A Proficient Performance Scrutiny of King Mesh Topology based on the Routing Algorithms

S.Sobana, T.Madhubala, A.Sakira Parveen, P.Karthika

Abstract: ***Network on Chip (NoC), is an associate degree approach to construct the interaction between subsystems. The number of cores in a System on Chip (SoC) increases gradually in the pre-decades and affect the system performance. The scalability of SoC is improved by NoC architectures where topology contains an important impact on the performance and cost of the network. Mesh, Torus is some of the topologies used in NoC system design. King mesh topology is the concept introduced to improve the performance of the NoC system. King topology introduces some new advancement in the performance of mesh and torus topology. The king mesh topology provides number of advantages such as reduced execution time in parallel processing applications. In king mesh topology the transmission latency of long distance traffic is high. The proposed XY routing and Weight based Path Selection (WPS) routing techniques increases the speed of the system, reduce the area utilization and power consumption and reduce the number of hop counts by finding the shortest path.***

Keywords: Topology, Oblivious routing, Concentrated Mesh, Communication network and switching, digital subsystem

I. INTRODUCTION

System on Chip (SoC) is too complicated to utilize a conventional gradable bus or crossbar interconnects. The increase in number of cores in bus based IP modules reduces the performance of SoC system interconnection. The complexity of electronic systems is increasing quickly due to the density of Very Large Scale Integration (VLSI) systems getting increase. The semiconductor corporation face the challenges to supply on chip interconnect rather than increasing the quantity of ports and processing components on a system. Multiprocessor System on Chip (MPSoC) is employing a complicated heterogeneous system in a single chip [3].Thus in parallel communication bus architecture does not achieve the required bandwidth and other parameters. Evolution of Network on Chip system design is the new technology uses the concept of embedded switching network and improves the performance of network. The NoC improves the scalability and flexibility of a network by interconnecting the module using proper Topology. One kind of NoC topological architectures known as mesh topology for a 3 ×3 network is shown in Figure 1. In network, the data is always transmitted in the form of packets which has a header for including source and destination address, control information and the payload contains the original message. The packets are processed and forwarded inside the network with the help of flow control mechanisms. The basic principle of NoC is the interconnection among the modules. The efficiency of data transmission depends on the effectiveness of the routing process. Routing algorithm is especially identifying the path of the data transmission and determines the performance of the system throughout the transmission. Routing algorithms aims to reduce the number of hop counts thereby reduce the overall latency. Routing algorithms identify the available paths and utilize them properly and balance the traffic load of the media.

A.Topology

Topology plays a very important role in Network on Chip (NoC). Topology decides the interconnection of nodes and links, physical layout of nodes in the network. The network performance and cost of the network depends on the type of topology in a network architectural design. NoC topology has two broad categories as direct network topology and indirect network topology. In direct network topology every node must be connected with a single central core network and in indirect network topology a set of switches area performing networking process independently and they are not connected to any core network [14]. Routers are used as switches to transmit the information between nodes either by half duplex or full duplex mode of transmission. The routers in between the transmitter nodes and receiver node are considering as the hops. The number of hop count increases or decreases latency of the system. Hop count metric is used to capture the number of router hops in a particular network. Path diversity technique identifies the unique path between the source node and destination. Thus a good traffic balance is achieved among multiple paths. Mesh, Torus Star, Octagon and Spin are some of the topologies supported in NoC system design. Among these topologies mesh topology is the widely used in NoC topological architecture.

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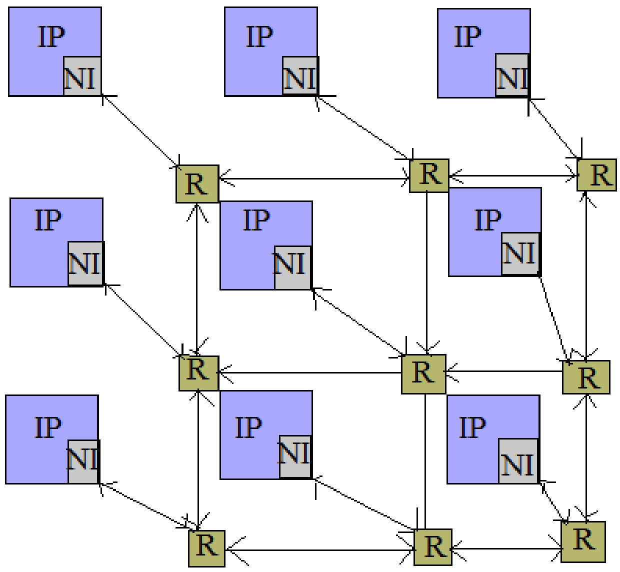

Fig. 1. NoC architecture using (3x3) mesh topology

B. Routing Algorithms

The concept of NoC is mainly designed for large scale network systems [5]. The routing techniques for NoC have different unique style concerns in low latency. Network designing process involves different types of routing algorithms. Based on the protocols used in the routing algorithm the packets are transmitted between two networks. The main categories of network routing algorithms are Oblivious, Deterministic and Adaptive algorithms. Oblivious routing algorithms do not deals with traffic conditions in the network where adaptive routing algorithm gives a detail description of congestion and traffic conditions.

Deterministic algorithm is an extension of oblivious algorithms. In deterministic algorithm the packets arrive in order so it is simple to use and easy to implement. However a path is outlined, the trail is totally specified from relative position and destination address or trail may be operated based on the traffic [16]. Based on the length of the trail, routing may be *minimal or non-minimal*. Minimal routing guarantees the shortest path between the source and destination where non-minimal routing offers good flexibility but causes live lock in the system and reduces the speed of delivery of the packet.

C. Router Architecture

Router is the main block of NoC because it performs the crucial process of coordinating the flow of data. Important operation of router is to assign the data path and usage of proper control function. A control logic helps to take the routing and arbitration decision for transmitting the information. Thus router architecture consists of set of ports to communicate [17]. The process is to receive the incoming data and forward the data to the next port. *Switching technique* is used to switch the data between nodes. Circuit switching and packet switching are the two main categories of switching technique. The main difference between the circuit switching and packet switching is the use of buffer [18]. The packet switching consists of buffer to transfer the huge information. For various applications both switching technique is used, based on the requirement of the system.

This paper proposes a novel topology, King Mesh, for NoC systems. The Aim of this work is to reduce the hop count and latency parameters. The performance of proposed king mesh topology is compared with the performance of existing mesh and torus topologies. Different network parameters are used for the performance comparison. The area and power consumption of the proposed king mesh topology using XY algorithm and path selection routing algorithm is analyzed by using RTL implementation. Section 2 describes the related existing works with detailed description of primary metrics in order to realize the NoC. Section 3 discusses the proposed King Mesh topology and its corresponding routing procedure. Section 4 addresses the analysis and results of king mesh topology compared with the different existing topologies. The paper is concluded by describing the future work in Section 5.

II. RELATED WORKS

A. Different Routing techniques in king mesh

Mesh topology is the widely used topology in NoC because of its simplicity. Mesh topology using source algorithm is chosen for improving the performance of NoC network architecture. The protocol used in the routing algorithm decides the way in which the architecture can be continued. In [14] the authors discussed about the widely used XY routing algorithm and Odd-Even (OE) routing algorithm. The authors measured the performance of the network by varying the network topology and for each topology they measured the performance by varying the routing algorithms used. Power consumption and throughput ratio are some of the measuring parameters used for the network analysis.

In order to enhance the performance of mesh topology cross lines are introduced in one direction and it is named as diagonally linked Mesh (DMesh). Using suitable routing rule the latency is reduced and the path diversity gets increased. The overall performance of the DMesh topology gets improved using DXY routing algorithm and RDXY routing algorithms are introduced in [13]. The DXY algorithms reduces the deadlock and live lock in the network whereas RDXY efficiently utilizes the path diversity and balance the traffic load of the network..

As per Moore's low if there is any increase in the number of cores in a system then there must be a change in the performance of the basic topology. This leads to the introduction of an efficient topology with concentric mesh at the center portion. Hot spot based routing process is introduced in [2] to improve the performance of the system in terms of latency. The routing quality is improved by using a hybrid algorithm as a combination of XY routing algorithm and center concentrated mesh (CMM) routing algorithm. The performance comparison reveals that the performance of the proposed algorithm is better than that of OE routing technique in terms of reduced area and power consumption. The overall performance of the network is estimated from the average mean of each node and it is given as,

$$\text{Average } (P_x) = \frac{\sum_{i=1}^{n} mean\ (Pxi)}{n} \quad (1)$$

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Usage of numerous modules in a single chip introduces network congestion and the package transmission will produce much more delay. The key problem in network architecture is to adopt an appropriate routing algorithm so as to balance the relation between the latency and throughput of the network. Priyanka N et al., [11] proposed a 3*3 torus network topology using XY routing algorithm and estimate the traffic load using Constant Bit Rate (CBR) in order to balance the throughput and latency characteristics. From the result of [11] it proved that as the packet data size increases the latency/packet increases with gradual increase in throughput (in Gbps) and gradual decrease in overall latency.

Basic input output system (BIOS) is another routing algorithm introduced in [5] that combines the features of both deterministic and adaptive routing techniques. BIOS improves both output selection and input selection process of the network. The paper also discusses about the network congestion conditions with respect to the tpe of routing algorithms used. It considers three traffic conditions such as (1) Uniform, (2) Transpose and (3) Hot spot to estimate the performance of the network. The results reveal that BIOS gives a better performance than the existing adaptive and deterministic algorithms.

The combination of mesh topology, torus topology and DMesh topology introduce the concept of King topology. The two different variations supported in king topology are named as king mesh and king torus topology [19]. The packets are transmitted in the directions similar to that of the movement of King in a chess board so [19] provided the name as King Topology. The folding schemes used in the king topology improves the performance of network in terms of bisectional bandwidth, path diversity. Here the network is of square dimensions, to provide a balanced usage of links. In king network the quality of the nodes are $n=s^2$ for any integer s > one. They proved that as per chess board the centred node in the network is also supporting eight degrees to support path diversity.

In diagonal topology the routing record has the sender and receiver address. For 2Dimensional mesh if the source address is (x_0, y_0) and the destination address is (x_1, y_1) then the routing record is calculated by $(\Delta x, \Delta y)$.

$$(\Delta x, \Delta y) = (x_1 - x_0, y_1 - y_0) \qquad (2)$$

Usage of different routing algorithms in different topologies provides different performance improvements but the main aim of network designing is to reduce the number of hop counts.

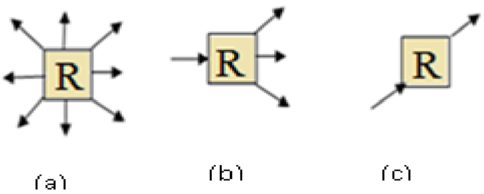


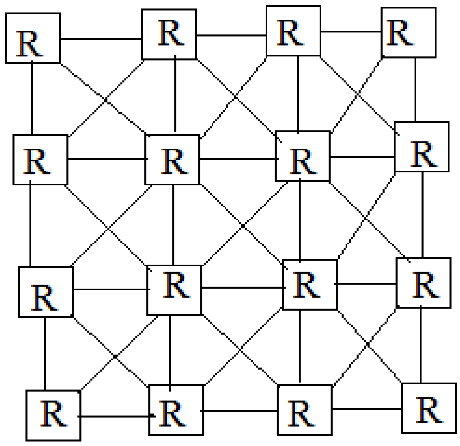
Fig. 2. Behavior of node during broadcast (a) Source Node (b) Orthogonal Node(c) Diagonal Node.

The performance of a network topology depends on different parameters. On the basis of these parameters a network topology is compared with the other topologies. The brief explanation of the network parameters are as follows.

- **Degree:** The degree of a network is also known as hop count of a network and it is defined as the number of adjacent neighbors connected to a router. As the degree of router increases the number of nodes, complexity, area of implementation and power consumption gets increased.
- **Path Diversity:** Path diversity is used to indicate the number of possible shortest path between the two nodes in the network topology. Better load balancing is achieved if the network has more path diversity.
- **Latency:** Average minimum latency is the measure of minimum latencies of all the packets. The latency of a network varies bits transmitted as the congestion and traffic load varies.
- **Throughput:** The number of bits transmitted per second is defined as the throughput of the network. Use of appropriate flow and error control mechanisms with the routing algorithms increases the network throughput.
- **Energy consumption:** Packet transmission through the network increases the power consumption as the number of hop increases.

III. PROPOSED KING MESH TOPOLOGY

In the proposed king mesh topology the number of links needed for a network is reduced by 33% by allocating duplicate link numbers. This also doubles the bisectional bandwidth of the network. Portioning of the nodes from the network is simple and easy in the king mesh and king torus topology. The efficient selection of routing algorithms increases the path diversity especially for the networks used in a large parallel network applications. The efficient selection of routing algorithm also increases the transmission efficiency of the network even in the heavy traffic load conditions. The torus network differs from the mesh network by having a direct connection from the top to bottom and from left to right of the network.



(a)

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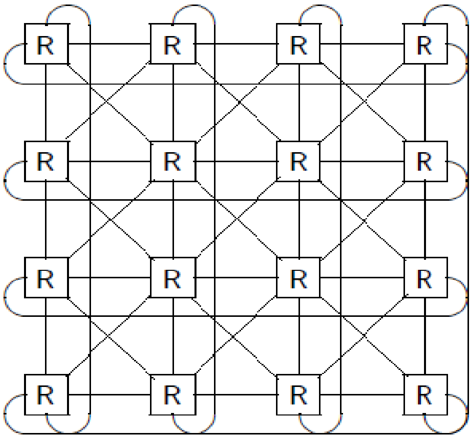

(b)

Fig. 3. 4x4 King topology (a) King Mesh (b) King Torus

Figure 3 reveals that the complexity of the torus network is high compared to that of the mesh network. The processing time of the parallel applications are reduced in King Mesh topological structure. In Dimension Ordered Routing (DOR) algorithm or XY-routing algorithm based topology, packet first routed to correct position in higher dimension before attempting to route in next dimension. For example in a 2D mesh, route first in X dimension, then route in Y dimension. Thus the number of hops in between the source and destination get increased that increases the area and power utilization. Hence, DOR algorithm is not widely used for practical application. The hop count of the network is reduced by taking path selection decision according to the path weight of the network. This type of path selection is known as Weight based Path Selection routing technique (WPS) and it does not consider about the traffic condition of the network. Switching process helps to transfer the data from one node to another node. Normally networks use either circuit switching or packet switching to communicate the information with the other networks. Because of reduced latency the packet switching enhance the performance of the network architecture.

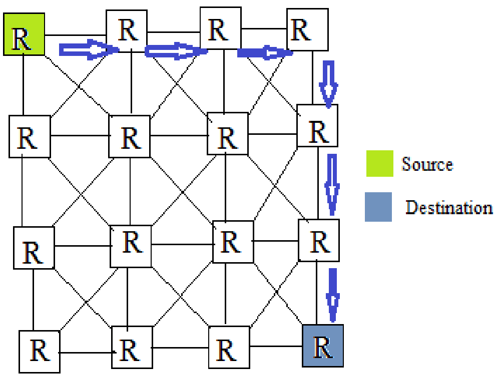

Fig. 4. XY Routing algorithm in King Mesh

Figure 4 shows the structure of XY algorithm in king mesh topology. In XY algorithm the lack of path diversity sometimes leads to poor performance in an unbalanced traffic load. Path selection using randomized routing algorithm enhance path diversity thereby reduce the defect of XY routing. In random WPS technique the path is assigned with some random weight for example 00, 01, 10 and 11.Then the path with highest weight is chosen as the route path to transmit the packet from the source node to the destination node. Compared with the existing random path selection algorithm in XY based routing technique has increased number of hop counts.

Thus, the number of LUT count and flip-flops required is getting increased in XY algorithm compared with the WPS algorithm. This will reduce the area requirement and power dissipation of the WPS based routing algorithms. The basic algorithm needed for the path selection is as follows,

For i=1 to N

Route the packet x_i by executing the following two steps independently of all the other packets

- Choose a random intermediate destination y_i from {i=1 to N}, and route x_i from i to y_i.
- Route the packet from x_i to its final destination d_i through y_i.
- In XY algorithm the y_i chosen as the adjacent nodes in the X direction first and in the Y direction as a continuous process as the destination d_i reached.
- In WPS algorithm the path with highest weight is chosen as y_i and the decision process is repeated until the destination d_i is reached.

IV. RESULTS AND DISCUSSIONS

The results of the proposed work are compared against the existing network topologies such as mesh and torus on the basis of the following network parameters [20].

Hop Count: The results showed in table 1 reveals that the King Mesh topology has a significant decrease in hop count when compared with the existing mesh and torus topology. The reduction in hop count when compared with the mesh topology is 29 %, for torus 13.5%.

Diameter: The minimal number of hops needed for the overall pairs of nodes is known as the diameter of the network. For a network with 'n' nodes, the diameter of mesh network is *2(n-1)*, torus network is *n-1* if n is odd and *n* if n is even. For king mesh and king torus diameter is *n-1*. The diameter of a network with 4 nodes is compared in table 1.

Latency: The latency of a congestion free network is defined as the average delay between all the nodes in the given topology**.** It can be calculated from the formula,

$$L = HT + \frac{D}{v} + \frac{P}{B} \quad (3)$$

Where H indicates the hop count, T denotes the delay introduced by the router, D is the distance between the source node to the destination node, v is the transmission velocity of medium, P is the length of the packet and B is the bandwidth of the channel. King topology has 23% less delay than mesh topology and 17.5% less latency than torus topology.

Table 1. Comparison of different Topologies

Topology	Mesh	Torus	King Mesh
Hop Count	634	520	450
Diameter n=4	6	4	3
Latency	13.2	12	10.1

Figure 6 compares the performance of King Mesh topology and basic Mesh topology in terms of the energy consumed by the network with respect to the traffic load per cycle. The results reveal that for example, if the traffic load is 0.3 phits/cycle/ node the energy consumed by the mesh network is approximately 0.0002 J and the energy consumed by the king mesh network is 0.00015 J. Thus the king mesh topology consumes 33.3% less energy when compared with the mesh topology.

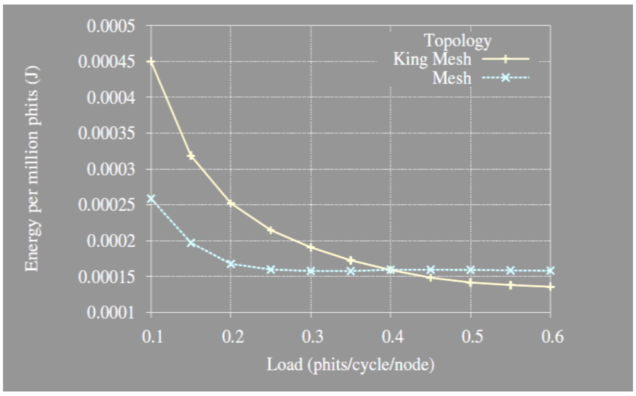

Fig.6.King Mesh and Mesh topology Energy comparison

Figure 7 presents an analysis of throughput versus latency comparison of 4×4 king mesh topology under uniform and non uniform traffic load conditions.

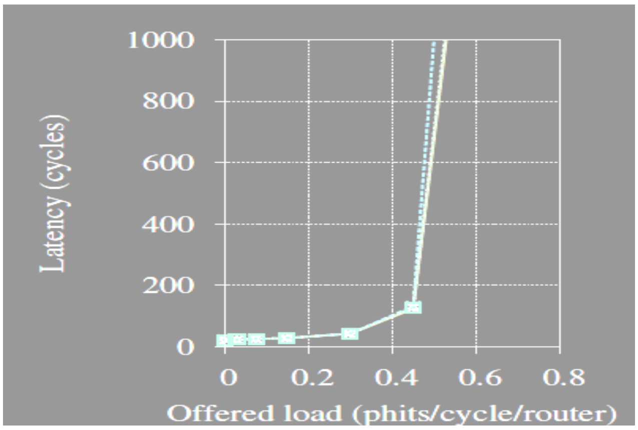

Fig.7.Comparison of Throughput and Latency of King Mesh Topology

The results shown in figure 8 and 9 shows the performances of XY algorithm and weighted path selection algorithm based routing techniques used in king mesh topology.

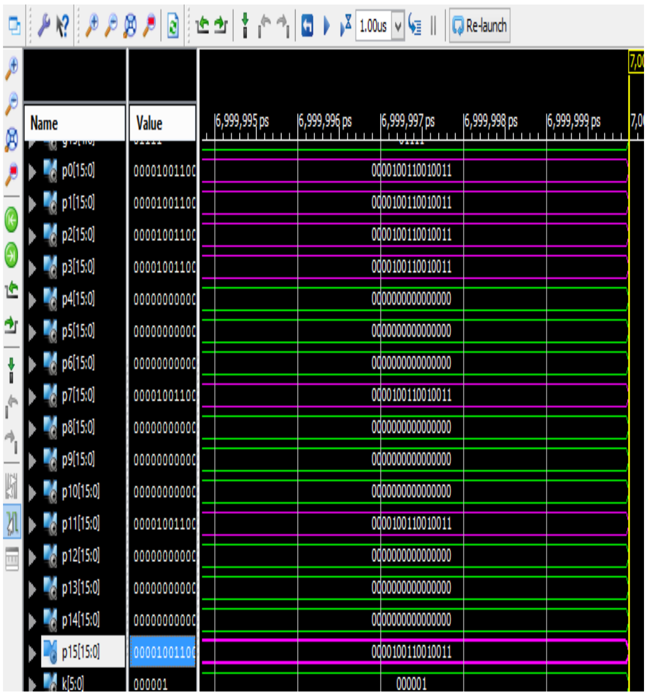

Fig. 8. Path selection using XY routing technique

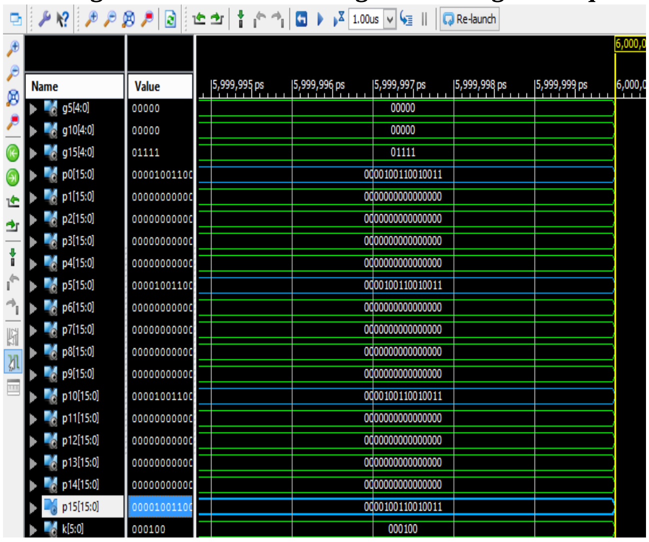

Fig. 9.Path selection using weighted path selection technique

In XY routing technique the data is transmitted in X axis and it is followed by Y axis as shown in Figure 6. It shows that the number of hops used to transmit the data gets increased. The shortest path is estimated by WPS method as shown in Figure 7.

Weighted path selection technique shown in figure7 depicts that the hop counts needed for transmitting data is less than that of the XY routing algorithm. The above results are obtained by analyzing the 4x4 king mesh network architecture using Xilinx 14.2. The comparison results of XY routing algorithm and WPS algorithm is shown in table 2.From the results, it clear that the utilization of slice LUTs and slice registers are less in WPS routing algorithm. Thus the utilization of area of WPS is appropriately reduced up to 40 percent than that of the XY routing algorithm.

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Table. 2. Comparison between XY routing algorithm and WPS routing algorithm.

PARAMETERS	XY routing	WPS routing
Number of slice LUTs	119	79
Number of slice Registers	294	196
Number of fully used LUT-FF pairs	115	76
Power Consumed	1.442W	1.440W

The bar chart shown in figure 8 describes the utilization of LUTs and registers utilized by the XY routing algorithm and WPS routing algorithm. The Number of LUT slices and Registers utilized are calculated using Xilinx software.

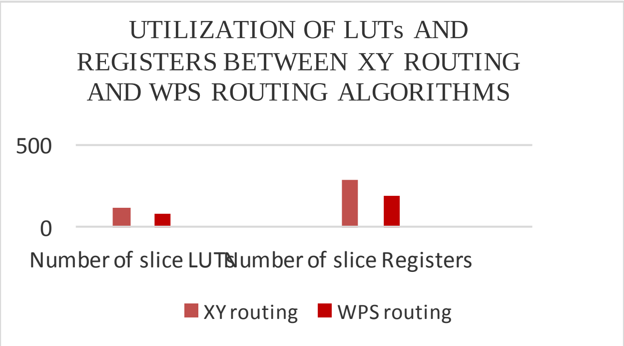

Fig. 8. LUTs and Registers utilized for XY and WPS routing algorithms

V. CONCLUSION

This paper presented an idea about the basic mesh and torus topology algorithms used in king topological architecture. The performance of king mesh topology is analyzed by using XY routing algorithm and weight based path selection routing algorithms. Among these two algorithms, the performance of WPS algorithm is better than that of XY algorithm in terms number of LUTs and Registers needed. The number of hop counts is minimized between the source and destination. The area utilization and power consumption is getting reduced in the WPS algorithm. The proposed routing algorithm considers only fault free links. In future a new routing algorithm for a faulty link will be developed.

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