Performance Analysis of NoC Architectures

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Abstract: **Network-on-chip (NoC) architecture grants the communication frame work for SoC design .The Performance dominating factors of NoC are architecture, node's size, and the routing algorithm. Various routing algorithms are proposed for the router design in Network on chip(NoC).According to the requirements of NoC application, analysis and simulations for various routing algorithms, such as C-routing, ADBR and adaptive congestion aware routing algorithm are considered for this work. The simulation results shows that Congestion aware adaptive routing algorithm has better performance than others. Here, the new adaptive routing algorithm by merging the features of ADBR and adaptive congestion aware routing algorithm has been discussed.**

Keywords: NoC, Routing algorithms and Performance analysis.

I.INTRODUCTION

The parameters which are used to measure the network's performance are topology, network routing algorithm, switching methodologies then regulation of flow. The routing algorithm is used to specify the path to the packet to arrive at its target node. The routing methods are collected in to two main clusters: adaptive and deterministic. In former one, many paths are possible for the transmission of packets from source node to target node. That is, it provides the better route with the better probability to avoid the hotspots and the regions that are affected by the in the network as compared with deterministic routing method. In the majority of adaptive routing methods the current node which holds the packet performs the route calculation in which the determination of the next node to route the packet is depends on the information about the congestion. In this method, there is no need to route the packet through the minimal path because it relies only on the information about the current node and the immediate neighbours of the current node. Whereas, the later one uses a single predefined route to transmit the packet between the source and the target node. In the later one, the route is determined by using some predefined algorithms like dimensional order routing. It is simple but it won't react to the current status of the network traffic so it leads to the poor performance. Hence, in this paper we will compare the some adaptive routing algorithms in the router based on the necessity of NoC (Network on chip).

II.DIFFERENT ADAPTIVE ROUTING ALGORITHMS:

A. C-Routing

C-Routing is an ordered group based adaptive routing in a 2-Dimensional Mesh topology of NoC[1]. The resolution lessens the size of routing table and offers deadlock liberty not considering custom of virtual channels at the same time as guaranteeing livelock free routing .It is somewhat(Partially) adaptive and averts livelock and the deadlock not including the need of VC.The Routing methodology of this algorithm is as follows:

1) *Routing idealogy:* C-routing mixes the XY deterministic and partially adaptive routing, contingent in the site of initial and target node. Later one is shadowed if the direction of routing is concerning East, the West and the South direction. The packet transmission directed in North phase is shadowed by using the deterministic routing. This approach is possible to evades the cyclic path and the deadlock. Each node preserves its address and an address of the cluster in which the node is located. Regardless of intra or inter cluster communication, XY routing is performed if the target is located in the north direction of initial node, else partially adaptive routing is concerned. It gains knowledge regarding congestion and apprises the routing table. Every time when packet desires to be routed between x and y, the C-routing verifies the routing table to find the neighbour with minimum amount of traffic, and it begins transmitting packets. Virtual channels are not required in C-routing for the prevention of deadlock .

2) *C-routing Algorithm:* Algorithm of C-routing is divided into 2 fragments. First fragment hires inter cluster routing to grasp the target cluster. Subsequently, in second fragment intra cluster routing is concerned .

Fragment 1:

In C-routing, each node should knows it's own node's address, the address of the cluster in which the node is located and the routing table which calculates the cost for data transmission between the inter cluster nodes and intra cluster nodes. Connection cost among 2 neighbouring nodes is denoted as q, and it updates every time single flit navigates. After a routing table is initialized, the Y-coordinate of target Cluster is related with initial cluster. XY routing is engaged when the y-coordinate of target cluster is smaller than the Y-coordinate of source cluster. Or else, partly adaptive routing will be engaged.

Fragment 2:

In C-Routing, when the packet inwards at destination clusters, it will check the target node's Y-coordinate, if the target node's Y-coordinate is smaller than the current node, it will execute XY routing(Deterministic routing). Or else partially adaptive routing is used. The variance between fragment 1 and 2 is instead of reaching a destination cluster it needs to touch the destination node by picking neighbour node either using minimum methodology or randomly.

Advantages:

- It is a cluster based approach so it reduces the routing table size.
- The time taken for the data transmission is more (i.e.) it is a time consuming process.

Disadvantage:

- It needs virtual channels to transmit the data.

B. An Adaptive Congestion-Aware Routing Algorithm for Mesh Network on- Chip Platform:

An adaptive congestion-aware routing algorithm is designed for the mesh topology of NoC (Network on Chip)platforms. Based on the congestion in the region of routed node, this algorithm considers both the Shortest path and non-minimal paths to route packets[2]. These shortest and non-minimal paths are depends on values obtained in the score calculation .This score calculation is performed using the odd even turn model in order to evade deadlock. These scores are calculated based on the utility of the buffer in the neighbour node and the definite transition value. In this technique ,the congestion criterias and the scattered hotspots is neglected. Higher performance is delivered.

Step 1: After the packet is arrived in the router, the score calculator calculates the available buffer spaces in the neighbour nodes

Step 2: This score calculation can be performed using odd-even turn model. The conditions to perform the OE turn model are given below

Condition 1:The East-North turn is not permitted for the packet which is situated in an even column and the North-west turn is not permitted for the packet which is situated in an odd column.

Condition 2: The East-South turn is not permitted for the packet which is situated in an even column and the South-West turn is not permitted for the packet which is situated in an odd column.

Step 3: The further step is the prediction of median score in the shortest path and then the comparison is made with the switching value .If the median score is larger, and then select the o/p path. Or else we have to check the non-minimal path score.

Step 4: if the non minimal path scores are smaller when compared with the shortest path scores, then the o/p port with larger score will be selected. Or else take the non-minimal path score as o/p port.

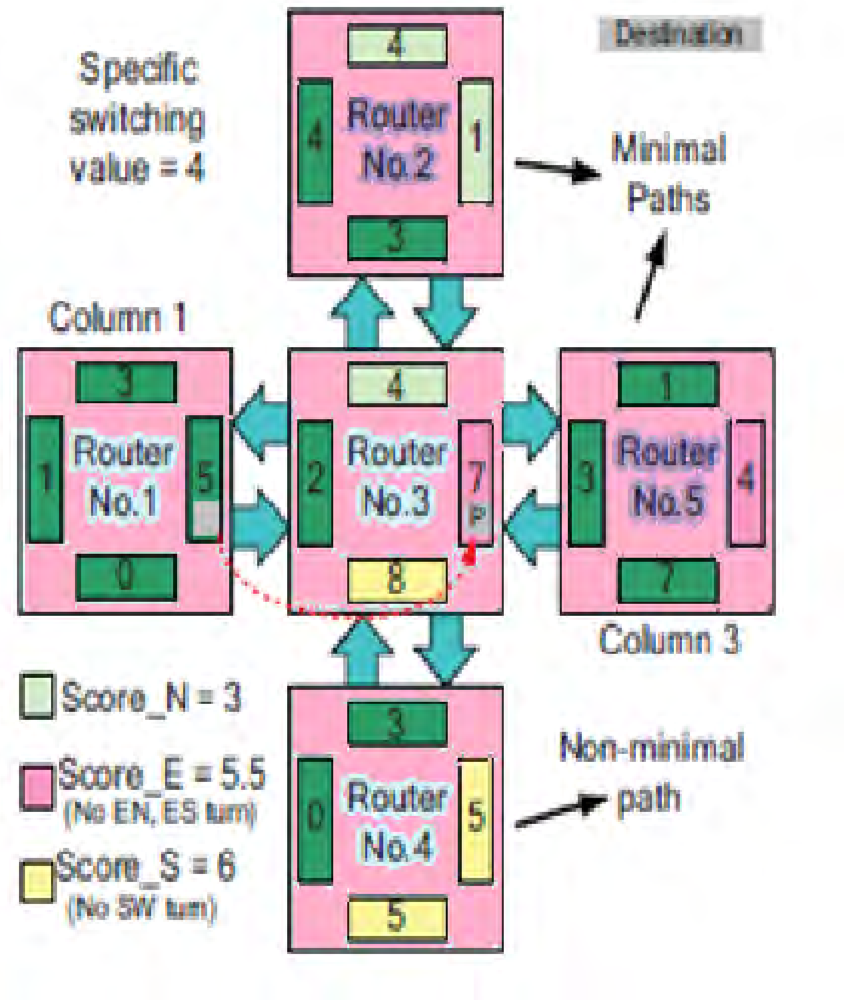

Figure 1: Example for the score calculation

The Pink block denote its router node and the Green colour block denotes the available buffer space. ‘P’ denotes a location of packet in current node. With addition, value in Green colour block indicate its number of obtainable buffer space.

Currently packet is located in router 1, before it sends the packet to the next node it should check the buffer availability of the neighbour nodes. Here the possible nodes for the router 1 to send its data are north, south and east of the router no 3.To compute the north score for router 3 the score calculator must obtain a score values of router no 2(The north score consists of the value belongs to obtainable buffer space of the output buffer in the north and a following possible output buffer spaces,here,because router is in an odd column , NW and SW turn is prohibited the score calculator eliminates the west score in the calculation of north score). Likewise, the south score of router no 3 is calculated. The east score calculation is depends on the odd-even turn models, so the East-North and East-South turn is banned, hence we eliminate the north and south buffer values while calculating the east score.

After the score calculation, the adaptive decision unit will chooses the output port to which the data has to be moved. Then the adaptive decision unit should check whether the median scores in the shortest paths are larger when compared with the definite switching value if so then chose the o/p port that holds maximum score on the minimal path, else have to check whether the median scores in the shortest paths are smaller when compared with a shortest paths . (Assume definite switching value =4).

If the available buffer spaces on the non minimal paths are smaller when compared to the scores on shortest paths, then we have to choose the o/p port that has the largest score in the shortest path, else chose the router that is having the largest score in the non-minimal path as an o/p port.

Advantages:

- It reduces more congestion when compared with C-routing in the hot spot traffic
- Results of simulation shows that this algorithm is higher to the remaining techniques for the mesh network of Network on Chip platforms.

Disadvantage:

- It also considers the non-minimal path to transmit the data.

C. A Fault tolerant adaptive routing algorithm in 2D mesh network

Flow control approach of the interconnection network specifies whether the packets has to move or stop. Flow control strategy is regularly depends on the credits, that is number of available buffers in the neighbouring router nodes. The neighbouring routers informs to one another about their free buffers as credits.

In this algorithm a novel flow control method, known as Dimensional bubble flow control(DBFC) is used, which deadlock among many dimensions in mesh NetworkonChip of the adaptive routing.

1) Flow control scheme DBFC:

For mesh network, the necessary condition for the packet(having routing hops in N direction) for entering into the buffer of the next router is that the availability of equal or more than free packets space(N<=n).By using the packet credit mechanism, each routerin the network calculates the buffer value in the neighbouring router nodes.Hence the DBFC scheme is designed in centralized routers with no means of central scheduling.

2) Adaptive routing algorithm:

With reference to DBFC, we can implement a fully adaptive routing algorithm known as ADBR. Initially, minimal amount of hops for the movement of packet is determined.Travelling with minimal number of hops assures about no dead locks present in the path.Then,the packets with a non zero valued hops token for target buffers in all directions.Once the tokens are serviced then the flow schedulers select single from many successful requests.After that the packet moves in that chosen direction with a single hop reduced value. The packets keep on moving in forward direction until the hop value becomes zero.

Faults are classified into two as transient or permanent. The former one can be solved by the communication protocols, which uses CRCs to recognize faults and to retransmit the packets. The later one can be dealt through two fault models: static or dynamic. M.E.Gomez proposed a scheme regarding fault tolerance by selecting the in-between nodes in the 3D tori interconnection networks, which requires numerous virtual channels. In this method the static fault model is assumed (i.e.) in earlier stage all the faults are known. By using intermediate nodes this method avoids those faults. First, the packets are moved to an in between node and then the packets are moved from that node to target node. Minimal adaptive routing is applied in two fragments. The scheme to chose the in between node is as follows,

Consider the source node be S , the target node be D , faulty links be F,in-between node say(I). If F is presented in the path between initial node to target node, then an in between node is preferred (if probable) with the purpose of avoiding the faulty links. If there is a failure beside any likely minimal path between initial and target node, then the in-between node is used. Packets can be adaptively routed in all fragment (s-I(source node to in between node) and I-D(in between node to destination node)).

Some probable I-nodes are available and these nodes can be utilized in every S-D couple. The scheme calculates the group of probable In-between nodes and then chooses a single node. Given an F, to find out the group of In-between nodes, available properties must be figured out in the relative locations of source, Destination, and Faulty link in 2Dimensional mesh network.

1) Within one of the two probable dimensions, the In-between node should be positioned between Faulty link and Destination. i.e, the node must conquer or exit after the occurrence of failure in one among two dimensions. This permits superseding the defeat in the route between source and target node.

2) In remaining dimensions, the I-node's coordinate must falls between Source and faulty link. It means that the other dimension's In-between node may not conquer the failure. This permits superseding the loss in the space described between Source and In-between node.

By observing the prior conditions, In-between nodes will neglect the loss, and provides minimal path too. Certain states are available in which the prior conditions must be completed more accurately:

If both the Source node's and F node's coordinates are equal in a single dimension, then this dimension should conquer by In-between nodes.

If both target node's coordinate and F node's coordinate are equal in one dimension, then I-node's coordinate in this dimension should be positioned between the coordinates of Source(S) and Faulty link(F). It means another dimension must be conquer.

If the source node, destinstion node, and faulty link are located at the similar line and flop are positioned among the source and destination in the minimal path, then that will be unfeasible for spotting an Intermediate-node in the shortest route between S(source) and D(target node). To appropriately reach In-between node from the Source, misrouting and turning off adaptive routing will be utilised. The faulty routing will leads the packet to move in multiple direction.After the faulty routing is finished, then the regular routing will apply to the packet.

Advantages:

- ADBR algorithm requires little buffer space .
- It decreases blocking time of network system.

III.FUTURE WORK

Hybrid of the adaptive Congestion aware routing algorithm and ADBR algorithm is taken as a proposed work. Features like Odd-Even turn model is taken from the adaptive congestion aware routing algorithm and hop count and buffer space are taken from the ADBR algorithm .In Proposed algorithm we combine this Features to transmits the data in the minimal path .In proposed algorithm we designed 2-Dimensional 8*8 mesh topology . For mesh network, the necessary condition for the packet (having routing hops in N direction) for entering into the buffer of the next router is that the availability of equal or more than free packets space (N<=n)..Based on the buffer size, we transmit the packets in one of the all minimal possible directions. The selection of dimension is depend on the Odd-even turn model to neglect the deadlock.

IV.RESULTS AND DISCUSSION

The C-routing, adaptive congestion aware routing and Adaptive Dimensional Bubble Routing algorithms has been designed and their area, power and speed performances has been computed using Xilinx virtex 5. The performance results of those algorithms has been analyzed and tabulated below.

TABLE I
Comparison of power parameters

Algorithm	**Leakage power(mW)**	**Dynamic power(mW)**
C-Routing	0.65	2.78
Congestion aware routing	0.547	0.48
ADBR	3.134	1.28

TABLE II
Comparison of device utilization

Algorithm	**Number of Slice LUT's**	**Number of LUT Flip Flop pairs Used**	**Number of bonded IoBs**	**Number of BUFG/BUFGCTRLS**
C-Routing	12%	18	7%	7
Congestion aware routing	0%	7	0%	3%
ADBR	23%	35193	9%	18%

TABLE III
Comparision of Speed

Algorithm	Maximum operating frequency
C-Routing	12.482MHz
Congestion aware routing	146.952MHz
ADBR	3.643MHz

By seeing the tabular column,one can decide that the adaptive congestion routing algorithm has the better performance when compared with remaining algorithms.It has the higher operating frequency than other two algorithms.

V.CONCLUSION

In this work , analysis of the performance of different adaptive routing algorithms and determine the best algorithm among three has been done .By the end, the future work has been given about the design of new adaptive routing algorithm, it reduces the congestion and deadlock.

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