A Survey of Router Design Algorithms for NoC Platform and their Performance Analysis

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ABSTRACT

Network on Chip (NoC) is an approach to designing the communication subsystem between IP cores in a System on a Chip (SoC). NoC improves the scalability of SoCs, and the power efficiency of complex SoCs compared to other designs. The purpose of NOC is to solve the choke point in communication and the clock problem from architecture. Each route 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.This paper basically review of XY routing algorithm for 2D torus topology of Network on chip architecture for constant bit rate (CBR) random traffic in NIRGAM simulator to reduce the average latency per packet and increase average throughput.

Keywords –Network on chip (NoC), 2D torus topology, XYrouting algorithm

1. INTRODUCTION

Nowadays design paradigms of highly complex and integrated system on chip are based on the assembling of predesigned cores and components (Intellectual property, IP cores). NoC is an efficient on chip communication architecture for SoC architectures that is reusable, high performance, integration of a large number of computational, scalable and storage blocks on a single chip. Network on Chip is characterized by routing algorithm, topology and switching technique.Routing is the mechanism responsible for determining the path that a packet traverses from the source node to the destination node. There are different types of routing algorithms such as XY routing algorithm, odd even routing algorithm, source routing algorithm etc. XY routing algorithm is one of the simplest and most commonly used routing algorithms used in NoC. It is deterministic, static and deadlock free routing algorithm. Deterministic and adaptive routing are types of XY routing algorithms. With deterministic routing, the path between source to destination pair is fixed, regardless of the current state of the network. On the other hand, an adaptive routing algorithm the router chooses a path from source to destination as per traffic conditions of the path.In XY routing algorithm, a packet must always be routed along horizontal or X axis until it reaches the same column as that of destination. Then it should be routed along vertical or Y axis and towards the location of destination resource.

Routing is in deadlock when two packets are waiting each other to be routed forward. Both of the packets are waiting each other to release the resources. Routers do not release the recourses before they get the new recourses and so the routing is locked.Numbers of topologies have been used for NoC such as mesh, torus, tree, star, octagon etc. Among these topologies, torus topology has gained lots of consideration by designer due to their simplicity.2D torus topology was first proposed by W. J. Dally in 1986 in California Institute of Technology. Compared to 2D mesh topology, the boundary nodes are also connected together so that all the communication nodes from a loop. This route provides more choices, lower average transmission paths, but due to the cross areas between the loops, the routing resources of the physical map realization are also increased.In this paper we use XY routing algorithm for 2D torus topology of network on chip architecture for CBR (Constant Bit Rate) random traffic. The traffic pattern is a very important factor for the performance of a network. Finally, we simulate the method by NIRGAM simulator and to reduce the average latency per packet and increase average throughput.

2. LITERATURE REVIEW

Jin-xiang Wang et al. [1] have described a new fault model, defines separately node-fault and link-fault, reduces situations classified as node-fault effectively and consequently improves the performance of the network. By defining some new paths to substitute failure paths, data packets can be routed along the new paths which are formed by the neighbor nodes of node-fault or link-fault. A fault-tolerant wormhole router based on XY routing algorithm is designed according to the solution. The evaluation results show that network performance can be improved by 15% when link-fault occurs in the network.

Hamed S. Kia and Cristinel Ababei [2] have described algorithm is based on the balland-string model and employs a distributed approach based on partitioning of the regular NoC architecture into regions controlled by local monitoring units. Each local monitoring unit runs a shortest path computation procedure to identify the best routing path so that highly congested routers and faulty links are avoided while latency is improved. To dynamically react to continuously changing traffic conditions, the shortest path computation procedure is invoked periodically. Because this procedure is based on the ball-and-string model, the hardware overhead and computational times are minimal. Experimental results based on an actual Verilog implementation demonstrate that the proposed adaptive routing algorithm improves significantly the network throughput compared to traditional XY routing and DyXY adaptive algorithms.

Ruizhe Wu et al. [3] have been described a new on-chip communication system & dubbed Wireless Network on- Chip (WNoC). This work centers on the design of a high-efficient, low-cost, deadlock-free routing scheme for domain-specific

irregular mesh WNoCs. A distributed minimal table based routing scheme is designed to facilitate segmented XY-routing. Deadlock-free data transmission is achieved by implementing a new turn classes based buffer ordering scheme.

Mohsen Nickray et al. [4] have described an adaptive routing algorithm which is based on deterministic XY routing algorithm. In their model a switch is a context-aware agent and a network is a society of context-aware agents which are ever learning and adapting to distribute the congestion uniformly and isolate the malformed switches (agents). In conventional XY routing, first, the load in the center of a network is much higher rather than total average and this leads to hot spot in the center of network. And second, a malfunction in switches could make part of network out of access. But in their proposed routing, first, all agents are aware from their neighbor's congestion and collaboratively try to route their input packets through less congested route, according to their experiences learned before and second, when a new malfunction takes place in the network, all agents collaborate each other to recognize the malformed agent and learn the best route. The main objective of their routing algorithm is to distribute network load uniformly throughout the network. They developed a NOC environment using SystemC.Masood Dehyadgari et al. [5] have described a pseudo adaptive routing which is an extension of classic XY routing. They consider mesh topology for evaluating proposed routing. Their switches use Pseudo adaptive XY routing algorithm. The load in the center of a network in ordinary XY routing is much higher rather than total average. This extra load on the center of mesh can cause spot hot. The main objective of their routing algorithm is to distribute network load. One of the advantages of distributing network load is balanced temperature on the mesh. Their routing algorithm has two modes that is deterministic and adaptive Packets are routed with classic XY routing (deterministic mode), when congestion in the network is low. When congestion is high, packets will be routed through less congested route adaptively (adaptive mode).Manas Kumar Puthal et al. [6] have described a new hierarchical cluster based adaptive routing called „C-Routing" in 2D mesh NoC. The solution reduces routing table size and provides deadlock freedom without use of virtual channels while ensuring livelock free routing. Routers in this method use intelligent routing to route information between the processing elements ensuring the correctness, deadlock freeness, and congestion handling. This method has been evaluated against other adaptive algorithms such as PROM, and Q-Routing etc. C-routing uses adaptively to avoid congestion by uniform distribution of traffic among the cores by sending flits over two different paths to the destination. Proposed technique achieves two objectives, as inferred from the results, reduction in area and higher throughput. These benefits are achieved at a marginal increase in power consumption and latency while preserving deadlock freedom with no extra virtual channels. Fault tolerance is another major issue in NoC design.

Shu Yan Jiang et al. [7] describe an online detection method of interconnection for 2D torus structure of NoC system. This method can detect the data errors during transmission and identify the error results from the routing switch failure or the data transmission interconnection line failure. They design a sub-router based on the wormhole exchange using E-cube routing algorithm and a check module which is suitable for the original routing node functions and work feature. They simulate the method by Verilog HDL and quartus II software. The experiment results show that the method can detect data errors caused by the router failure or interconnect failure and can locate the fault.

Yang Quansheng & Wu Zhekai [8] have described an improved topology called Tmesh, which is based on standard mesh network by inserting four long links to connect the vertices to reduce the communication delay between some remote nodes. They also present a deadlock-free routing algorithm for Tmesh named TXY algorithm. The results of this algorithm show a certain reduction in the average packet delay and routing hops. When the network has 64 nodes, the average delay and routing hops of Tmesh are 2.92% and 3.53% lower than those of mesh respectively.

A.H. Borhani et al. [9] described a new fault tolerant routing algorithm, which is based on dimension order routing, is proposed for k-ary 2-cubes. Packets are sent to their destination through XY routing algorithm and if this transmission is not possible, YX routing algorithm is applied. The result shows that these method is preferred, especially in the environments where the fault probability is low and the message generation rate is high.Xiaoqiang Yang et al. [10] described node coding and routing methods are important to the design of NoC. By the combination of network topology with corresponding, a two dimensional code based on Johnson code in Torus topology is proposed. The node coding implies the relation between neighboring nodes and has a good scalable characteristic. The two methods for code compressing are also presented to reduce the storage space of node address and increase the utilization rate of channel bandwidth. The improved algorithm for XY routing based on the code is presented and node structure is designed. The experimental results show combination of the code can simplify the routing algorithm in the implementation of NoC, decrease silicon resource consumption and greatly improve communication performance.Slavisa Jovanovic et al. [11] have been described a new deadlock free fault tolerant adaptive routing algorithm for 2D mesh NoC interconnection. The main contribution of this routing algorithm is that it allows both, routing of messages in the networks incorporating the regions not necessarily rectangular and routing to all nodes which are not completely blocked by faulty nodes. The proposed routing algorithm is based on a modified turn model and well known XY algorithm. The basic principle of this routing algorithm, prove its deadlock freeness, its feasibility and efficiency through the simulation results.

Xiaohang Wang et al. [12] described a simple, yet efficient hardware based multicasting scheme is proposed for irregular mesh based NoC. First, an irregular oriented multicast strategy is proposed. Following this strategy, an irregular oriented multicast routing algorithm can be designed based on any regular mesh based multicast routing algorithm. One such algorithm, namely, Alternative XY (AL+XY), is proposed based on XY routing. Experimental results shows that AL+XY achieve significant reduction in power consumption and packet latency compared with existing solutions. AL+XY saves 29% power consumption than that of multiple unicast. In terms of average packet latency, when injection rate is high (e.g. near 0.15), the latency of AL+XY is only 50%.

Mehrdad Seyrafi et al. [13] have been described a new fault tolerant routing algorithm with minimum hardware requirements and extremely high fault tolerance for 2D-mesh based NoCs is proposed. The LCFT (Low Cost Fault Tolerant) algorithm, removes the main limitations (forbidden

turns) of the famous XY. So not only many new routes will be added to the list of selectable paths as well as deadlock freedom, but also it creates high level of fault tolerance. All these things are yielded only bythe cost of adding one more virtual channel (for a total of two). Results show that LCFT algorithm can work well under almost bad conditions of faults in comparison with the Extended-XY, Extended-YX algorithms.

Yonghui Li & HuaxiGu [14] described a new model called the XY-turn model for designing partially adaptive or deterministic routing algorithms for honeycomb networks on chip without adding virtual channels. The model prohibits two turns in opposite directions at some particular nodes so that the deadlock can be avoided. The restricted turns result in simplified router architectures especially for photonic NoCs. They have implemented a deterministic routing algorithm is carried out to test the performance of the algorithm in end to end delay and throughput under the conditions that messages length are 128 bytes, 256 bytes and 512 bytes respectively, as well as the network size varies from 36 cores to 64 cores and 98 cores. The results deterministic that the honeycomb NoCs would benefits from the XY-turn model in terms of communication efficiency..

3. ROUTING ALGORITHMS

Routing on NoC is quite similar to routing on any network. A routing algorithm determines how the data is routed from sender to receiver.

Deterministic XY routing algorithms route packets every time from a certain point A to a certain point B along a fixed path. Deterministic algorithms are used in both regular and irregular networks. In congestion free networks deterministic algorithms are reliable and have low latency. They suit well on real time systems because packets always reach the destination in correct order and so a reordering is not necessary. Deterministic algorithms are used in both regular and irregular networks. Deterministic routing has better latency at low traffic.

Dimension Order Routing (DOR) is a typical minimal turn algorithm. The algorithm determines to what direction packets are routed during every stage of the routing.

Deterministic XY routing is a dimension order routing which routes packets first in x- or horizontal direction to the correct column and then in y- or vertical direction to the receiver. Figure 1 shows XY routing from router A to router B. Deterministic XY routing suits well on a network using mesh or torus topology. Addresses of the routers are their xy-coordinates. Deterministic XY routing never runs into deadlock.

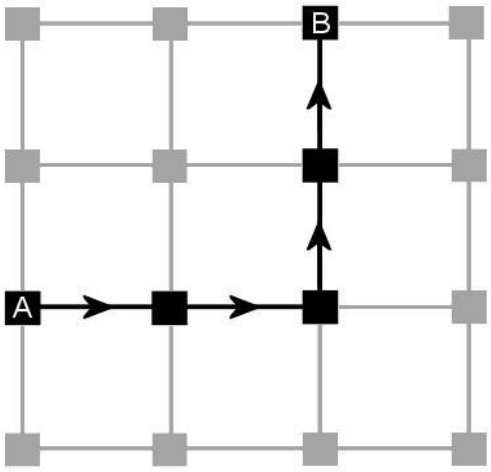

FIG 1: XY ROUTING FROM ROUTER A TO ROUTERB (SOURCE: VILLE RANTALA ET AL. "NETWORK ON CHIPROUTING ALGORITHM")

Routing is in deadlock when two packets are waiting each other to be routed forward. Both of the packets reserve some resources and both are waiting each other to release the resources. Routers do not release the resources before they get the new resources and so the routing is locked[17].

4.TOPOLOGY

A network can be regular or irregular and it is non-blocking if it can manage all the requests that are offered to it. In a packet switched case this kind of network is also called as non-interfering network. Non-interfering network can deliver all the packets in guaranteed time[17]. Topology is a very important feature in the design of NoC because design of a router depends upon it. The basic regular network topologies are mesh, torus, tree, butterfly, polygon, star & etc. The main problem with the mesh topology is its long diameter that has negative effect on communication latency. Torus topology was proposed to reduce the latency of mesh and keep its simplicity. Figure 2 shows torus network. A simple torus network is a mesh in which the heads of the columns are connected to the tails of the columns and the left sides of the rows are connected to the right sides of the rows. Torus network has better path diversity than mesh network, and it also has more minimal routes. The only difference between torus and mesh topologies is that the switches on the edges are connected to the switches on the opposite edges through wrap-around channels [17].

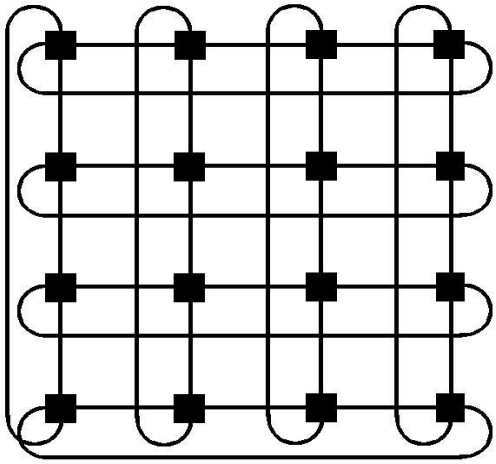

Fig 2: Torus network
Source: Ville Rantala et al. "Network on Chip Routing Algorithm"

5. TRAFFIC

The traffic pattern is a very important factor for the performance of a network. In uniform random traffic each source is equally likely to send to each destination. Uniform random traffic is the most commonly used traffic pattern, however it implies a balancing of the load, which often does not cause a problem for the network.

There are two types of Constant Bit Rate (CBR) traffic

1. Fixed CBR
2. Random CBR

Configurable parameters for CBR 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[18]

6. COMPARATIVE STUDY

Table 1. Comparison of different routing algorithms & their results

Parameters	[1]	[2]	[3]
Routing Algorithm	XY Routing	Adaptive XY routing	XY routing
Topology	2D Mesh	2D Mesh	Irregular 2D Mesh
Latency	Average latency reduce to 50%	Average latency reduce to 32.5%	Average latency reduce to 41%
Throughput	It is double	It is incremented by 21%	It is incremented by 64%

It is observed in literature review on design of NoC architecture that maximum paper used deterministic XY routing or adaptive XY routing with 2D-Mesh topology to reduce the latency & improve the throughput. Up to yet no one used 2D-Torous topology to improve the throughput. So that we would like to use deterministic XY routing algorithm with 2D-Torous topology

7. CONCLUSION

XY routing algorithm is one of the simplest and most commonly used NoC routing algorithms. It is deterministic, static and deadlock free routing algorithm. We observed that most of the XY routing algorithms are implemented on 2D mesh topology to increase throughput & reduce latency. But most of them is facing problem of traffic congestion in the centre. There are number of topologies available but the torus topology has gained lots of consideration by designer due to their simplicity. So we propose new design method using a XY routing algorithm for 2D torus topology to solve above problem. We will use NIRGAM simulator for simulation & performance analysis. We expect the result with reduce the average latency per packet and increase average throughput.

8. REFERENCES

[1] Jin-xiang Wang, Fang-fa Fu, Tian-Sheng Zhang & Yu-Ping Chen,"A Small-Granularity Solution on Fault Tolerant in 2D-Mesh Network-on-Chip", IEEE, 2010, pp. 382-384.

[2] Hamed S. Kia and Cristinel Ababei,"A new Fault tolerant and Congestion-aware Adaptive Routing Algorithm for Regular Networks-on-Chip", IEEE, 2011,pp. 2465-2472.

[3] Ruizhe Wu, Yi Wang & Dan Zhao,"A Low Cost Deadlock-free Design of Minimal-Table Rerouted XY-Routing for Irregular Wireless NOCs", 2010, Fourth ACM/IEEE International Symposium on Networks-on-Chip, pp. 199 – 206.

[4] Mohsen Nickray, Masood Dehyadgari & Ali Afzali-kusha, "Adaptive Routing Using Context-Aware Agents for Networks on Chips ", IEEE, 2009, pp. 1-6.

[5] Masood Dehyadgari, Mohsen Nickray, Ali Afzali-kusha, Zainalabein Navabi,"Evaluation of Pseudo Adaptive XY Routing Using an Object Oriented Model for NOC", IEEE, 2005, pp. 204-206.

[6] Manas Kumar Puthal, Virendra Singh, M. S. Gaur, Vijay Laxmi, "C-Routing: An Adaptive Hierarchical NoC Routing Methodology", 2011, IEEE/IFIP 19th International Conference on VLSI and System on Chip, pp. 392 – 397.

[7] Shu Yan Jiang, Hao Liang, Shuo Li, Yong Le Xie, "A Test Method of Interconnection Online Detection of NoC Based on 2D Torus Topology", IEEE, 2011, pp. 183 – 187.

[8] Yang Quansheng, Wu Zhekai, "An Improved Mesh Topology and Its Routing Algorithm for NoC", IEEE, 2010, pp. 1-4.

[9] A.H. Borhani, A. Movaghar, R. G. Cole, "A New Deterministic Fault Tolerant Wormhole Routing Strategy For k-ary 2-cubes", IEEE, 2010, pp. 1 – 7.

[10] Xiaoqiang Yang, Huimin Du, Jungang Han, "A Node Coding and the Improved Routing Algorithm in Torus Topology", IEEE, 2008, pp. 443 – 447.

[11] Slavisa Jovanovic, Camel Tanougast, Serge Weber, Christophe Bobda, "A New Deadlock-Free Fault-Tolerant Routing Algorithm For NoC Interconnections", IEEE, 2009, pp. 326 – 331.

[12] Xiaohang Wang, Mei Yang, Yingtao Jiang, Peng Liu, "Efficient Multicasting Scheme for Irregular Mesh-Based NoCs", IEEE, 2010, pp. 384 – 387.

[13] Mehrdad Seyrafi, Arghavan Asad, Amir Ehsani Zonouz, Reza Berangi, Mahmood Fathy, Mohsen Soryani, "A New Low Cost Fault Tolerant Solution for Mesh based NoCs", 2010 International Conference on Electronics and Information Engineering (ICEIE 2010), pp. V2-207 - V2-213.

[14] Yonghui Li, HuaxiGu, "XY-Turn Model for Deadlock Free Routing in Honeycomb Networks on Chip", IEEE, 2009, pp. 900 – 903.

[15] Wang Zhang, Ligang Hou, Jinhui Wang, Shuqin Geng & Wuchen Wu,"Comparison Research between XY and Odd-Even Routing Algorithm of a 2-Dimension 3X3 Mesh Topology Network-on-Chip", IEEE, 2009, global congress on intelligent systems, pp. 329-333.

[16] Pan Hao,Hong QiI,Du Jiaqin & Pan Pan,"Comparison of 2D MESH Routing Algorithm in NOC", IEEE, 2011, pp. 791 – 795.

[17] Ville Rantala, Teijo Lehtonen & Juha Plosila, "Network on Chip Routing Algorithms", TUCS Technical Report No 779, August 2006.

[18] "A Simulator for NoC Interconnect Routing and Application Modeling", University of Southampton UK and Malaviya National Institute of Technology India, by Lavina Jain, September 1, 2007.