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# *A Topology for Network-on-Chip*

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***Abstract*—Network on chip is an advanced version of System on chip which gives both scalabilities and flexible communication inside the chip. In this paper we proposed a new topology by keeping in mind the factors like minimum chip area, high throughput and minimum latency with path diversity. We compared our proposed topology with some existing topologies like fat tree and Multipath Topology in terms of latency, throughput, hop count, the hardware used and the number of events to be carried out the simulation. The proposed topology provides us with minimum latency, less hardware used, high throughput better than the existing topologies that we compared. We used an adaptive routing algorithm which is a deadlock and live lock free algorithm, provides path diversity along with a proper load balance and maximum channel utilization in our proposed topology. The required simulation is done using with an open source simulator named OMNET++.**

***Keywords—Network on-chip,Toplology,perfomance,scalability***

## I. INTRODUCTION

As we know, day by day the size of the IC is getting reduced while the number of components connected to it is growing rapidly. For this reason the concept of Network-on-chip emerged. Before, the introduction of Network-on-chip, System-on-Chip was introduced, where via a single bus all the IP (Intellectual Properties) cores are connected as shown in figure 1. But it has several disadvantages like single channel, global interconnection, low bandwidth, high latency, power consumption and last but not the least scalability. To overcome all these problems Network-on-chip was introduced [5]. In Network-on-chip several cores are connected through network of routers. Network of routers means the bus in System-on-Chip is being replaced by some routers, which are available to take care of the transmitted message from one node to another. For this network of routers designers already proposed number of different topologies. These topologies are evacuated with different algorithms to get the best results but all these topologies with different algorithms has still failed to fulfill the current demands of chip. So designers are working hard to get a topology with an algorithm to get a fruitful result.

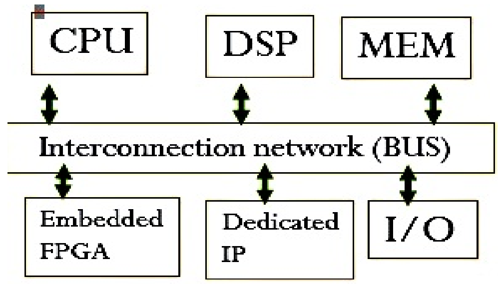


Fig. 1. Traditional System-On-Chip [2]

In this paper we introduced a new Topology along with a suitable algorithm which gives better result in comparison to some existing topology in terms of scalability, throughput, latency and hardware used.

In the next part of this paper we have discussed about some existing topologies and then discuss about our new Topology and after that compared it with some existing topologies and ends up the paper with a brief conclusion.

## II. REVIEW OF SOME EXISTING TOPOLOGY

The most popular existing Topology for Network-on-chip are Ring Topology, Star Topology, Mesh Topology, Torus Topology and Tree topologies like Fat tree Topology and butterfly Topology. In this section we are trying to summarize the pros and cons of these existing few topologies.

### *A. Ring Toplogy*

One of the most popular existing Topology is ring Topology. In ring Topology every node is connected with a single wire. So each nodes has two neighbors as shown in figure 2. Therefore degree of each node in Ring Topology is two which signifies equivalent available bandwidth to each and every node. The main disadvantage of this topology is that the diameter increases when the number of nodes is increased and for this reason, expansion in the network degrades the performance. Moreover a single break in the cable breakdowns the entire network.

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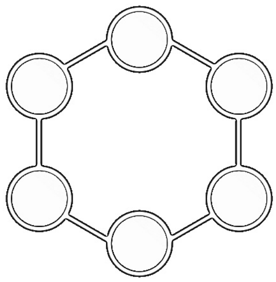

Figure. 2. Ring Topology [4]

*B. Star Topology*

In Star Topology all the nodes are connected to a central node as shown in below figure 2. Here the main disadvantage is that central node failure. If the central node goes down then the entire network goes down. Moreover the diameter of the central node increases with the number of increased nodes, hence bottleneck occurs in the central node. Main advantage of this Topology is simplicity and the minimum hop count is always 2.

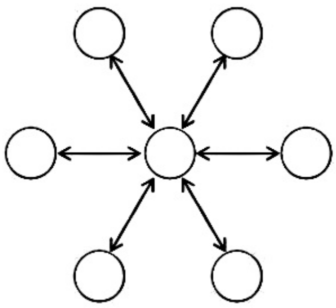

Fig. 2. Star Topology [4]

*C. Mesh Topology*

In Mesh Topology nodes are connected to each other as shown in figure 3. It gives a good result for scalability, path diversity but the main disadvantages are diameter will be very large for increased number of nodes and due to irregularity in degree, the bandwidth will differ from node to node.

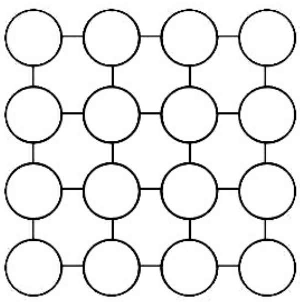

Fig. 3. Mesh Topology [4]

*D. Torus Topology*

Increase in diameter for mesh Topology with the size of the network was overcame by the torus network by adding direct connection between the end nodes as shown in figure 4. The problem of diameter is overcame, but the increase in the length of the wire produces higher latency which pops out a disadvantage of the network.

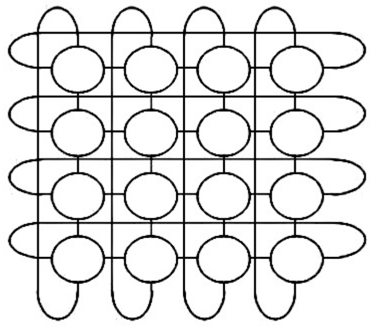

Fig. 4.Torus Topology [4]

*E. Fat tree Topology*

In Fat tree topology intermediate routers will work as a forwarding routers while only the leave routers are connected with the clients as shown in figure 5. Though there is path diversity available but the ratio of router and clients is very high. Means several router has to be integrated to connect fewer clients, which maximize the hardware use.

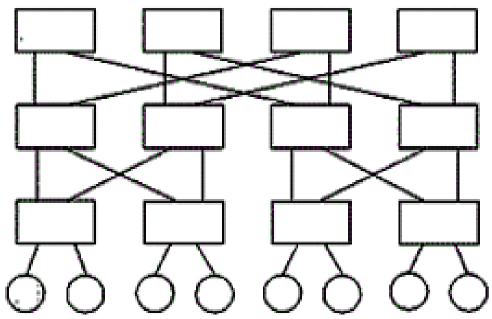

Fig. 5.Fat Tree Topology

*F. Butterfly Topology*

In butterfly Topology nodes are connected as below figure 6. The main disadvantage of butterfly Topology is the lack of path diversity. Because there is only a single path available from its source to destination. Another disadvantage of this network is that long network diameter which consumes more energy.

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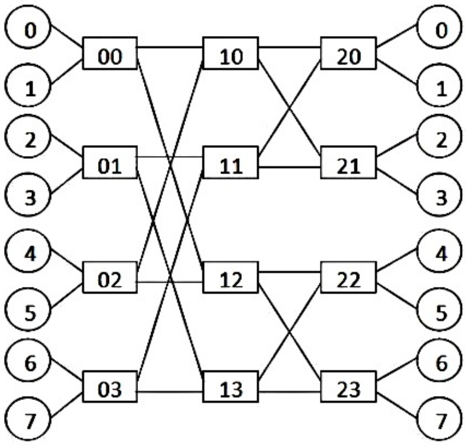


Fig. 6. Butterfly Topology [4]

## III. PROPOSRD TOPOLOGY

As there are so many topologies already exist for Network-on-chip but all of them have some of demerits regarding the number of links, Network size, and more or less the bandwidth. So we are trying to get a Topology to be fair with the mentioned major problems.

Our Topology provides high degree of the scalability and throughput with path diversity, lowering the latency and network size. The below figures describe our Topology for 24 clients, 48 Clients, 96 Clients and the internal configuration of router.

### *A. Router Design*

The routers always plays the vital role for performing the whole routing operations. The packets are forwarded from source to destination through one or more routers. In the proposed topology we used three types of routers i.e. green routers, blue routers and red routers [3]. The routers are composed with six different ports. The ports are connected to each other by some internal gates. All the ports have three modules to calculate the next path. The modules are scheduler, inport and opcal as the author A. Biswas et.al [1] describes in their paper. In Scheduler packets are received. If it is coming from some internal gates then it directly sends the packet to next port by its internal connection. And if the packets are coming from an external links i.e. clients or other routers, it forwards the packet to opcal via inport. After calculating the routing part in opcal again the packet forwarded to scheduler via inport and finally the scheduler forward the packet to next router. In our topology how the different ports of different routers are connected is shown in figure 6.

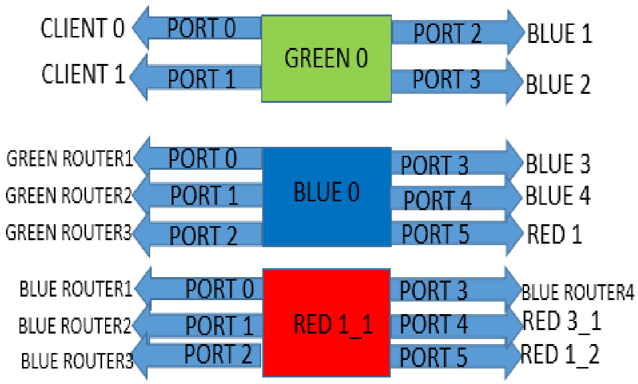


Fig. 6.Router with their Port description

The green routers were connected with the Clients by its two ports and the rest of the two ports is connected with the neighboring two blue routers.

Three ports of the blue router is connected with the neighboring green router, other two are connected with the neighboring blue router and rest is connected with the neighboring red router

The red routers are differentiated by its id and level number. Each red router also have 6 number of ports. In level one router four of its port are connected to the blue router and one port is connected with the same level red router and the rest is connected with the higher level red router.

In level two or more than two, four of its ports is connected with the immediate lower level red router, one port is connected with the same level red router and the rest is connected with the next level red router. And the Topology goes on accordingly.

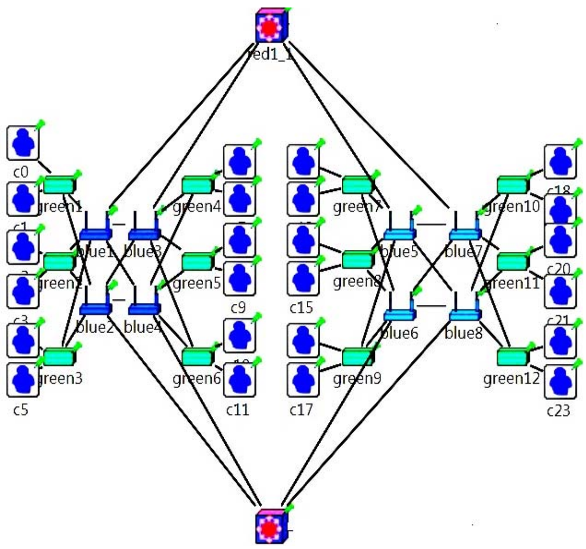


Fig. 7. Topology for 24 Clients

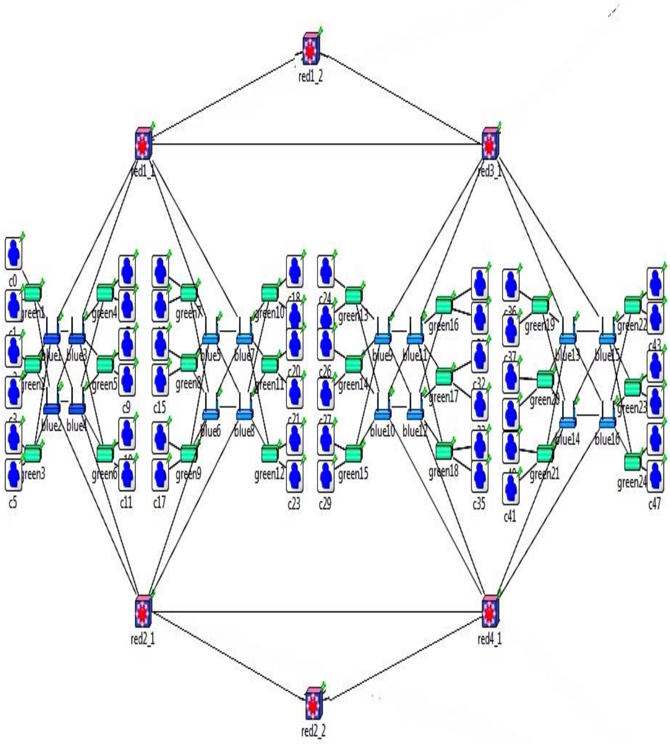


Fig. 8.Topology for 48 Clients

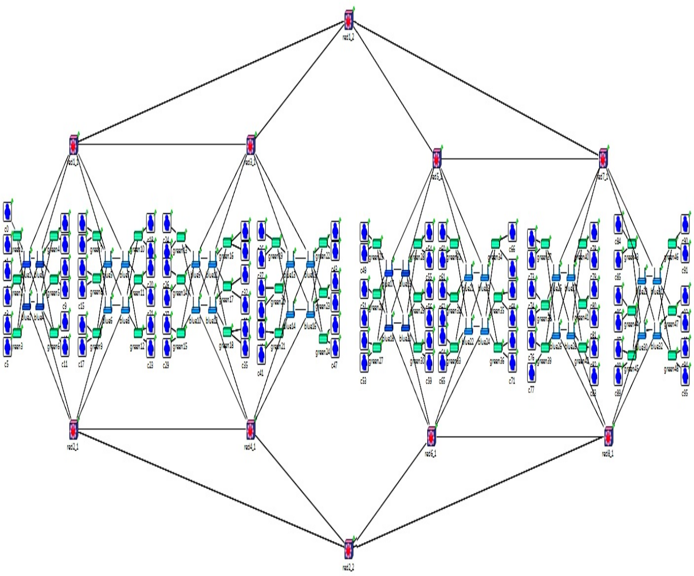

Fig. 9.Topology for 96 Clients.

## *B. Proposed Routing Algorithm*

DESTINATION ID=DEST_ID
CURRENT ROUTER=CUR_ROUTER
DESTINATION GREEN ROUTER=DEST_GREEN
DESTINATION BLUE ROUTER=DEST-BLUE
DESTINATION RED ROUTER=DEST_RED

Step 1. Receive the packet and extract the dest_id of the packet.

Step 2. Calculate the dest_green, dest_blue and dest_red by following

dest_green=(dest_id/2+1)

dest_blue1={2*(dest_id /6)+1}

dest_blue2={2*(dest_id /6)+2}

dest_red1(level 1)={2*(dest_id/24)+1}

dest_red2(level 1)={2*(dest_id/24)+2}

dest_red1(level 2/more) ={2*{24*pow(2,level)/4} +1}

dest_red1(level 2/ more) ={2*{24*pow(2,level)/4} +2}

Step 3. Read the color and id of the cur_router.

Step 4. If the cur_router color=green

If cur_router_id=dest_green_id
Send the packet to its destination client.
Else,
Forward the packet to its neighbor blue router

If the cur_router color=blue

If cur_router_id=dest_blue1 OR cur_router_id=dest_blue2
Forward the packet to connected green router.

Else if cur_router_id AND dest_blue1 OR dest_blue2 are in same group,
Forward the packet to the dest_blue.

Else
Forward the packet to its connected red router.

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If the cur_router color=red

If(level==1)

If cur_router_id=dest_red1 OR cur_router_id=dest_red2
Forward the packet to connected Blue router.

Else if cur_router_id AND dest_red1 OR dest_red2 are in same group,
Forward the packet to the dest_red.

Else
Forward the packet to its connected upper level red router.

If(level==2 or more)

If cur_router_id=dest_red1 OR cur_router_id=dest_red2
Forward the packet to connected lower level red router.

Else if cur_router_id AND dest_red1 OR dest_red2 are in same group,

Forward the packet to the dest_red.

Else
Forward the packet to its connected upper level red router.

### *C. Packet Structure*

The message are being sent from source to destination in terms of the packet. The basic packet size is 20bytes. Five fields are there, each field is of 4Bytes. The Packet fields are Packet Id, Source Id, Destination Id, Output Line and Data [1,2].

## IV. THE THEORITICAL AND PRACTICAL PERFOMANCE ANALYSIS

### A. Number of events

A. Biswas et al. in [1] compared their results with the existing Fat tree network and they were able to get high performance in terms of total number of events to be carried out the simulation. Again K. Ray in [2] compared his new architecture for network on chip with the existing Fat tree with packet based routing and partial group based routing [1] and found better results than them in terms of number of events. Therefore we compared our proposed topology with K. Ray's [2] topology and got the following results.

TABLE I. NUMBER OF EVENTS FOR RANDOM DESTINATION

| **Network Size** | ***Number of Events*** | |
|---|---|---|
| | ***Multipath Topology*** | ***Proposed Topology*** |
| 12 | 232 | 234 |
| 24 | 666 | 612 |
| 48 | 1760 | 1524 |

TABLE II. NUMBER OF EVENTS FOR STATIC DESTINATION

| **Network Size** | ***Number of Events*** | |
|---|---|---|
| | ***Multipath Topology*** | ***Proposed Topology*** |
| 12 | 220 | 228 |
| 24 | 612 | 606 |
| 48 | 1702 | 1512 |

### B. Hardware Cost:

In our Topology we used minimum number of routers and links for communication among the core which reduce the hardware cost as compared to fat tree and the multipath topology. Following table represents the number of routers used in different networks.

| ***Total Routers use*** | | | | | |
|---|---|---|---|---|---|
| ***Multipath network Topology*** | | ***Fat tree*** | | ***Proposed Topology*** | |
| ***Router*** | ***Client*** | ***Router*** | ***Client*** | ***Router*** | ***Client*** |
| 6 | 8 | 12 | 8 | 5 | 6 |
| 14 | 16 | 32 | 16 | 10 | 12 |
| 30 | 32 | 80 | 32 | 46 | 48 |
| 62 | 64 | 192 | 64 | 90 | 96 |

TABLE III. NUMBER OF ROUTERS USED

Here, if we take the Client-Router Ratio, then our topology gives better results than the rest for more numbers of client.

### C. Path Diversity

Our proposed topology provides multiple path diversity. If a link goes down then there is always another path to reach the destination though the network set up with minimum number of links. Hence provide a reliable communication in the entire network.

D. End to End latency:

End to end latency is calculated by the difference between the creation time and the arrival time of the message in the destination. Here we found that when messages are sent randomly then our proposed topology gives better result than the multipath topology [2] or fat tree topology [1]. But when all the packet forwarded to a single destination then it takes little more time than the multipath topology. Following table represents the end to end latency

TABLE IV. AVERAGE PACKET LATENCY

| Network Size | ***Average Packet Latency in $10^{-8}$sec*** | | | |
|---|---|---|---|---|
| | ***Multipath Topology*** | | ***Proposed Topology*** | |
| | ***Static Dest.*** | ***Random Dest.*** | ***Static Dest.*** | ***Random Dest.*** |
| 8 | 10.5 | 2.5 | 10.375 | 2.87 |
| 16 | 25.07 | 1.375 | 34.375 | 1.75 |
| 32 | 96.468 | 2.625 | 162.19 | 1.375 |
| 64 | 620.86 | 3.91 | 1895.73 | 1.890 |

E. Hop Count:

The proposed topology uses less number of hops than the multipath topology and Fat tree topology. When the network increased significantly hop count decreases in compared to the multipath topology, fat tree and mesh topology.

## V. CONCLUSION AND FUTURE WORK

In this paper we proposed a Topology for network on chip along with a deadlock and live lock free algorithm. The number of the nodes and routers influence a great impact on performance of the Topology and for this very reason we are trying to minimize the number of routers with an arrangement, which gives higher performance, scalability and low latency. Our future work over this Topology is to make it a fault-tolerant Topology and reduce the end to end latency when all the packets forwarded to a single destination.

## ACKNOWLEDGMENT

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