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DISTANCE ROUTING ON MESH NETWORK ON CHIP

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ABSTRACT

NoC (Network on Chip) is a promising technology for the interconnection network. Performance of an interconnection network depends on the routing logic. We explore the state of art of the existing routing algorithms for mesh connected network. In this paper we have tried to model the distance routing for mesh connect NoC network. The performance of the distance routing is compared with that of the dimension order and odd-even routing algorithms. Experimental analysis on synthetic traffic shows that our proposed distance routing outperforms the state of the art of routing algorithms by increased link utilization fairness.

Keyword: network on chip, mesh, routing algorithm, distance routing.

INTRODUCTION

Advancement in the VLSI technology lay down the path for an era of on-chip multiprocessors. The interconnection network plays a critical role in the performance of the multi-core processors [4]. Intercommunication requirement of the System-on-Chip (SoCs) made of hundreds of cores is not feasible by making use of the bus architecture. Network-on-Chip (NoC) is a promising prototype to replace SoC. NoC is launched to overcome the communication problems in the bus-based interconnections.

NoC consists of a number of interconnected intellectual properties (IPs) cores that are connected using links which carry the data packets in the interconnection network. The IP cores or the processing cores consist of routers. Each router is connected to five ports (East, West, South, North and local core). Every router can be a source as well as a destination in the network. Source router is one which injects the packet into the network and destination router ejects the packet from the network to the local core. Packets are injected into the network from L1/L2 cache miss, coherence transactions and inter-core synchronisation.

Routing logic, switching method and the topology are the important techniques in the design of NoCs. Topology defines the arrangement of the nodes in the chip. 2D mesh topology is one of the most popular topologies in which the cores form a 2D array. In NoC the packets are routed using the routing logic between different cores. The packets are again sub-divided into flow control units called flits [5].

The architecture of a conventional router is shown in Figure-1. Buffered router in the interconnection network consists of five major components: Routing Computation logic (RC), Virtual channel Allocator (VA), Switch Allocator (SA), Virtual Channels (VCs) and crossbar. Virtual channels are used to store the flits coming from the neighbouring routers. RC unit based on the routing function returns the possible routers and the selection strategy determines the output port. The RC also looks into the VC for the next downstream router for each packet.

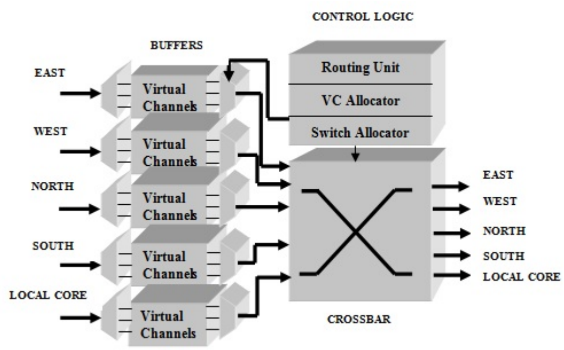

Figure-1. Input buffered router.

The VA arbitrates amongst all packets requesting access to the same VCs. A Packet will be forwarded only if there is a free VC in the downstream router. Once the route has been determined and a virtual channel got allocated the flits are forwarded over this virtual channel. SA arbitrates among the packets and forwards the packet along the crossbar. Input buffered routers can increase the bandwidth of the system. A packet can stay in the buffer for any number of cycles before it gets routed i.e. a packet will stay in the VC until it gets a productive output port [10].

In this paper we explore the distance routing for mesh connected NoC network. The paper is organized in such a way that section I deals with introduction, a brief description of the routing algorithms is covered in section II. In section III an example of distance routing is explained. Next section deals with the details experimental methodology and results. We conclude in section V.

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ROUTING ALGORITHMS

Routing algorithms can be classified into different categories, based on the routing decision and degree of adaptiveness. Depending on the routing decision it is classified into source routing and node routing. In source routing the path taken by the packet is fixed and is precomputed and stored in the packet header. In node routing every node performs the route computation by extracting the details from the packet header [1].

Based on the degree of adaptiveness routing algorithm can again be divided into non-adaptive, fully adaptive and partially adaptive. In non-adaptive or deterministic algorithm routes the data packets along the same predermined path. Partial adaptive algorithm includes the turn models like north-last, west-first and negative-first [2]. Varying nature of the network is considered in fully adaptive routing algorithm. The turn models prohibit certain turns but the odd-even routing [6] [8] [3] is a deadlock-free adaptive routing which restricts the location of the turn. XY routing, the most popular dimension order routing, routes the packet first in the X - direction to correct column and then in Y-direction to reach the destination. YX routing is also a dimension order routing [9].

DISTANCE ROUTING

Routing of data packets from the source router to the destination router is governed by a routing algorithm. Here we have used distance routing on a mesh topology. In distance routing after each cycle the packets are routed towards the destination router. Live lock is a condition in which the packet never reaches the destination even after infinite link traversals. Live lock can be avoided when distance routing is used.

In Distance Routing (DR) each router in the mesh network finds the neigbouring nodes. The number of hops from each neighbouring nodes to the destination router are calculated and one with the least number of hops is selected as the next source. If there are two neighboring nodes with the same number of hops, one along the X direction is declared as the winner source. The winner source router forwards the packet along the direction of the minimum number of hops. The Winner source again performs the same operation to reach the destination. Once the destination is reached the packets get ejected into the destination router. The algorithm of the distance routing is given below. Figure-2 shows the distance routing process.

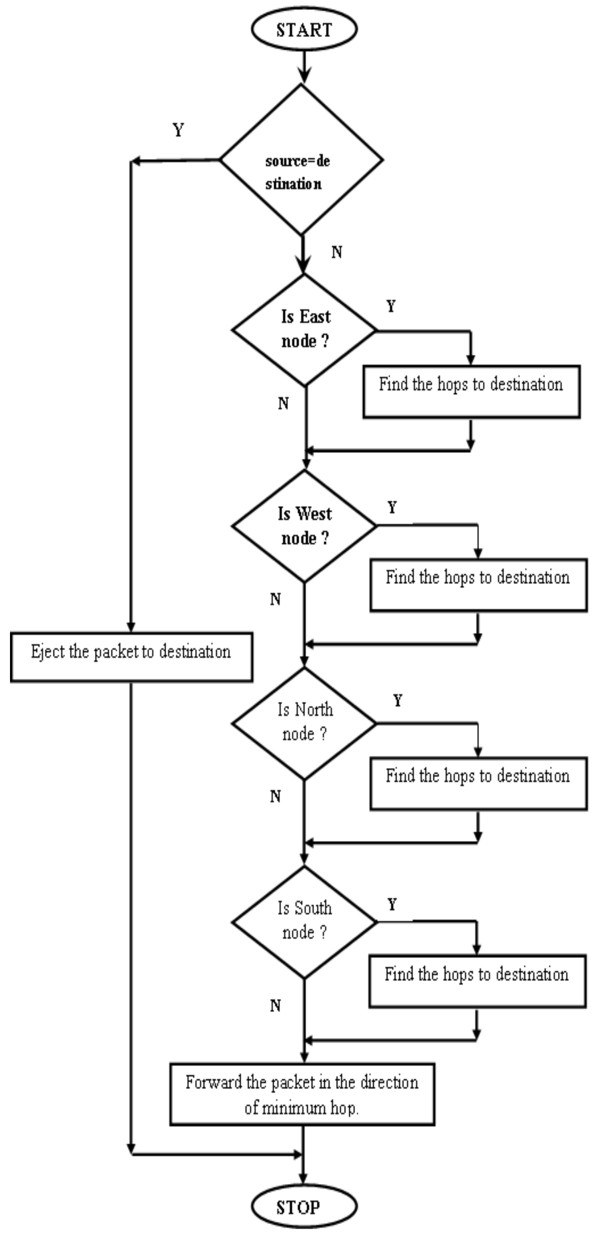

Figure-2. Distance routing process.

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Algorithm

Find_hop (source, destination)
Begin:
Calculate X-hops from Xsource to Xdestination
Calculate Y-hops from Ysource to Ydestination
Calculate Total_ hop= total distance
Return hop
End
Distance routing (Source, Destination)
Begin:
If source equals destination
Eject the packet
Else
Find_neighbours.
For each neighbors
Find_hop (neighbour, destination)
Near_neighbour=Sort bases on the hops to find the Nearest Neighbour.
Route the packet in the direction
Distance routing (near_neignbour)
End

The main function Distance routing ejects the packet if the destination router is reached else the presence of neighbours are checked. The Find_ neighbours returns a set of available neighbours. The function Find_hop (source, destination) returns the number of hops from the neighboring nodes to the destination. Figure-3 shows the process of finding the number of hops. The distance along x direction is calculated by subtracting the destination distance along x and y directions. Total number of hops is the sum of the hops in x and y directions. In a mesh topology edge routers have three neighbours and one in the corner has only two neighbours while the other routers have four neighbours. Then the selection strategy chooses one from the neighbours based on the number hops and route the packet along the shortest distance.

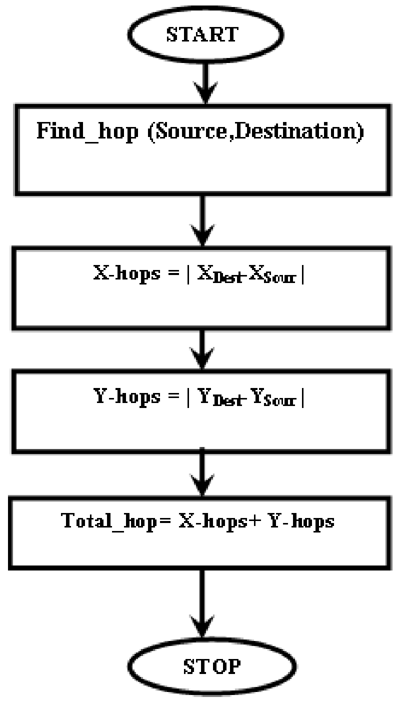


Figure-3. Hop distance calculation.

Figure-4 shows the working of distance routing. Router (1, 1) is the source and (3, 3) is the destination. Node (1, 1) is neither edge nor a corner has four neighbours- (1, 2), (2, 1), (0, 1) and (1, 0). Considering the neighbour router (2, 1) number of hops to the destination router along x direction(x-hops) is calculated by finding the difference between the x coordinates of the destination and source routers. i.e., (3-2=1). Number of hops along y-direction (y-hops) is calculated by deducting the y coordinate of the source node from the destination node i.e., (3-1=2). The total number of hops is the sum of the x-hops and y-hops (X-hops + Y-hops i.e., 2+1=3). Thus node (2, 1) router is 3 hops away from destination router.

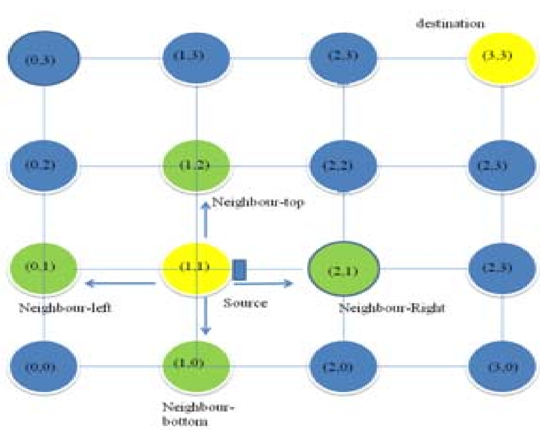


Figure-4. Example distance routing.

Similarly (1, 2) router is also 3 hops away from the destination. The other neighbouring routers (0, 1) and (1, 0) have to travel 5 hops to reach the destination. Both (2, 1) and (1, 2) are at same hops away from the destination. Since X direction routers are given more priority than Y direction routers the node (2, 1) is the new source router and the packet gets forwarded to (2, 1). Again the process of finding the neighbour with (2, 1) as the source router continued and (2, 3) is the winner. This process is continued until the packet reaches the destination router.

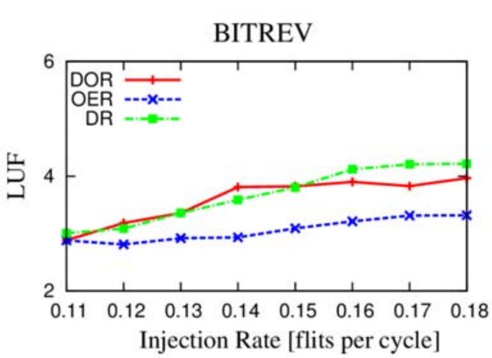
EXPERIMENTAL METHODOLOGY AND RESULT ANALYSIS

We use a traditional VC based NoC simulator Book-sim [7] to implement distance routing. In order to show the robustness of distance routing we evaluate our design algorithm using the standard synthetic traffic patterns: transpose and bitrev. Link utilization fairness values are collected for these traffic patterns under various injection rates. We used 4 VCs per router port with 3-flit buffers per VC.

Effect on link utilization fairness

Link Utilization Fairness (LUF) is defined by Equation 1[8]. LUF denotes how efficiently the links are being utilized and also represents the fairness in load distribution. We computed the LUF for transpose and bitrev traffic patterns and for varying injection rates in a 4X4 mesh. The results are depicted in Figure-5. From the Figure it can be seen that for bitrev traffic pattern distance routing shows a higher performance than Dimension Order Routing (DOR) at higher injection rate. For transpose traffic pattern distance routing shows a higher performance than Dimension Order Routing (DOR) at lower and higher injection rates. Performances of both bitrew and transpose for distance routing are much better than odd even routing (OER).

$$LUF = \frac{\text{Average number of flits per link}}{\text{Standard deviation of flits per link}} \quad (1)$$



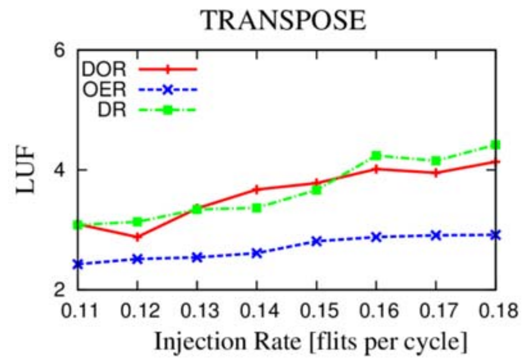


Figure-5. Link Utilization Fairness comparison using various synthetic traffic patterns in 4x4 mesh network.

CONCLUSIONS

Network on Chip is a platform for single chip systems which scales well to an arbitry number of processor like resources. Devising an effective routing algorithm for NoC is a challenging task. When more and more components are integrated into an on-chip system, communication issues become complicated. In addition to a good routing algorithm a better router design may be able to also give a better performance. Distance routing algorithm can be a better than other routing algorithms thereby providing better load balance. Distance routing leads to uniform wear and tear and hence can increase the life-time of links.

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