Indonesian Journal of Electrical Engineering and Computer Science
Vol. 10, No. 2, May 2018, pp. 514~520
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v10.i2.pp514-520

Reducing Total Power Consumption and Total Area Techniques for Network-on-Chip Through Disable Cores and Routers Based on Clustering Method

Ng Yen Phing*, M.N.Mohd Warip, Phaklen Ehkan, S.Y.Teo
School of Computer and Communication Engineering, University Malaysia Perlis,
Pauh Putra Main Campus, 02600 Arau, Malaysia.

Article Info

Article history:

Received Nov 22, 2017
Revised Jan 30, 2018
Accepted Feb 13, 2018

Keywords:

Area
Clustering
Mesh topology
Network-on-Chip
Power consumption

ABSTRACT

Network-on-Chip (NoC) is a promising solution to overcome the communication problem of System-on-Chip (SoC) architecture. The execution of topology, routing algorithm and switching technique is significant because it powerfully affects the overall performance of NoC. In the Network-on-Chip, the total power consumption increasing due to the large scale of network. In order to solve it, a clustering method and disable cores and routers based on clustering method is apply onto mesh based NoC architecture. In the proposed approach, the optimization of total area and total power consumption are the major concern. Experiment results show that the proposed method outperformas the existing work. The clustering-mesh based method reduced the total area by 22% to 40 % and total power consumption by 22% to 56% compare to mesh topology. In addition, the proposed method by disable cores and routers based on clustering-mesh based method has decrease the total area by 45% to 87% and total power consumption by 33% to 75% compare to mesh topology.

Corresponding Author:

Ng Yen Phing,
School of Computer and Communication Engineering,
University Malaysia Perlis,
Pauh Putra Main Campus, 02600 Arau, Malaysia.
Email: nyenphing@gmail.com

1. INTRODUCTION

In recent year, there are several research paper about the basic issue and traditional challenges of Network-on-Chip (NoC) [1]. The performance such as low power consumption, low area, low latency, and high throughput are the main desirable characteristic for NoC architecture. However, the performance is drop as the number of cores is increasing [2]. This is because the number of cores is proportional to the average latency and total power consumption. The choice of a network topology for NoC is significantly impacts its performance [3][4]. The term of network topology can define as how the router is interconnect to each other [5]. The network topology can be designed as application specified or regular. Regular topology have been successfully employed in a number of tile-based chip multiprocessor project because of processor homogeneity and application traffic variability.

There are number of research discovering the pros and cons of clustering method in different topologies to improve the overall performance. Clustering can define as dividing the nodes in the networks into different cluster according to certain principle. A node is selected as a cluster header in each cluster. A cluster header is responsible for the communication between clusters and management within its cluster. The header of the cluster has the average minimum distance to all its member. Clustering method may able to share common intermediate network resources. Disable cores and routers based on clustering method proposed here is based on 4x4 mesh topology. Figure 1 show a 2-dimesional 4x4 mesh topology.

The efficiency of the proposed new cluster-mesh based method and disable cores and routers based on clustering method is investigated by using BookSim 2.0 simulator, a cycle-accurate simulator for NoC [6]. To obtain the total power consumption, Orion 2.0 power library [7] was integrated in BookSim 2.0. The main contribution of this paper are investigate the performance of cluster mesh based topology and the performance of disable routers and cores based on clustering mesh method with a focus on the optimization of the total power consumption and total area. The rest of this paper is organized as follow. Section 2 present the related work. Section 3 discuss the proposed method by disable cores and routers based on clustering technique. Section 4 give the experiment results. Finally, section 5 concludes this paper.

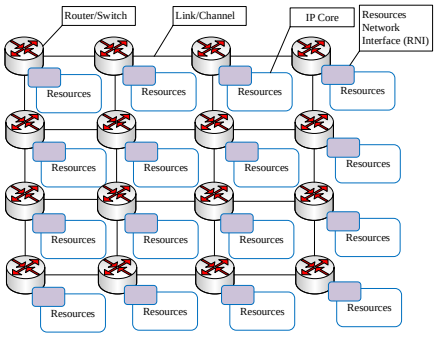

Figure 1. A 2-Dimension 4x4 Mesh Topology NoC

2. RELATED WORK

There are several research have been done mainly to minimize the total power consumption by applying clustering method. Regarding [8], a decompose and clustering with refinement algorithm is proposed to reduce the total power consumption with considering of Central Processing Unit (CPU) time. The proposed algorithm reduced the total power consumption by using two-stage method for decompose and cluster. In addition, a fault tolerant routing algorithm method of Network-on-Chip system based on clustering method is proposed by [9]. The aim of the fault tolerant routing algorithm in this paper is to reduce the average latency. The fault tolerant routing algorithm is based on existing adaptive, deterministic and router clustering technology. Based on [10], reducing the total power consumption by using clustered routerd routing in Network-on-Chip (NoC). A heterogeneous and hybrid clustered topology for NoC is proposed by [11] to optimized the average latency and response time. The geometry of the heterogeneous and hybrid clustered topology is same as that of mesh topology. Lastly, a NoC architecture based on cluster method is proposed by [12]. This cluster method is based on topology with long range link insertion algorithm.

3. CLUSTER-MESH METHOD

The clustering method and disable nodes based on clustering method is discuss in the section. Clustering is the task of grouping the nodes in the networks into different cluster according to certain principle. In each cluster, a node is selected as a cluster header. A cluster header is responsible for the communication between clusters and management within its cluster. The three main rules to form a cluster in 16 nodes mesh topology are:

Rule 1: The number of nodes in each group is equal. The following formula is used to determine the number of cluster. Number of cluster (n) is accepted as a number of cluster when no remainder from the following equation.

$$\text{Number of Cluster (n)} = \frac{16}{n}\ , \ n \neq 0 \text{ and } 1$$

Rule 2: Minimum one or more nodes is connected to the header node of cluster.

Rule 3: Each header of cluster will connected together form a mesh topology.

Rule 4: A hierarchical Clustering topology with sub header will be form when the number of node connected to the header is equal to 3 or more than 3.

The explanation of each colour node is explained in table 1.

Table 1. Explanation of Colour in Figure 1

Colour	Explanation
	Node (Core and Router)
	Cluster Header
	Cluster Sub Header

Figure 2 shows the 16 nodes mesh topology and the cluster-mesh based topology. Based on the proposed cluster rule, 16 nodes mesh topology is possible to form a total of five type of cluster-mesh topology. The five type of cluster-mesh based topology are mesh cluster header two, mesh cluster header four, mesh cluster header eight, mesh cluster header two with sub header two, and cluster header four with sub header four. Based on rule 4, a hierarchical Clustering topology with sub header will be form when the number of node connected to the header is ≥ 3. Therefore, a cluster header 2 with sub header 2 and a cluster header 4 with sub header 4 hierarchical cluster is form based on 16 mesh cluster header 2 and 4. A hierarchical cluster is a combination of mesh and tree topologies.

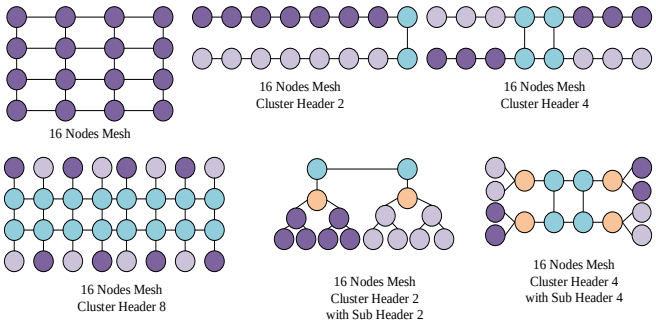

Figure 2. 16 Nodes Mesh and Cluster-Mesh Based Topology

3.1 DISABLE ROUTERS AND CORES BASED ON CLUSTER-MESH TOPOLOGY

This paper proposed a disable nodes based on clustering method. The main rule to disable node are:
Rule 1: Number of clustered header > 2
Rule 2: Disable nodes based on clustering methods. Disable minimum 1 group of cluster.
Rule 3: Maximum Number of Disable Cluster = Number of Cluster Header – 2

Figure 3 shows the clustered header 4 mesh topology and disable mode based on clustering method in clustered header 4 mesh topology. Based on rule 3, the maximum number of disable clustered in clustered header 4 topology is:
Maximum Number of Disable Clustered = 4 – 2 = 2 Group

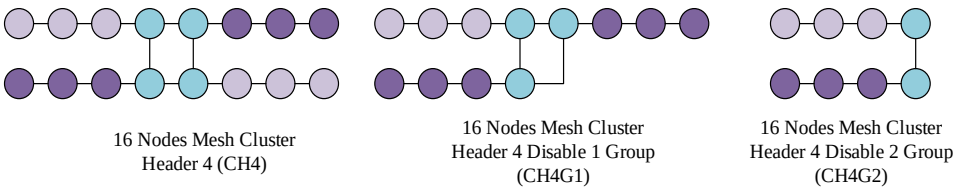

Figure 3. Clustered Header 4 Mesh Topology and Disable Mode Based on Clustering Method in Clustered Header 4 Mesh Topology

Figure 4 shows the clustered header with sub header 4 mesh topology and disable mode based on clustering method in clustered header with sub header 4 mesh topology. The maximum number of disable clustered in clustered header with sub header 4 topology is:

Maximum Number of Disable Clustered = 4 – 2 = 2 Group

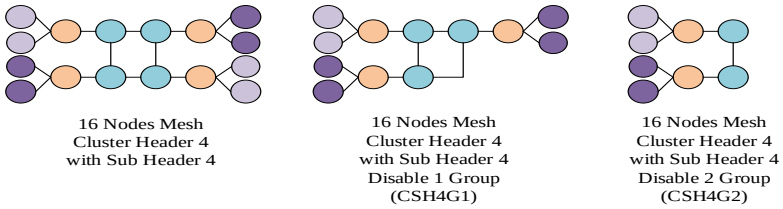

Figure 4. Clustered Header with Sub Header 4 Mesh Topology and Disable Mode Based on Clustering Method in Clustered Header with Sub Header 4 Mesh Topology

Figure 5 shows the clustered header 8 mesh topology and disable mode based on clustering method in clustered header 8 mesh topology. The maximum number of disable clustered in clustered header 8 topology is:

Maximum Number of Disable Clustered = 8 – 2 = 6 Group

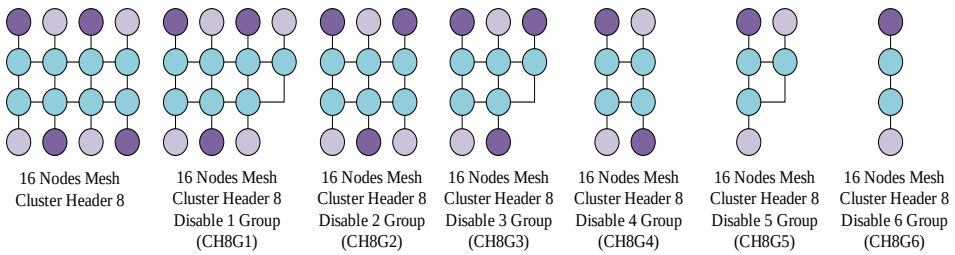

Figure 5. Clustered Header 8 Mesh Topology and Disable Mode Based on Clustering Method in Clustered Header 8 Mesh Topology

Table 2 shows the comparison of the number of nodes between the mesh topology with the cluster-mesh topology and disable cores and routers based on clustering method. The number of group of cluster is based on the cluster header. Based on table 2, the number of node decreases as the number of routers and cores is disable based on clustering method.

Table 2. Number of Nodes in 16 Nodes Mesh Topology

Topology	Number of Nodes
16 Nodes Mesh Topology (Mesh)	16
16 Nodes Mesh Topology Cluster Header 2 (MeshCH2)	16
16 Nodes Mesh Topology Cluster Header 4 (MeshCH4)	16
16 Nodes Mesh Topology Cluster Header 8 (MeshCH8)	16
16 Nodes Mesh Topology Cluster with Sub Header 2 (MeshCSH2)	16
16 Nodes Mesh Topology Cluster with Sub Header 4 (MeshCSH4)	16
16 Nodes Mesh Topology Cluster Header 4 Disable 1 Group (MeshCH4G1)	12
16 Nodes Mesh Topology Cluster Header 4 Disable 2 Group (MeshCH4G2)	8
16 Nodes Mesh Topology Cluster Header 8 Disable 1 Group (MeshCH8G1)	14
16 Nodes Mesh Topology Cluster Header 8 Disable 2 Group (MeshCH8G2)	12
16 Nodes Mesh Topology Cluster Header 8 Disable 3 Group (MeshCH8G3)	10
16 Nodes Mesh Topology Cluster Header 8 Disable 4 Group (MeshCH8G4)	8
16 Nodes Mesh Topology Cluster Header 8 Disable 5 Group (MeshCH8G5)	6
16 Nodes Mesh Topology Cluster Header 8 Disable 6 Group (MeshCH8G6)	4
16 Nodes Mesh Topology Cluster with Sub Header 4 Disable 1 Group (MeshCSH4G1)	12
16 Nodes Mesh Topology Cluster with Sub Header 4 Disable 2 Group (MeshCSH4G2)	8

Table 3 shows the simulation parameter setup. In this experiment, we investigate the performance of 16 nodes mesh topology under clustering mesh topology and disable cores and routers based on clustering mesh based method. The injection rate also known as the average number of packet it inject per cycle in this

experiment is set to 0.1 to 1.0. Shortest path routing algorithm is used. The result is collected from uniform selection path. In the uniform traffic pattern, each source sends an equal amount of traffic and has the same probability to each destination node.

Table 3. Simulation Setup

Parameter	Technique
Network Size	16 Nodes
Injection Rate (Packet/Cycle/Node)	0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0
Routing Algorithm	Shortest Path Routing Algorithm
Selection Path Strategy	Uniform traffic

4. RESULTS AND ANALYSIS

Figure 3 shows the simulation results of total area (mm2) for 16 nodes mesh topology. Based on figure 3, clustering method and disable cores and router based on clustering method in mesh topology has reduce the total area compare to the 16 nodes mesh topology. The five type of cluster-mesh based topology is mesh cluster header two, mesh cluster header four, mesh cluster header eight, mesh cluster header two with sub header two, and cluster header four with sub header four has decrease the total area by 39.5%, 34.3%, 22.06%, 36.76% and 32.47% compare to mesh topology. The proposed method of disable routers and cores based on clustering method has decreasing the total area compare to cluster mesh and mesh topology. The 10 type of disable group based on cluster-mesh based topology is CH4G1, CH4G2, CH8G1, CH8G2, CH8G3, CH8G4, CH8G5, CH8G6, CSH4G1, and CSHG2 decrease the total area by 50.73%, 71.44%, 30.50%, 44.15%, 52.59%, 66.24%, 74.68%, 87.41%, 49.35%, and 70.53%.

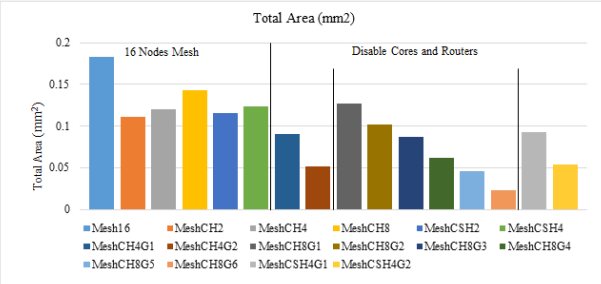

Figure 3. Total Area (mm^2) for 16 Nodes Mesh Topology

4.1 Total Power (Watt)

Total power consumption can defined as the total of power consumed by the network during the passing of the packet from the source node to the destination node in the network.

Figure 4 shows the total power consumption in 16 nodes mesh and clustered mesh topologies. Based on the result from figure 4, clustering method in 16 mesh topology has reduced the total power consumption. The CH2, CH4, CH8, CSH2, and CSH4 reduces the total power consumption by 50.34%, 38.71%, 21.72%, 56.59%, and 41.55% compare to mesh topology. Therefore, clustering mesh topology method reduce the total power consumption of mesh topology.

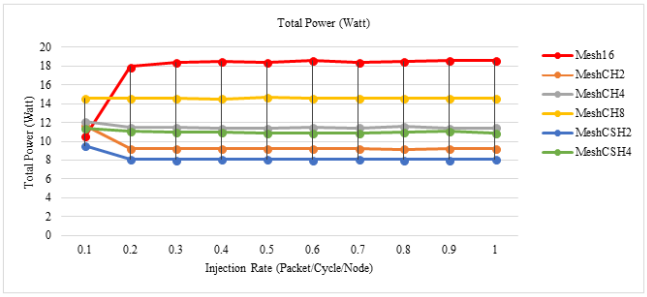

Figure 4. Total Power (Watt) for 16 Nodes Mesh and Cluster-Mesh Topology

Figure 5 shows the total power (watt) for disable cores and router in each cluster header 4 mesh topologies. Based on figure 5, the disable cores and router based on cluster mesh topology has lowest total power consumes comepare to cluster mesh topology and mesh topology. The CH4G1, CH4G2, CSH4G1, and CSH4G2 decrease the total power comsumption by 44.75%, 62.50%, 46.71%, and 64.08% compare to mesh topology.

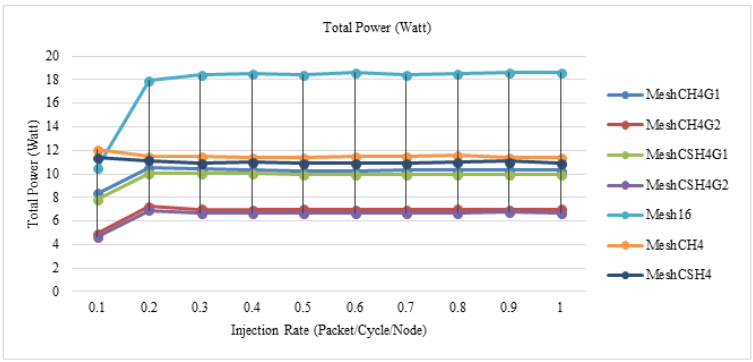

Figure 5. Total Power (Watt) for Disable Cores and Router in each Cluster Header 4 Mesh Topologies

Figure 6 shows the total power consumption of the proposed method by disable cores and router based on cluster with header 8 mesh topology. Based on figure 6, the CH8G1, CH8G2, CH8G3, CH8G4, CH8G5, and CH8G6 decrease the total power consumption by 32.82%, 36.54%, 37.30%, 54.92%, 54.95%, and 74.05% compare to mesh topology. Based on figure 5 and 6, we can conclude that the total power consumption is affected by the number of cluster and the number of disable cluster. The total power consumption is decreasing as the number of disable group cluster is increasing.

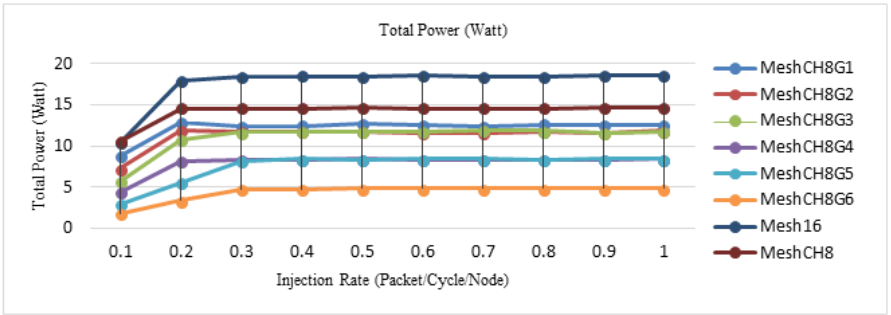

Figure 6. Total Power (Watt) for Disable Cores and Router in each Cluster Header 8 Mesh Topologies

5. CONCLUSION

In this paper, we proposed a disable cores and routers based on new cluster mesh based method to minimize the total power consumption and area of the Network-on-Chip (NoC). We analyzed the performace of the disable routers and cores based on clustering method with the cluster mesh and mesh topology. Experimental results show that the proposed technique is efficient to reduce the total power consumption and area. The clustering-mesh based method reduced the total area between 22% to 40 % and total power consumption between 22% to 56% compare to mesh topology. By disable cores and routers based on cluster mesh topology method has reduced the total area by 45% to 87% and total power consumption by 33% to 75% compares to mesh topology.

ACKNOWLEDGEMENTS

The authors sincerely acknowledge the Malaysian Government for providing financial support in the form of Fundamental Research Grant Scheme (FRGS) [FRGS number: 9003-00463] under the Malaysian Ministry of Higher Education (MOHE).

REFERENCES

[1] N. Y. Phing, M. N. M. Warip, P. Ehkan, R. B. Ahmad, F. F. Zakaria, and F. Wahida, "Towards High Performance Network-on-Chip : A Survey on Enabling Technologies , Open Issues and Challenges," pp. 259–263, 2016.

[2] N. Y. Phing, M. N. Mohd Warip, P. Ehkan, F. W. Zulkefli, and R. B. Ahmad, *"Performance Analysis of the Impact of Design Parameters to Network-on-Chip (NoC) Architecture,"* in Recent Trends in Information and Communication Technology: Proceedings of the 2nd International Conference of Reliable Information and Communication Technology (IRICT 2017*)*, F. Saeed, N. Gazem, S. Patnaik, A. S. Saed Balaid, and F. Mohammed, Eds. Cham: Springer International Publishing, 2018, pp. 237–246.

[3] S. Yan and B. Lin, "Application-Specific Network-on-Chip Architecture Synthesis based on Set Partitions and Steiner Trees," pp. 277–282.

[4] S. S. Bhople and M. A. Gaikwad, "Design of Mesh and Torus Topologies for Network-On-Chip Application," vol. 2, no. 2, pp. 76–82, 2013.

[5] N. Y. Phing, M. N. M. Warip, P. Ehkan, F. Wahida, and R. B. Ahmad, "Topology Design of Extended Torus and Ring for Low Latency Network-on-Chip Architecture," vol. 13, no. 2, 2015.

[6] N. Jiang, D. U. Becker, G. Michelogiannakis, J. Balfour, B. Towles, D. E. Shaw, J. Kim, and W. J. Dally, "A Detailed and Flexible Cycle-Accurate Network-on-Chip Simulator."

[7] A. B. Kahng, B. Li, L. Peh, K. Samadi, S. Diego, and L. Jolla, "ORION 2 . 0 : A Fast and Accurate NoC Power and Area Model for Early-Stage Design Space Exploration," pp. 1–6.

[8] J. Ma, C. Hao, W. Zhang, and T. Yoshimura, "Power-efficient Partitioning and Cluster Generation Design for Application-Specific Network-on-Chip," pp. 83–84, 2016.

[9] J. Minzheng, "Fault-Tolerant Routing Method of NoC System Based on Clustering," pp. 543–547, 2016.

[10] P. B. T, "Power Minimization for Clustered Routing in Network on Chip," no. Icecs, pp. 1584–1588, 2015.

[11] S. Johari, A. Kumar, and V. K. Sehgal, "Heterogeneous and Hybrid Clustered Topology for Networks-on-Chip," pp. 183–187, 2015.

[12] R. K. S, "Network-on-Chip Architecture Based on Cluster Method," vol. 3, no. 3, pp. 61–65, 2015.