Performance Analysis of 4x4 and 8x8 Mesh Topologies Based on Partitioning Technique in Network-on-Chip (NoC)

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Abstract
Network-on-Chip (NoC) has been introduced as a solution to solve the problem of buses and point-to-point communication architecture in System-on-Chip (SoC). Due to advanced VLSI technology, the power consumption and performance has become a major part of NoC. In this paper, the impact of using partitioning technique on mesh topology is analyzed based on the different metric: namely area, power, latency and throughput. Simulation of the proposed methods has been carried out using Booksim simulator. Simulation results indicate that the performance of the proposed technique has reduced the total area from 16% to 84%, and 45% to 75% of power consumption. Initially, the average network latency increasing, and the throughput is decreasing in partitioning technique but disable the nodes based on partitioning technique has improved the performance compared to mesh topology.

Keywords: Partitioning, Mesh; Disable Nodes; Area; Power.

1. Introduction
In recent decades, more and more IP core to be integrated on a single chip. Therefore, the buses and point-to-point communication architecture is replaced by Network-on-Chip (NoC) in System-on-Chip (SoC). NoC can handle the communication of hundreds of cores and allow several transactions concurrently. A NoC system comprised of network interface (NI), IP core, routers, as well as the link that connect all the routers together. All the IP cores, such as memories, microprocessor, and other cores are connected to the routers. The operation of IP cores is focused on the more important computations and other operation, while the routers are responsible to forward packet across the network. NoC design consists of router, topology, buffer, routing algorithm, flow control, and switching algorithm design. Routing algorithm defines the route for the packet to send from the source node to the destination node. Topology describes the arrangement of the nodes.

Topology is a key element for the efficient of NoC communication system [1][2]. The NoC topology not only plays an important role in performance parameters such as area, power consumption [3], latency, and throughput but also keep the scalability [4] and reusability of the NoC design. The study of impact in design parameter is done in [5]. There are two major types of topology called regular and irregular topology. Mesh and torus topology are regular topology. Irregular topologies are proposed in [6][7][8] for application specific. In this paper, the proposed mesh based partitioning and the disable nodes based on mesh based partition topology will be concisely discussed. There are two designs for mesh called full mesh and partial mesh topology. In the partial mesh topology, only some nodes are directly connected to all nodes in the network. The simulation and analysis of the result are presented.
This paper is organized as follow. Section 2 discusses about the related works. In section 3, the proposed mesh partitioning, and disable cores and routers based on partition method in 4x4 and 8x8 mesh topology are discussed. Section 4 presents the experiment results and analysis, and lastly section 5 concludes the paper.

2. Related Works

In this section, some of the research topics on NoC architecture are introduced and discussed. In [9], authors presented a layer aware partitioning algorithm for through-silicon via (TSV) minimization in 3D NoC. This algorithm is divided into divergence stage and convergence stage. The propose partitioning technique used multi-way min-cut partitioning to gradually divide a given design layer by layer in the divergence stage in order to get the initial solution, then this solution is refined in convergence stage. The results show that the layer aware partitioning algorithm performs a better capacity. Heterogeneous and hybrid clustered topology is proposed by [10]. The main objective of the heterogeneous and hybrid clustered topology is to reduce the average latency, response time, and keeping the area of the topology constant. Paper in [7] proposed a ZMesh topology to reduce the total energy in NoC. The result shows that the proposed ZMesh topology has a huge reduction in area and better latency when compared with existing topology. In [11], extended torus and ring topology is proposed. The extended ring topology reduces the average latency in NoC architecture compared to the existing topology. Article in [12] has proposed clustering methods in mesh topology to reduce the total area and power consumption, but the performance of average latency and throughput was not discussed.

3. Proposed Mesh Partitioning and Disable Cores, and Routers Based on Partition Method in 4x4 and 8x8 Mesh Topology

In this section, the mesh partitioning and disable nodes based on partition method are studied. Figure 2 shows the mesh partitioning and disable cores, and routers based on partition method in 4x4 mesh topology. Each partition has the equal number of nodes. The steps in algorithm include

Step 1: Consider the mesh topology

Step 2: Four partition to be formed. Define the number of cores that can be accommodated in a partition.

Step 3: Each partition has an equal number of routers.

Step 4: Each partition is connected to the edge of the node to limit the output port of each node to 4.

Step 5: Form the mesh partitioning topology.
Figure 3 shows the mesh partitioning and disable cores, and routers based on partition method in the 8x8 mesh topology. 4 partitions are formed in the 8x8 mesh topology.

Tables 1 and 2 show the comparative number of nodes and links in mesh, and with and without disabling nodes based on mesh partition topology. It is clear that partition method reduced the number of links and disable nodes in mesh partition technique reduce the number of nodes and links.

**TABLE 1** Number of Nodes in Mesh and Partitioning Mesh Topology

<table>
<thead>
<tr>
<th>Topology</th>
<th>Number of Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 Nodes Mesh Topology (Mesh)</td>
<td>16</td>
</tr>
<tr>
<td>16 Nodes Partition Mesh Topology (Mesh16P)</td>
<td>16</td>
</tr>
<tr>
<td>16 Nodes Partition Mesh Topology Disable 1 Group (Mesh16PG1)</td>
<td>13</td>
</tr>
<tr>
<td>16 Nodes Partition Mesh Topology Disable 2 Group (Mesh16PG2)</td>
<td>10</td>
</tr>
<tr>
<td>16 Nodes Partition Mesh Topology Disable 3 Group (Mesh16PG3)</td>
<td>7</td>
</tr>
<tr>
<td>16 Nodes Partition Mesh Topology Disable 4 Group (Mesh16PG4)</td>
<td>4</td>
</tr>
<tr>
<td>64 Nodes Mesh Topology (Mesh)</td>
<td>64</td>
</tr>
<tr>
<td>64 Nodes Partition Mesh Topology (Mesh64P)</td>
<td>64</td>
</tr>
<tr>
<td>64 Nodes Partition Mesh Topology Disable 1 Group (Mesh64PG1)</td>
<td>53</td>
</tr>
<tr>
<td>64 Nodes Partition Mesh Topology Disable 2 Group (Mesh64PG2)</td>
<td>42</td>
</tr>
<tr>
<td>64 Nodes Partition Mesh Topology Disable 3 Group (Mesh64PG3)</td>
<td>31</td>
</tr>
<tr>
<td>64 Nodes Partition Mesh Topology Disable 4 Group (Mesh64PG4)</td>
<td>20</td>
</tr>
</tbody>
</table>
Table 3 shows the simulation parameters. The experiment setup considered for the simulation of the proposed approach is the 4x4 and 8x8 mesh topology. Shortest path routing algorithm is chosen as the path to send the packet with injection rate is 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0.

We aim on the reduction of the number of nodes and links between the communications cores, so that the power consumption involved is reduced, and the number of wire is reduced due to which the complexity of the network is reduced along the cost.

### 4. Experimental Result

In this section, the effect of partitioning and disable nodes based on partition method is considered. In order to show the comparative results of our proposed technique the partition and disable technique was run on Booksim simulator. As the network size increasing from 4x4 to 8x8 mesh topology, the total area, power consumption, average latency, and throughput is increased. Figures 4 and 5 show the total area for 4x4 and 8x8 partitioning mesh topologies and disable nodes based on partitioning method. The 4x4 mesh partition technique reduced the total area approximated 17% compared to mesh topology. The total area by disable the nodes have reduced up to 84% compared to activate all the partition.
In 8x8 mesh partition topology has reduced the total area up to 16.5% compared to mesh topology. The total area by disable the partition has reduced up to 73% compare to mesh topology.

Figures 6 and 7 show the total power consumption for 4x4 and 8x8 partitioning mesh topologies and disable nodes based on partitioning method. Total power consumption is defined as the amount of power consumed by the network during passing the packets from source node to destination node. From table 2, the mesh based partition design has decreasing the total number of link; therefore, the total power is decreasing compared to mesh topology. In addition, by disable the nodes, the number of activating nodes and the link is decreasing. Indirectly, the total power consumption is decreasing.
Fig. 7 Total Power for 8x8 Partitioning Mesh Topology and Disable Nodes Based on Partitioning Methods

Figures 8 and 9 show the average network latency for 4x4 and 8x8 partitioning mesh topologies and disable nodes based on partitioning method. Average network latency is the total time needed to send a packet from source node to destination node. The average network latency is increasing in mesh partition topology. However, by disabling 3 to 4 partitions in 4x4 mesh partition, topology has lower average latency approximately 24% to 63% compared to mesh topology.

Fig. 8 Average Network Latency for 4x4 Partitioning Mesh Topology and Disable Nodes Based on Partitioning Methods

Fig. 9 Average Network Latency for 8x8 Partitioning Mesh Topology and Disable Nodes Based on Partitioning Methods

In 8x8 mesh partition topology, at least disable 4 partitions to lower the average latency by 50% compared to mesh topology.
Figure 10 ad 11 shows the average accepted packet rate for 4x4 and 8x8 partitioning mesh topologies and disable nodes based on partitioning method. As the latency increases, the throughput is decreasing in mesh partition topology. By disabling the nodes based on partition mesh topology has increased the average accepted packet rate in 4x4 and 8x8 topology as shown in figure 10 and 11. The average accepted packet rate increasing approximately 22% to 62% in 16 nodes topology and 100% in 64 nodes topology compared to mesh topology.

Fig. 10 Average Accepted Packet Rate for 4x4 Partitioning Mesh Topology and Disable Nodes Based on Partitioning Methods

Fig. 11 Average Accepted Packet Rate for 8x8 Partitioning Mesh Topology and Disable Nodes Based on Partitioning Methods

5. Conclusion

The new 4x4 and 8x8 mesh based partition and disable nodes based on partitioning method are presented in this paper. The results illustrate that the proposed method can improve the performance by reducing the total area and power consumption by 16% to 84% and 45% to 75% respectively. The average latency is decreased and the average accepted packet rate is increased when the technique of disabling the nodes is applying in the 4x4 and 8x8 mesh partition topologies. The average latency is decreasing approximately 24% to 63% in the 4x4 mesh topology and 50% in the 8x8 mesh topology. Lastly, the average accepted packet rate is increasing approximately 22% to 62% in the 4x4 mesh topology and 100% in the 8x8 mesh topology.
References


