A Performance Enhancing Hybrid Locally Mesh Globally Star NoC Topology

Tuhin Subhra Das [†], Prasun Ghosal [†‡], Saraju P. Mohanty [‡], Elias Kougianos [‡]
[†] Bengal Engineering and Science University, Shibpur, Howrah 711103, WB, India
[‡] University of North Texas, Denton, TX 76203, USA
tuhinbcrec@gmail.com, prasun@ieee.org, Saraju.Mohanty@unt.edu, eliask@unt.edu

ABSTRACT

With the rapid increase in the chip density, Network-on-Chip (NoC) is becoming the prevalent architecture for today's complex chip multi processor (CMP) based systems. One of the major challenges of the NoC is to design an enhanced parallel communication centric scalable architecture for the on chip communication. In this paper, a hybrid Mesh based Star topology has been proposed to provide low latency, high throughput and more evenly distributed traffic throughout the network. Simulation results show that a maximum of 62% latency benefit (for size 8×8), 55% (for size 8×8), and 42% (for size 12×12) throughput benefits can be achieved for proposed topology over mesh with a small area overhead.

Categories and Subject Descriptors

B.7.1 [**Hardware Integrated Circuits**]: Types and Design Styles—*Advance technologies*

Keywords

NoC topology; Throughput; Latency; Load balancing; Performance.

1. INTRODUCTION

To cater modern day's complex high performance processing needs network on chips (NoC) are getting much more attention by the researchers day by day. To provide the massively parallel distributed communication environment during on-chip communication among hundreds of processing cores on an NoC, design of an efficient network topology with proper routing, flow control, deadlock prevention, and scalability plays an important role.

Novel contributions of this paper: The major contributions of this paper include the development of a new hybrid Locally Mesh Globally Star (LMGS) NoC topology with an objective to design a balanced network with low network latency benefit. Besides this, system performance improvement in terms of high throughput as well as low packet loss rate have been studied and optimized. A novel routing scheme also has been proposed to distribute packet more evenly throughout the network and thus to make system much more reliable by reducing channel contention problem.

GLSVLSI'14, May 21–23, 2014, Houston, Texas, USA.
ACM 978-1-4503-2816-6/14/05.
http://dx.doi.org/10.1145/2591513.2591544.

2. BACKGROUND AND MOTIVATION

In some recently proposed topologies viz. star-type 2D mesh [2], L2STAR [3], low latency based topology [7] researchers have followed some hybrid techniques to improve the performance. Objective is to design a low latency based parallel scalable architecture. Most of these approaches suffer from either higher node degree or from channel contention problem with increase in network size. In this paper, we overcome these limitations due to latency, throughput, and scalability through our proposed hybrid topology.

3. PROPOSED HYBRID NOC TOPOLOGY

Proposed hybrid topology (see Fig. 1) offers the advantages of both mesh and hierarchical star [5]. It facilitates both long distance and short distance traffic by using two different types of connections at different levels. Usually a mesh facilitates short distance local traffic, whereas star is used to facilitate long distance traffic.

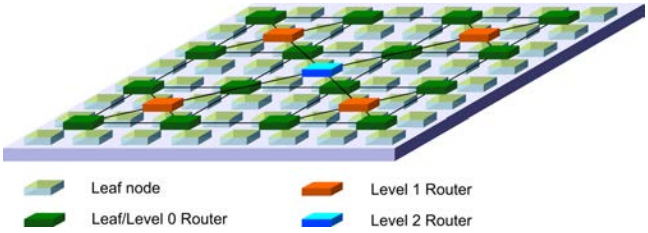

Figure 1: Proposed Hybrid topology for N=4

Some important parameters of an $M \times M$ sized proposed architecture are shown in Table 1, where, $M = 2^m$ for $m = 2, 3, \ldots, n$.

4. EXPERIMENTAL RESULTS

4.1 Experiments for Performance Evaluation

NS-2 simulator [1] is used for simulation that provides NAM (Network Animator) that helps to visualize network operation in real time by tracking data flow. Tcl scripts are used to create four different types of topologies of sizes 4×4, 8×8, and 12×12. Each router at leaf level (i.e. at level-0) is connected to its neighbour router as well as next higher level router by a maximum channel bandwidth of 1Mb. Routers at next higher level (i.e. at level-1) are connected to same level and next higher level router by double i.e. 2 Mb. Thus for a 4×4 sized proposed topology total eight 2Mb channels are required. A single IP core is assumed to be connected to each leaf level router. UDP is selected for communication protocol. Each source (i.e. UDP agent) is attached to an *exponential* traffic generator. Traffic ON and OFF periods are set to 2 ms and

Table 1: Important parameters of proposed architecture.

Bisection width	$M + 4$
Maximum node degree of non-leaf router	7
Maximum node degree of leaf router ($N = 4$)	9
Maximum node degree of leaf router ($N = 1$)	6
Maximum number of IP cores connected to a network where N is number of IP cores connected to each leaf level router.	$M \times M \times N$

0.1 ms respectively. Each node uses a *DropTail* queue with maximum size of 8. Link delay for short and long channels are set to 0.1 and 0.12 milliseconds respectively. A communication scenario has been defined by selecting 15-27% of nodes to generate traffic and by running simulation for 15 seconds.

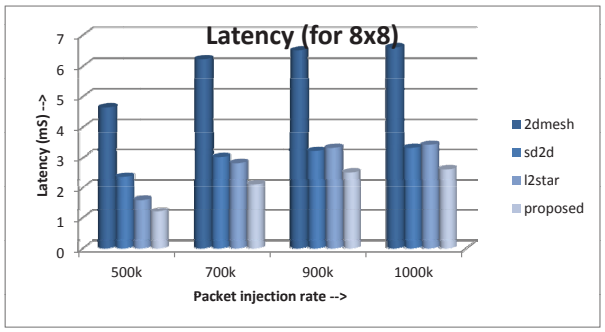

Figure 2: Packet latency vs network load for 8×8 sized topology.

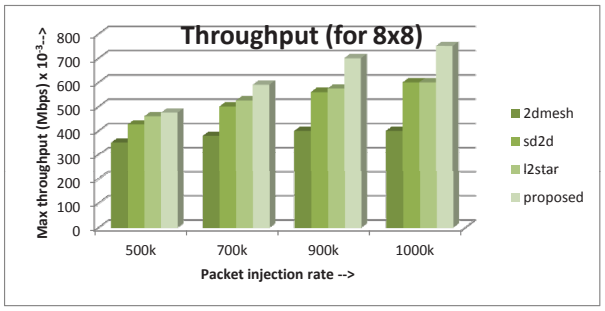

Figure 3: Max throughput vs network load for 8×8 sized topology.

4.2 Simulation Results and Discussion

Network performance parameters e.g. network latency, throughput, and packet loss rate are calculated based on the information retrieved by Perl scripts from output trace files for different topologies with varying network loads. Latency benefits of 30%, 30%, and 64% (for 8×8 size) compared to SD2D [4], L2STAR [3], and simple mesh have been observed for proposed topology (see Fig. 2). Packet delay for proposed topology reaches threshold at higher loads compared to others. Improvements of 20%, 20%, and 55% in maximum throughput compared to SD2D, L2STAR, and simple 2D mesh respectively are observed for proposed topology of size 8×8 (see Fig. 3), and 14%, 27%, and 42% respectively for 12×12 (see Fig. 4). Packet loss rate is negligible compared to others signifying lower channel contention problem. A comparison on required additional area has been calculated followed by a method proposed by Suboh *et al.* in [6]. A 31% to 13% area overhead has been observed by varying N from 1 to 4 for proposed topology over 2D mesh of size 8×8.

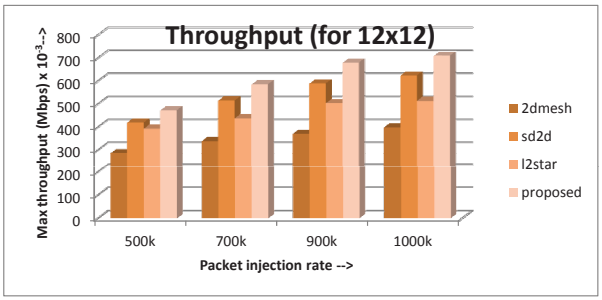

Figure 4: Max throughput vs network load for 12×12 sized topology.

5. CONCLUSION

A considerable amount of improvement in latency as well as throughput and packet drop rate has been achieved through the proposed hybrid topology with a small area overhead. Future works may be extended to minimize the area overhead as well as channel contention problems further.

6. REFERENCES

[1] The Network Simulator-NS-2. Online. Available: http://www.isi.edu/nsnam/ns/.

[2] K.-J. Chen, C.-H. Peng, and F. Lai. Star-type architecture with low transmission latency for a 2D mesh NOC. In *IEEE Asia Pacific Conference on Circuits and Systems (APCCAS)*, pages 919–922, 2010.

[3] P. Ghosal and T. S. Das. L2STAR: A Star Type level-2 2D Mesh architecture for NoC. In *Asia Pacific Conference on Postgraduate Research in Microelectronics and Electronics (PrimeAsia)*, pages 155–159, 2012.

[4] P. Ghosal and T. S. Das. Network-on-chip routing using Structural Diametrical 2D mesh architecture. In *Third International Conference on Emerging Applications of Information Technology (EAIT)*, pages 471–474, 2012.

[5] Z. Song, G. Ma, and D. Song. Hierarchical Star: An Optimal NoC Topology for High-Performance SoC Design. In *International Multisymposiums on Computer and Computational Sciences (IMSCCS '08)*, pages 158–163, 2008.

[6] S. Suboh, M. Bakhouya, J. Gaber, and T. El-Ghazawi. Analytical modeling and evaluation of network-on-chip architectures. In *International Conference on High Performance Computing and Simulation (HPCS)*, pages 615–622, 2010.

[7] X. Wang and L. Bandi. A low-area and low-latency network on chip. In *23rd Canadian Conference on Electrical and Computer Engineering (CCECE)*, pages 1–5, 2010.