and P(OE)=1.09. Thus, OE routing algorithm better than XY routing algorithm[14].

Parag Parandkar, Jayesh kumar Dalaland ,Sumant Katiya[15], authors performed Comparison of XY, OE and DYAd Routing Algorithm by Load Variation Analysis of 2D Mesh Topology Based Network-on-Chip in which three algorithms used XY, OE, DyAD. simulation is performed on NIRGAM NoC simulator version 2.1 for constant bit rate traffic condition. The simulation results reveals the dominance of DyAD over XY and OE algorithms depicting the minimum values of overall average latency per channel (in clock cycles per flit) as 1.58871, overall average latency per channel (in clock cycles per packet) as 9.53226, overall average latency (in clock cycles per flit) as 26.105, and total network power as 0.1771 milliwatts, achieved for DyAD routing algorithm. it is concluded that compared to both deterministic and adaptive routing, significant performance improvements in terms of total network power as well as overall average latency can be achieved by using the DyAD approach for constant bit rate traffic conditions.

4. SIMULATION PLATFORM

NIRGAM[16] is a discrete event, cycle accurate simulator targeted at Network on Chip (NoC) research. NIRGAM is a joint effort by people from Electronic Systems Design group, School of Electronics and Computer Science, University of Southampton UK and Department of Computer Science and Engineering, Malaviya National Insitute of Technology, Jaipur India. Original software is developed by Lavina Jain. NIRGAM Simulator works in LINUX operating system..It provides substantial support to experiment with NoC design in terms of routing algorithms and applications on various topologies. NIRGAM is an extensible and modular system C based simulator. It allows to experiment with various options available at every stage of NoC design: topology, switching technique, virtual channels, buffer parameters, routing mechanism and applications. The simulator can output performance metrics (latency and throughput) for a given set of choices.

5. CONCLUSION

From different routing algorithm such as XY,OE and Source routing algorithms, This paper proposes OE routing algorithm because observed that comparison result made by authors between XY and Odd-Even routing algorithm of a 2-D 3X3 Mesh topology network-on-Chip. Identification is that, result obtained in some papers for average latency per packet and average throughput for CBR traffic and also comparison made between OE, XY routing algorithm OE is more better than

XY routing algorithm. So, this paper will analyze performance and simulation of Odd-Even Routing algorithm for 2D mesh topology of Network-on-chip architecture for busty communication traffic. Performance which is to be measure in terms of Latency and Throughput.

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