Fault-tolerant MIN Shuffle-Exchange NoC

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Abstract: In this paper, a fault tolerant routing algorithm for the newly introduced MIN Shuffle-Exchange network is introduced. For more comprehension the MIN Shuffle-Exchange average message latency and power consumption are compared with same feature in MESH and conventional Shuffle-Exchange networks with the same simulation rules and the different traffic patterns and different numbers of faulty links. As a result, the simulation has shown the lower message latency for the MIN Shuffle-Exchange in comparison with two other networks. The power consumption has slightly increased because of the MIN inherent characteristics and wiring length but, it is negligible in comparison with the increment in system performance.

Keywords: NoC, Topology, MIN, Interconnection network.

1. Introduction

Transferring the data between the processing elements need the proper networks which guides the data packets through the safe and reliable paths with a suitable routing algorithm. Hence, the designers have introduced different topologies and routing algorithms to improve NoCs performance. The performance of the NoCs is especially considerable in the face of the high rated traffic injection.

Now a day computing systems need to implement on an appropriate substrate to provide the proper performance. The NoCs are known as a proper context to serve for multi-processor design in parallel processing. They have been used vastly for make the connection between the processing units in the parallel processing systems. The NoCs improve the system’s scalability besides increasing system efficiency. One of the conversational subjects in face with complex network on chip is faults. The occurred faults affect network performance directly by reducing the whole system throughput. So, the designers try to design new networks in order to topology or routing algorithm to detect and correct the emerged faults. Hence, the NoCs features improvements are the hot conversational field for the network designers.

For a while the 2D MESH network was the dominate topology for designing NoCs. Because of the MESH network symmetric structure, implementing the routing algorithm is easier than other topologies. As an instant we mentioned XY routing strategy. Applying an XY algorithm for 2D MESH network give more scalability and simplicity to the designed parallel systems.

Another considerable network in NoC realm is 2D Shuffle-Exchange network. The 2D Shuffle-Exchange network [1] have similar diameters with the MESH network and have ability to apply a variety of routing algorithm [2], [3] beside reducing the average message delay for parallel processing systems.

The parallel processing was expressed to solve complex calculations in a fraction of a second with consuming as less as energy in different environments. The different environment can impose different type of fault to the systems. The faults can be permanent or transient in their nature and the designers have to apply the different strategies to detect and cover them. Hence, finding a suitable network is a main matter in designing network on chip.

Relying on the different topology and its proper routing algorithm besides changing the network parameters guide designers to approach the new NoC which cover system requirements and provide higher communication speed between existence processing elements in the network [4], [5]. As mentioned, fault is one of the important issues in the NoCs. A fault tolerant network continues its activity in face with faults [6]. The Systems have to continue their activity in the face of known faults and detect new emerged faults and cover them. The network will enter into a tolerant condition when a fault or the faults emerge [7].

The different strategy has introduced to detect and cover the faults in different networks. The majority of fault tolerant networks lean on changing and providing new hardware. These strategies impose an extra cost to the network. Also, the final design needs more time to be ready for the market.

In this paper we take advantage of Multi-Stage Interconnection Networks (MINs). MINs consist of more than one stage of small interconnection elements called switching elements [8] and links interconnecting them [9]. A multi-stage interconnection network is a compromise between crossbar [10] and shared bus networks.
This paper explains a new fault free 2D MIN Shuffle-Exchange Network and its proper routing algorithm which gives better performance in comparison with the conventional Shuffle-Exchange network and the MESH network without using any redundant module and extra hardware costs.

In the rest of the paper, section 2 proposes the method. Section 3 introduces simulation environment and section 4 shows simulation results. Finally, section 5 concludes the paper.

2. THE PROPOSED METHOD

In the usual routing algorithms the source node starts to send data packets to the defined node in the network; in this way the transmitter node has no feedback from the receiver node, then, the network can work properly until there are no faulty nodes or links.

In this type of network in the presence of failing the system cannot recognize the problem and continue its activity; this problem will cut the system's efficiency and accuracy; the traffic management part of the network can recognize the probability of faulty node or link just by controlling the throughput of the systems.

In conventional systems the traffic management part after recognizing the decrement in the output will exchange some part respectively and check the throughput until achieving to proper output. Need for several circuits to replacing with a damaged part in faulty network increase cost and impose a complex management system. On the other hand increasing in the consumed area will impose to the design as well as static power consumption.

Using the optimized routing algorithm and suitable topology will increase network performance. The designers always try to implement a new routing and topology to develop better networks in order to fault, latency and power consumption.

In this paper we have mapped the linear MIN network to the MESH network and applying a new routing algorithm for the first time to introducing our network. The 8×8 MIN Shuffle-Exchange performance has simulated and compared with the MESH and the conventional Shuffle-Exchange networks.

The 4×4 MIN Shuffle-Exchange network has shown in the Fig. 1 as an instant.

In case of any problem the confirmation signal will never reach to the transmitter node. After spending the time out, which defined according to network dimension the transmitter node will try to send data packets through the other existence virtual channel. This function will be continuing to send data and receiving confirmation signal until reaching to virtual channel limitation otherwise transmitter node will send data packet through the new neighbor. The recent receiver neighbor starts route the packet to the destination independently, so that, never meet faulty or transmitter node in its path. In this way packet will traverse the new path to the defined destination.

In our applied algorithm each packet has four fields for defining address in its header. The first field is considered for the receiving node address; the second field is for the transmitter node address and the third and fourth is for the first neighbor address and the current node address respectively. With this address segmentation each node knows the confirmation signal is belong to which node also, knows the message generator and receiver node addresses. Each node has to put its and neighbor address in fourth and third fields after sending data packet and receiving a confirmation signal.

In proposing algorithm the routing start on existing columns, after reaching to proper column address the routing will continue to route packet through the rows till reaching the end point. In the presence of the fault while routing algorithm works on column the routing path will change to the row in one step. After that routing will be continue through the column again. During routing on the row the similar action will perform. With the fault on the row, the routing algorithm will change data path through the column in one step. The explained procedure simplify in Fig. 2 & 3.
3. SIMULATION ENVIRONMENT

We use the Booksim simulator to simulate our proposed network. The Booksim is an open source program which designed for improving NoCs functionality by Standford University [11].

In our survey the 2D MESH network and the conventional 2D Shuffle-Exchange network features are compared with the 2D MIN Shuffle-Exchange network. Each phase of simulation applies 10000 Uniform and 10000 Shuffle packets.

Simulation parameters were set according to the Table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Radix</td>
<td>8</td>
</tr>
<tr>
<td>Network Dimension</td>
<td>2</td>
</tr>
<tr>
<td>Number of Virtual Channels</td>
<td>2</td>
</tr>
<tr>
<td>Buffer Size</td>
<td>8</td>
</tr>
<tr>
<td>Traffic Pattern</td>
<td>Uniform and Shuffle</td>
</tr>
<tr>
<td>Flit per Packet</td>
<td>1</td>
</tr>
<tr>
<td>Injection Rate</td>
<td>From 0.002 Flit/Cycle to 0.02 F/C</td>
</tr>
<tr>
<td>Sample Periods</td>
<td>1000</td>
</tr>
<tr>
<td>Technology</td>
<td>65 nm</td>
</tr>
<tr>
<td>Faulty Links</td>
<td>5, 10, 15 links</td>
</tr>
</tbody>
</table>

4. SIMULATION RESULT

Simulating the MESH, conventional Shuffle-Exchange and the MIN Shuffle-Exchange network with similar parameters revealed that proposed method provides better functionality and performance in the presence of faults.

4.1. Uniform Traffic

The average message latency of mesh and MIN shuffle-exchange network with uniform traffic pattern and the message length of 32 and 64 flits are compared in Fig. 4 and 5. As seen in the figures, the MIN shuffle-exchange achieves a reduction in message latency with respect to the mesh network for the full range of network load under uniform traffic patterns.
The power consumption of mesh and MIN shuffle-exchange network with uniform traffic pattern and the message length of 32 and 64 flits are compared in the Fig. 6 and 7. As shown in the figures, the MIN shuffle-exchange can effectively reduce the power consumption of the NoC compared to the equivalent mesh topology before reaching the saturation point. The main source of such a noticeable reduction is the less hop counts taken by the messages (on average) and hence saving the power which is consumed in intermediate routers in an equivalent mesh topology. Obviously, handling more traffic load (after the point that the 2D mesh is saturated) requires more power. Note that when the mesh network approaches its saturation region, the MIN shuffle-exchange can still handle the traffic effectively and the saturation point is higher than that in the equivalent mesh network. Moreover, the extra stages in MIN and imposed longer wiring length increased the power consumption.

Simulating the mesh and the MIN shuffle-exchange network with similar parameters revealed that proposed topology provides less message latency and a little increase in power consumption in all traffic samples.

Then we have compared the average message latency of MESH, conventional Shuffle-Exchange and MIN Shuffle-Exchange network with uniform traffic pattern and the message length of 32 and 64 flits with 10 faulty links in the Fig. 8 and 9.

The power consumption of MESH, conventional Shuffle-Exchange and MIN Shuffle-Exchange network with uniform traffic pattern and the message length of 32 and 64 flits with 10 faulty links are compared in the Fig. 10 and 11.
The average message latency of MESH, conventional Shuffle-Exchange and MIN Shuffle-Exchange network with uniform traffic pattern and the message length of 32 and 64 flits with 15 faulty links are compared in the Fig. 12 and 13.

4.2 Shuffle Traffic

In this section, we have used shuffle traffics. The average message latency of MESH, conventional Shuffle-Exchange and MIN Shuffle-Exchange network with shuffle traffic pattern and the message length of 32 flits with 5 faulty links are compared in the Fig. 14.
4. CONCLUSION

This paper showed a fault free routing algorithm for the 2D MIN Shuffle-Exchanged topology. The MIN topology offers less average message latency in comparison with the MESH and the conventional Shuffle-Exchange networks. The 2D MIN Shuffle-Exchange network was developed by mapping the linear MIN network on the 2D MESH network.

Three mentioned networks were simulated with the Booksim simulator in similar condition. As a result, the simulation showed the new routing algorithm and topology improve message latency in the presence of the faulty link in comparison with two other networks but the power consumption of 2D MIN Shuffle-Exchange network slightly increases. This increment in power consumption is because of extra stage in MIN and an increase in wiring length.

REFERENCES


