Dual Path Odd-Even Routing Algorithm for Network on Chips

Marjan Morvarid  
School of Computer Engineering  
University of Science and Technology  
Tehran, Iran  
ma.morvarid@gmail.com

Reza Berangi  
Department of Computer Engineering  
University of Science and Technology  
Tehran, Iran  
rberangi@iust.ac.ir

Mahmood Fathy  
Department of Computer Engineering  
University of Science and Technology  
Tehran, Iran  
mahfathy@iust.ac.ir

Abstract – 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, we present a multipath routing scheme which is called DPOE (Dual Path Odd-Even). In DPOE, 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, we will provide load balancing and improve efficiency of the network. By comparing simulation results, it will be observed that this method, under different traffic patterns, will significantly perform better than other methods.

Keywords- Network on Chip, Dual Path Routing, Adaptive Routing, Turn Model, Deadlock, Performance Improvement.

I. INTRODUCTION

A group of heterogeneous processing elements are integrated on a single chip, known as a System-on-Chip (SoC) to overcome the ever-increasing design complexity. However, the interconnection system of SoC should be carefully managed to avoid the communication bottleneck [1]. Network on Chip (NoC) has been presented to solve these problems as a packet-based on chip communication networks. NoC is based on the key idea of the interconnection network. Several network properties, such as topology, switching technique, routing algorithm, and flow control strategy, could affect the performance and power consumption of the NoC. An important problem in NoC design is deciding the type of routing, moreover, more complicated routing strategies result in larger design. Hence, this introduces interesting trade-offs between area and performance [15]. Many properties of the interconnection network are a direct consequence of the routing algorithm used. Among these properties we can cite Deadlock freedom. A deadlock occurs when some packets cannot advance toward their destination because the buffers requested by them are full. All the packets involved in a deadlocked configuration are blocked forever. Deadlock is by far the most difficult problem to solve. There are two strategies for deadlock handling: deadlock avoidance, deadlock recovery. Freedom from deadlock is crucial for NoCs, since deadlock detection and recovery mechanisms are expensive and they may lead to unpredictable delays. The deadlocks can be avoided by providing sufficient number of virtual channels or by prohibiting the minimum number of turns that break all of the cycles, because deadlock in wormhole routing is caused by packets waiting for each other in a cycle.

Routing algorithms can be classified according to the way in which to choose a path among the set of possible paths from source to destination. The routing algorithm can be either deterministic or adaptive. Deterministic routing algorithms always supply the same path between a given source and destination pair. Adaptive routing algorithms use information about network traffic and channel status to avoid congested or faulty regions of the network [3]. In adaptive technique, a routing function computes the set of admissible output channels toward which the packet can be sent. Then, a selection function is used to select one output channel from the set of admissible output channels depending on dynamic network conditions, such as the presence of faulty or congested channels [7]. In contrast, adaptive routers avoid congested links by using alternative routing paths; this leads to higher throughput. However, due to the extra logic needed to decide on a good routing path, adaptive routing has a higher latency at low levels of network congestion [6]. The effectiveness of any adaptive routing algorithm strongly depends on the underlying selection strategy.

There are two main approaches to packet routing, single path routing and multipath routing. In single path routing, only one path is used per source-destination pair to transfer the packets. In multipath routing algorithms, more than one path is discovered for a given source-destination pair. These multiple paths can be used either in case of failures as backup paths to replace the primary path or they can be used simultaneously in the routing process of different data packets via splitting. Multipath routing via splitting helps to increase the network performance by balancing the network traffic and consequently decreasing the queuing delay, also reduced network bandwidth requirements and power consumption. Many of today’s NoC designs are based on single path.

In this paper an adaptive dual path algorithm is proposed which is called DPOE (Dual Path Odd-Even). In DPOE method, we have chosen the turn model Odd-Even (OE) algorithm as the base algorithm. DPOE technique operates based on the usage of the shortest route between source and destination, and has the ability to send the traffic through two minimal routes toward the destination. DPOE method
completely prevents deadlocks by using OE’ admissible turns, and there will be no need to use other deadlock prevention methods.

In the next section, we review the related work. In Section III, the dual path routing technique is presented. In Section IV, the simulation results are discussed. Section V draws the conclusions.

II. RELATED WORK

Many routing algorithms for wormhole-switched networks have been proposed in the literature [4], [5], [6], [7], [14]. A lot of researches have illustrated that adaptive routing algorithm could yield higher performance than deterministic one. Glass and Ni [4] propose a turn model for designing wormhole routing algorithms that are deadlock and livelock free. The basic idea of the model is to prohibit the minimum number of turns that break all of the cycles so that deadlock can be avoided without virtual channels. Based on the turn model, three partially adaptive routing algorithms, namely West-First, North-Last, and Negative-First, were presented for two-dimensional meshes. This model was later utilized by Chiu [5] to develop the Odd-Even (OE) adaptive routing algorithm. The Odd-Even routing strategy has greatly improved the degree of adaptiveness over other adaptive routing strategies. It restricts some locations where turns can be taken so that deadlock can be avoided without virtual channels. Hu and Marculescu [6] propose a routing scheme called DyAD. This algorithm is the combination advantages of deterministic OE-fixed routing and adaptive Odd-Even routing. The router can switch between these two routing modes based on the network’s congestion conditions. In order to achieve the potential performance improvement of the adaptive routing scheme, an efficient selection policy should be designed to select one output path among the set of paths provided by the adaptive routing algorithm. The NoP selection strategy attempts to choose one path according to the network payload status. In [14], a dynamic routing algorithm called III Modes was proposed. The proposed routing algorithm for avoiding congested areas switches among three routing modes deterministic, minimal adaptive and non-minimal adaptive routing to lead to select the best port to the destination, also it present a novel selection policy that can be coupled with any adaptive non-minimal routing algorithm.

III. PROPOSED ROUTING ALGORITHM

Our proposed routing technique called DPOE’ is a dualpath distributed algorithm with high adaptability. In DPOE method, we have chosen the turn model Odd-Even (OE) algorithm as the base algorithm. The turn model routing algorithms are based on analyzing the directions in which packets can turn in a network and the cycles that the turns can form. The basic idea of the turn models is to prohibit the minimum number of turns that break all of the cycles so that deadlock can be avoided without virtual channels. The OE routing algorithm restricts the locations at which some turns can be taken so that deadlock is avoided. In comparison with the other turn model, the degree of routing adaptiveness provided by the model is more even for different source-destination pairs.

An important issue to be considered in choosing the routes in multipath algorithms is that selecting different routes must prevent deadlocks from happening while the lowest possibility of conflicting packets of different paths is provided. In DPOE method, we will completely prevent deadlocks by using the powerful OE algorithm and it’s allowed turns, and there will be no need to use other deadlock prevention methods. Otherwise we will have to use techniques such as virtual channel to avoid deadlock. As it was mentioned, the OE algorithm has the highest rate of adaptability among adaptable algorithms, and actually we have utilized this feature in our proposed method.

DPOE technique operates based on the usage of the shortest route between source and destination, and has the ability to send the traffic through two minimal routes toward the destination. Traffic distribution is possible only in the source node. Each received packet will be checked within the node and there are two situations for routing a packet based on the situation of the current node as source node or middle node:

1- The current node is the source node: Because the base of DPOE algorithm is on choosing the minimal route, consequently maximum of two outgoing routes will be specified. After running the OE routing algorithm there will be two different scenarios based on the number of admissible output directions:

A- First scenario: If only one channel is specified as the admissible output directions by the OE algorithm, the packet is sent on this path to the destination. In fact, the routing method is same as regular single path routing protocols.

B- Second scenario: If there are two channels as the admissible output directions, we will enter the multipath routing phase. For this purpose, the desired packet number is checked and packets with even number are sent through y axis and packets with odd number through X axis.

In Fig.1, two different cases in source node are shown. In Fig.1a, source node (5,1) sends packets to destination node (1,5), only its west neighbor (4,1) could be returned by the OE routing algorithm to be the possible output direction. Therefore packets are sent on this path to the destination. But in Fig.1b, we have source node (1,4) and destination node (5,1). In this case, the nodes (1, 3) and (2, 4) could be returned by the OE routing algorithm and we will enter the dual path routing phase.
2- The current node is one of the middle nodes: in DPOE technique the middle nodes act only as transmitter nodes, therefore the packet is sent toward destination through a route that is specified by the OE routing function and the policy function.

Since the OE routing algorithm is an adaptable algorithm this must be discussed if different packets of a traffic pattern which are sent through separate routes, collided in one of the middle nodes, in this case be the advantages of multipath will be reduced. To avoid this special selecting policy called DPSP (Dual Path Selection Policy) is introduced. After the current node is recognize as a middle node, and running the OE routing algorithm, if the number of allowed directions is more than one, we use DPSP selecting policy to determine the final direction among outgoing allowed directions.

At first DPSP checks the source and destination node address. This checking is to recognize the way to transmit the packet in source; there are two different scenarios and two different reactions from DPSP selecting policy:

1- First scenario: it is understood that the packet is sent from source node to destination node by a single path routing. In this case DPSP policy selects the final outgoing direction with lowest congestion between two allowed directions.

2- Second scenario: if it is understood that multipath ability is utilized to send the packet; DPSP starts its expertism phase, and checks the packet’s number to determine the direction which the packet must be sent. For instance the Y axis is chosen for even packet number. In fact this method tries to reduce the possibility of collision of the packets of the single message that are sent through separate paths in middle nodes. For this purpose, if the respective channel is not available or if it is in congested situation, the second direction is checking. It sends the packet through the mentioned path if second direction is free and with no congested situation.

Figure 1. Two different cases in source node based on the number of admissible output directions, (a) Single path (b) Dual path

![Figure 1](image1.png)

Figure 2. DPOE routing algorithm and DPSP selection policy

![Figure 2](image2.png)

IV. EXPERIMENTAL RESULTS

For the evaluation of the performance of the DPOE method five routing algorithms are implemented and compared. These algorithms are XY [4], Odd-Even [5], DyAD [6], NoP[7] and the proposed algorithm in this paper. For implementing the algorithms, we have used an open source simulator called Noxim [9]. Noxim is an open source SystemC simulator of a mesh-based NoC, which is capable of calculating the average delay, the average throughput and the power dissipation of the packet transportation. The simulator is capable of simulating different traffic schemes. We added our routing algorithm into its routing types and compared DPOE routing results with other algorithms. For each traffic scenario and algorithm, we will give the average packet delay and throughput with various packet injection rates.

Simulations are carried out on an 8 × 8 mesh NoC. In this simulation, PE’s generate 8-flit packets and inject them into the network in intervals determined from an exponential distribution. Each input channel has a buffer size of 5 flits, with the congestion threshold set at 60% of the total FIFO capacity. Each simulation was run for a warm-up period of 1000 cycles, it was executed for 20,000 cycles.

A. Evaluation under Random Traffic

Fig. 3 shows the results obtained when the network has random traffic. In the random traffic, each PE can send a packet to every other PE with an equal probability [11]. As
can be seen, XY routing performs better than Odd-Even, DyAD, NoP and DPOE routing algorithms under random traffic load. The main reason for this is that, although the XY algorithm is nonadaptive, it embodies global long-term information about the uniform traffic pattern [4]. The adaptive algorithms, on the other hand, select channels based on local short-term information. This type of decision benefits only the packets in the immediate future, which tend to interfere with other packets [6]. The result is increased contention and decreased performance at higher packet injection rates [4].

B. Evaluation under Transpose Traffic

For \( n \times n \) mesh, under the first transpose traffic model, each PE at \((i, j)\) position can send its packet to the PE at \((n-1-i, n-1-j)\) position. Taking the results using transpose traffic, in Fig.5 it is observed that a network adopting XY performs poorly due to its determinism in distributing packets. But Odd-Even, DyAD and DPOE routing algorithm are able to achieve a higher throughput than XY. For the same traffic pattern and the injection rate, DPOE routing algorithm achieves shorter average packet latency and higher throughput in all these experiments compared to Odd-Even, DyAD and NoP. The average latency a packet experiences in Odd-Even, DyAD and NoP are 33%, 28% and 12% higher compared to that in DPOE, when the network is lightly loaded.

Other non-uniform traffic patterns have been simulated as well and the results were similar to that under transpose traffic pattern.
is not considerable when compared with other advantages of proposed method, and DPOE has the best performance of all other methods considering Fig.8.

![Figure 8. Power Delay Product (PDP) diagram for first transpose traffic model](image)

V. CONCLUSION

In this paper an adaptive dual path algorithm is presented which is called DPOE. This technique operates based on the usage of the shortest route between source and destination, and has the ability to send the traffic through two minimal routes toward the destination. DPOE via splitting traffic helps to increase the network performance by balancing the network traffic. This method completely prevents deadlocks by using OE’ admissible turn, and there will be no need to use other deadlock prevention methods. By comparing simulation results, it will be observed that this method, under different traffic patterns, will significantly perform better than other methods.

REFERENCES