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Diagonal Connected T Mesh

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Abstract

Objectives: The high computing demands leads to high communication between the various cores on the chips. This leads to the exploration of various topologies. The Mesh based topologies are widely accepted due to simplicity. This mesh topology is modified with objective to reduce inter node distance. **Methods/Statistical Analysis**: Proposed topology has been generated as the union of the Diagonal connected mesh and T Mesh. To test the performance the proposed topology that is Diagonal connected T mesh is compared with diagonal connected mesh and T Mesh. To test the performance of the topology static routing algorithm is used. The various traffic patterns have been used for the analysis of latency and bandwidth. **Findings:** The proposed topology has performed better in comparison to Diagonal connected Mesh and T Mesh in case of Uniform traffic and Bit Complement traffic. In case of tornado traffic results are identical to that of Diagonal connected mesh. The hop count analysis shows that there is always a positive improvement. Average Hop count of the diagonal Connected T mesh is 87% less than that of it counterpart. This makes the proposed proved to be better than the existing topologies. **Application/Improvements:** The proposed topology for network on chip will always be suitable for the applications in which the communication is either uniform among the nodes or is communicating to the nodes having complement traffic match.

Keywords: Hop Count, Mesh, Network on Chip, Topology, Traffic Analysis

1. Introduction

With the development in the nano - technology, the large number of processor on a single chip is feasible. The increase in the number of processor leads to the demands of high communication between them. This demand is to be served by the Network residing on the chip and referred as Network On Chip (NOC)[1]. The increase in demand usually creates the bottleneck in the system[2-4]. Earlier when there was less number of cores the buses were used for the communication but as the demands have increased the buses are being replaced by different topologies. The NOC mainly consist of topology and it is underlying hardware like routers, switches and software's in the form of routing algorithms and arbitration algorithms. The topologies are defined to be the key source of performance issues and many topologies have been developed in the past like Mesh, Torus, FAT Trees. Among these topologies Mesh and torus topologies seems to gain more popularity and found the space in various machines that may be used in commercial or academic purpose like Intel TFLOPS supercomputer, DASH multiprocessor[5], and Intel Paragon[6]. The popularity of the mesh topology lies in the simplicity of the mesh network. The other factor for the popularity of mesh architecture is efficient layout and addressing scheme[7]. The popularity of mesh interconnection network attracted the research community to explore the topologies that can harness the properties of the mesh interconnection network and increase the performance in some of its topological factors. The most popular variant of the mesh topologies are X mesh, D mesh, T mesh, C[2] mesh[8-14] and torus like X torus, SD torus, xx torus[15-19].

Most of these topologies have focused to reduce the inter-node distance parameters. The four topological

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parameters that are used for observing the performance of the system are degree, diameter, bisection width and Edge length. These fours parameters are used for the analytical analysis of the topologies[20,21] .

In this paper our focus is on designing a topology that is based on the two variant of the mesh topology that is T mesh[13] and Diagonal connected mesh (DCM)[1]. The main objective of designing this topology is to reduce the average inter-node distance of the complete topology and provide the better quality of service to the nodes participating in the communication.

The paper has been divided into 6 sections. Section 2 describes the detail insight of the underlying topologies T mesh and DCM. In section 3 the proposed topology has been described. Section 4 describes the Experimental Setup. Section 5 provides the results and detail discussion. Section 6 concludes the paper detailing about the merits and demerits of the proposed topology.

2. The DCM and T Mesh Topology

The Diagonal connected mesh has been derived from the basic mesh topology the 4×4 DCM has been described in the Figure 1 below. According to the authors neighbors in the DCM can be of 2 types of neighbors:

1. Normal neighbors
2. Diagonal neighbors

2.1 Normal Neighbors

When there exist a horizonatal or vertical link that exists in the traditional mesh then it is called as the normal neighbour. The condition for the simple mesh edges is very simple as it can be described as simple node of graph G. The nodes a,b can be connected by a horizontally by substituting the x coordinates keeping thr y coordinates as the same and satisfies the equation 1 and it can be connected. Similarly by substituing the y coordinates and keeping the same X coordinates results in the links between the 2 nodes in vertical separation.

$$\begin{aligned} b_i &= a_i \pm 1 \mid \forall\ 1 \le i \le n-2 \\ b_i &= a_i + 1 \mid i = 0 \\ b_i &= a_i - 1 \mid i = n-1 \end{aligned} \quad (1)$$

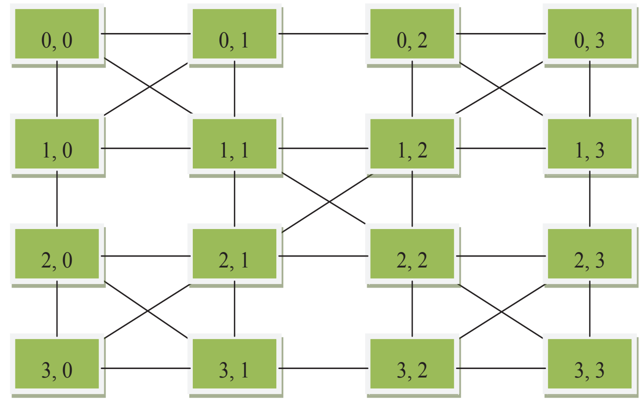

Figure 1. DCM of 4X4

2.2 Diagonal Neighbors

When in DCM there exists a link between two nodes that are situated diagonally they will be referred as diagonal nodes. Now there are two types of the diagonals for a rectangle or a square they may be referred as the major diagonal and the minor diagonal. As from the Figure 1 we can see that the degree of the node is maximum 6 that is node will be either having the major diagonal or the minor diagonal, this is done easily by the equation 2 according to which it states that if the node coordinates are summing up to even then node will connected to nodes which forms the major diagonal. If the node coordinates sum to odd, then it will connect to the minor diagonal

$$(Dx, Dy) = (x_i \pm 1, y_i \pm 1) \mid \forall i : 1 \le i \le n-2 \; and \; x_i + y_i \; is \; Even \quad (2a)$$

$$(Dx, Dy) = (x_i \pm 1, y_i \mp 1) \mid \forall i : 1 \le i \le n-2 \; and \; x_i + y_i \; is \; odd \quad (2b)$$

such that 0< = Dx and Dy< = n-1

The DCM has been not using the complete diagonal nodes this due to the fact that introducing the complete diagonals will increase the cost of the routers as it incresses the degree of the nodes not only it also incresses the link the in the mesh.

The T Mesh is the topology based on the mesh topology; the topology can be described by adding the four long links on the corner links of the mesh[13]. This reduces the diameter of the mesh is reduced as the distance between the extreme nodes are reduced. The extra links in the T Mesh can be described the equation given below:

$$T(x, y) = (x_i \pm n-1, y_j \pm n-1) \mid i = 0 \vee i = n-1 \wedge j = 0 \wedge j = n-1 \quad (3)$$

This equation 3 along with the equation 1 is capable of drawing the T Mesh as in Figure 2. The degree of the

T Mesh is with in the boundary of the mesh topology that is four. The bisection width of the topology has been incressed by two as two extra links have to be deleted to divide the network into two equal halves.

3. Proposed Topology

The Proposed topology is the combination of the DCM and T Mesh. The main objective of desiging the topology that has the less internode distance than the DCM and T Mesh topologies. The suggested topology reduces the diameter of the topology, The bisection width of proposed

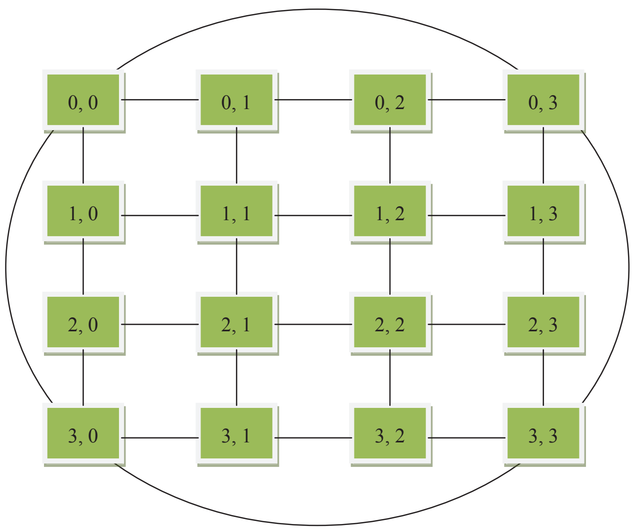

Figure 2. TMesh 4X4

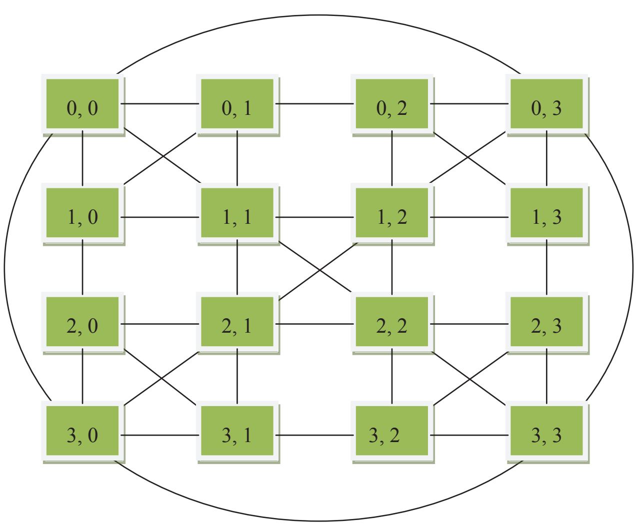

Figure 3. DCT 4 X 4

topology is higher in comparision to that of the DCM topology. The proposed topology is called as Diagonal Concentrated T Mesh (DCT). DCT is described in the Figure 3 below. As from the Figure 3, it can be observed that the degree of DCT is maximum of 6, the bisection-width has been incressed by 2 in comparision to that of DCM. DCM is already having higher bisectionwidth in comparision to that of T Mesh. Mathematically, we can write the topology as described by the equation 4.

$$DCT = DCM \bigcup Tmesh \tag{4}$$

This imples extra links other than of the normal neighbour links can be described by the equations 5 as:

$$DT(x, y) = D(x, y) \bigcup T(x, y) \tag{5}$$

The complete topology of 4×4 has been described below. From the figure 3 it can be easily observed that the topology is simple in nature as T Mesh and DCM. As there are only few extra links in the DCM so the increase in the cost due to extra links will not be more.

4. Experimental Setup

4.1 Hardware Specification

To perform the simulation of the topology under consideration, we have used a window 7 SP1 based 32-bit machine. The machine is having Intel® Core™2 CPU T5200 running at the rate of 1.60 GHz. The System is equipped with 2 GB of Ram and HDD running at the speed of 7200 RPM.

4.2 Software Specification

To analyze the performance of the topology for the interconnection network the omnet++ simulator has been used. It is a open source simulator and is based on the C programming language[22,23]. It is basically a discrete event based simulator. To test the performance we have considered each node as the source and each node as the destination.The simualtions are done at the packet level. At different load factors. To create the different loads the packet injection rate of the source is varied from 163.84µs to 4.09µs. The node in the simulator is supposed to consist of various modules as

4.2.1 App

Here App is module that is behaving as the source and the sink application. This App can be considered as the processing element in the SOC. The App module is responsible for the generating of packets which may at the slow rate or at the busty rate. When the packet has reached at the destination App module the various parameters are recorded that can be used to estimate the performance of the network design[22].

4.2.2 Queues

The queue is used to store the packets at the various intermediate nodes or at the source and destination nodes for their processing. The Queue module is responsible for getting the idea of the queuing delay and packet dropped. To get the idea of exact latency in which queuing delay is also a part we have considered the infinite queue length so there will be no packet drop due to small queue length.

4.2.3 Router

This module is used for the routing of the packet from the current node towards the destination node. The various approaches can be used for routing algorithm the two prime ways are using routing tables and second based on the algorithm to take the decision that may be using as Finite State Machine (FSM)[7] model. In the current scenario as our interest is to design more efficient topology not the routing algorithm so we have used the routing algorithm based on the tables. Using router based on tables generally cost more consumption in power and area of the router but has the added advantage of fault tolerance as an alternate path could be suggested immediately[7].

4.2.4 Communication Channels

The communication channel is generally classified into two categories as ideal channels and the channels with the delay. The ideal channel do not show any delay but delay channel show the delay in the communication as this may occur when we are using the links for the communication. There is one more parameter that describes the performance of the communication links is the data rate. Data rate is generally defined as the rate at which the data can be transferred through the channel.

The parameters used while designing the topology for the experiments is described in the Table 1 described below:

Table 1. Describing the Parameters of the topology in OMNeT++

Sl. No.	Parameter Name	Value
1	Rows	4
2	Coloums	4
3	Packet size	1024 bytes
4	Data rate	1Gbps
5	Simulation time	10ms
6	Warmup time	0.5ms

4.3 Performance Factors under Observation

To analyze the performance of the topology the following two parameters QoS parameters are used.

4.3.1 End to End Latency

It is defined as the maximum time required by the packet to reach from to source to destination. By latency it is generally understood as the delay. This delay may be due to the various factors like delay due to propagation of the packet and is referred as the propagation delay. Another delay that is the part of the end to end delay is the queuing delay this delay is time for which the packet is queued in the router. Another delay is the delay that is due to the routing decision time.

4.3.2 Sink Bandwidth

It is another parameter that is used to analyze the performance of the network. It described the maximum bandwidth which is available at the sink. In general if more packets are received successfully more is the sink bandwidth.

4.3.3 Hop Count Analysis

It is an done by using a simple program in c language to do so each link in the topology is assigned as weight of 1 unit and the shortest distance between the various nodes is analyzed. Hop count is an important factor for the analysis. The latency of the system directly depends upon the number of hops that occurs in the path from the source to destination.

5. Results and Discussions

To analyze the performance of the network the various traffic patterns can be used, in our experimental analysis the 3 traffic patterns are used.

5.1 Uniform Traffic

As the name says, that traffic is uniform in nature. That means every node has the equal probability of sending the packet to every other node in the topology. Similar every node has the equal probability to receive the packet from every other node. The Uniform traffic is supposed to be the very simple traffic and the performance of the mesh topologies always better on this type of traffic. The uniform traffic to prove the DCT is better than DCM and TMESH it should either equal or better in performance. From the Figures 4 it can be identified that DCT topology is having lower latency than other two topologies. The variance in the performance of the topologies can be identified at the higher packet injection rates. In case of sink bandwidth also the DCT topology has dominated the other two topologies the same has been described in the Figure 5.

5.2 Bit Complement Traffic

In this type of traffic the source node address is converted into binary address which is then complemented to get the destination address. For the simplicity in generating the destination address we have used the mathematic formulae as described by the equation 6 described below.

$$D = N - S \qquad (6)$$

In the equation D is the destination node address and S is the source node address in the above equation it is assumed that the both S and D are beginning form the 0 and terminating n. The value of N is always remaining to be one less than the number of nodes.

As we know to achive the better performance the throughput should be higher and end to end latency should be lower. The performance graph of the end to end latency and sink bandwidth are described in the Figure 6 and 7 below. It can be infered that the DCT has been good in both of the factors.

5.3 Tornado Traffic

Tornado traffic is considered to be traffic which affects the performance of the topology under consideration. It is a kind of the diagonal traffic. In this kind of traffic the nodes are supposed to communicate by sending the packet to a destination node which is at the distance of n/2. This distance of n/2 can be either in the x-dimension,

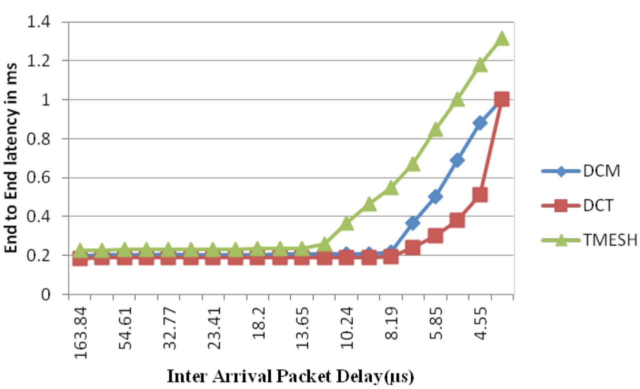

Figure 4. Average end-to-end latency with uniform traffic

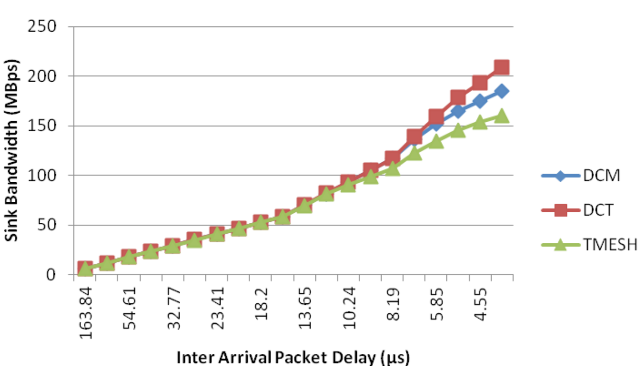

Figure 5. Sink bandwidth with uniform traffic

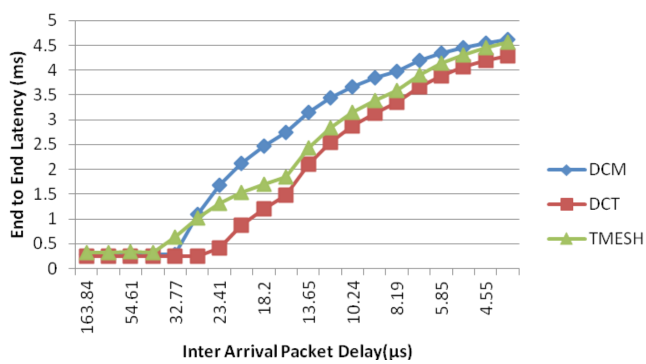

Figure 6. Average end-to-end latency with bit complement traffic

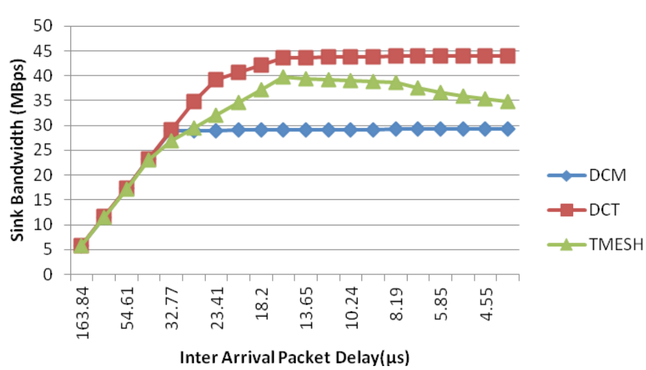

Figure 7. Sink bandwidth with bit complement traffic

y-dimension or in both the x and y dimension. In our case we have considered the destination node to located away in both the x and y dimension by the distance of n/2. This can be described by the equation given below.

$$D = Mod(Mod((S + n * n / 2), N) + n / 2), N) \qquad (7)$$

In the above equation 7 first id is incremented by n∗n/2 this will place the destination node position to n/2 rows away from the current node but this calculation may reach to a point which is out of the mesh therefore the modulus of the value is taken, then again the destination id is added with n/2 to increment the value to n/2 columns away from the node and modulus is taken to get the value inside the topology itself

The tornado traffic is actually a diagonal traffic and we have added links in the horizontal and vertical corners of the node. The diagonal traffic will be routed mostly by the diagonal links this will not affect the latency and bandwidth of the system. The same can be seen in the Figure 8 and 9 the DCT and DCM plot are just overlapping each other.

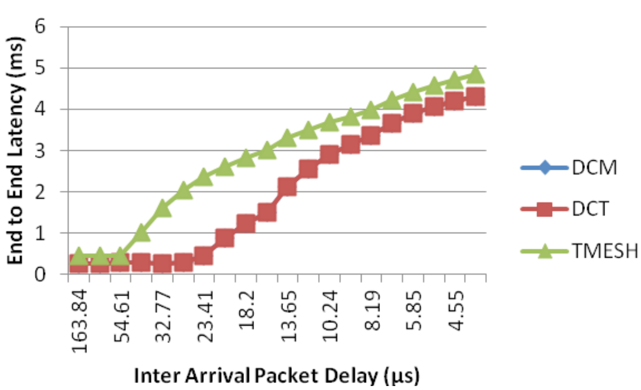

Figure 8. Average End to End latency with Tornado traffic

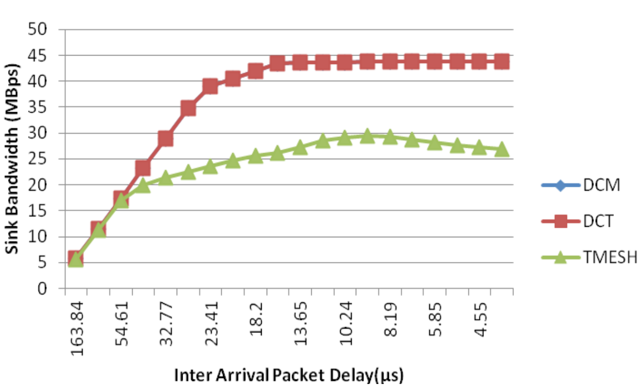

Figure 9. Sink Bandwidth with Tornado traffic

5.4 Hop Count Analysis

5.4.1 Single Source Analysis

To perform the Hop count analysis the source is kept fixed and destination is varied to the other nodes. It is well known fact if the hop count of the topology is low in comparision to that of the compared topology then the topology is considered to be better. From the Figure.10 it could be identified that the DCT has always been smaller value of hop count. T MESH topology has the higher hop count for the various destination like 6, 7, 10, 11. Similarly the DCM topology has the higher hop count for the nodes 4, 8, 13, 14, 16. So we can say that 33% of the routes of DCM have become shorter for the source node 1.

5.5 Average Hop Count

To get the average hop each source is considered to the source to every other node and the avereage of the result is shown in the Figure. 11. From the figure it can be iden-

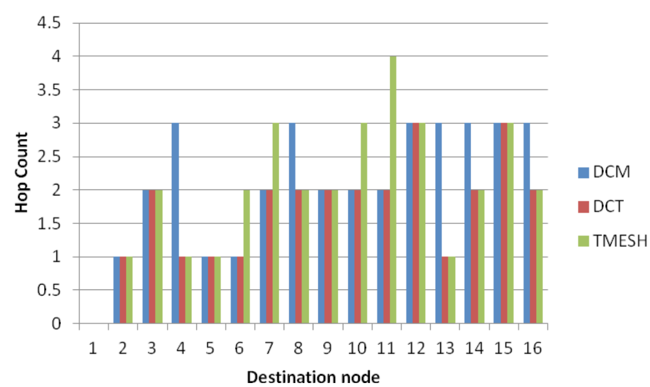

Figure 10. Hop Count to all other nodes keeping source as node 1

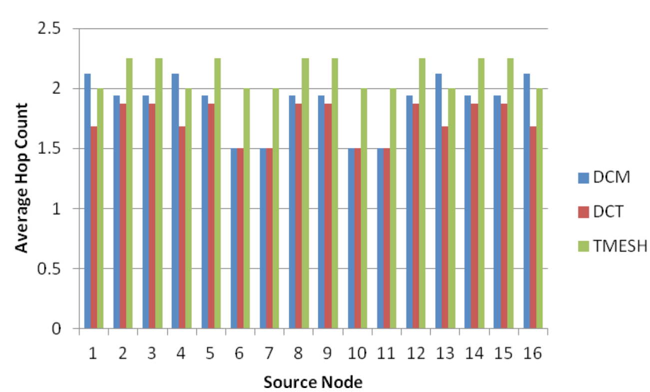

Figure 11. Average hop count of each to other node in the topologies

tified that the average hop count of DCT is always less in comparision to that of the DCM and T Mesh.

6. Conclusion

On the basis of the results obtained it can be observed that the proposed topology has performed better than the DCM and T Mesh topologies. This make the above mentioned topology a better substitute against DCM and T Mesh. The proposed topology was able to perform better at the higher loads and this has been described by the results. In the Average hop count analysis we can identify that the average hop count of the DCT is 87% less in comparison to that of DCM. In future, we will focus on designing routing algorithm so that the performance of the proposed topology can be further enhanced.

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