Performance Analysis of Different Interconnection Networks

Sapna Yadav
Assistant Professor,
IMSEC Department of Computer Science and Engineering, Ghaziabad

Aastha Sharma
Department of Computer Science and Engineering
Ghaziabad, India

Preeti Kumari
Department of Computer Science and Engineering
Ghaziabad, India

Sahiba Gupta
Department of Computer Science and Engineering
Ghaziabad, India

ABSTRACT
Interconnected networking or inter networking is the connection of multiple networks. Internet is an example of inter-networking where various networks are connected together to exchange messages, data for process synchronization among various device and applications.

In addition to providing external connectivity, networks are commonly used to interconnect the components within a single computer at many levels, including the processor micro architecture.

Definitions of Physical and Logical Topologies are provided. Additionally common Computer Network realizations of Physical Topologies are reviewed. This is followed by a discussion of Graph Theory and its relation to topological analysis. These examples are discussed to underscore the importance of topological design when constructing a new computer network, or adding to an existing one. Performance evaluation of such connected and interconnected networks has become a major concern. This project aims for evaluating the performance of various interconnection networks mainly different versions of Meshes and Torus networks. Various interconnection networks are analyzed and compared for major performance parameters like throughput and delay.

Keywords
Torus interconnection networks, CBR, FTP, delay, and throughput.

1. INTRODUCTION
Initially designed for the challenging requirements of the multicomputer, interconnection networks are starting to replace buses as the typical system-level interconnection [1]. Meshes and torus like networks have been exploited widely in the construction of parallel computers in previous years. Computer engineer always tried hard to enhance the performance of the computer architectures. The fast intense circuitry and parallelism may give high performance. The length of a link connecting a number of processors decreases as a result of increase in processor packaging density [2].

Interconnection networks cover up a wide variety of applications; much like memory hierarchy covers a broad range of speeds and sizes. Networks used inside processor chips and systems are probably shared features, which are common with processors and memory, depends a lot on high speed hardware solutions and less on the software solutions. Networks used to connect system elements have a quality to share a lot in common with storage and I/O elements, depends more on the software protocols and operating system than high speed hardware solutions [3]. Interconnection Network topology is the arrangement of the several elements of a computer or network. Basically, it is the topological structure of a network, and may be described physically or logically. Physical topology is regarding position of the network's various components, including device location and cable fitting, while logical topology shows flow of data within a network, regardless of its physical structure and position [4]. Distances between nodes, interconnections through physical media, transmission rates, and signal nature may vary between two networks; however their topologies may be identical. To evaluate the performance of the interconnection networks, the comparison of topological properties and performance metrics of the network must be compared with other networks [5]. The topological properties and performance metrics for interconnection networks are node degree, diameter, regularity, symmetry, and latency, throughput, bisection width, scalability etc.

In this paper we analyze the major performance metrics like delay and throughput. Different framework for torus interconnection networks has been designed, where the packet delay and throughput analysis during the transmission has been evaluated. The torus interconnection network is evaluated under CBR over UDP and FTP over TCP traffic using NS2 simulation tool.

The structure of this paper is as follows. In section II, we have discussed the related work. Section III describes the performance metrics used and section IV describes the traffic applications used in this paper. Section V describes the structure of the torus interconnection. In section VI, we have shown the performance evaluation in two different scenarios and also discuss the results of simulation. Finally in section VII, we have drawn conclusion based upon the simulation result.

2. RELATED WORK
At present the Network-on-Chip (NoC) is a new research field that focuses on modeling and evaluating the network on-chip interconnection. Complicated interconnection networks that have dedicated switches, routers and definite topologies are the main NoC structures for study and optimization [6].

NS-2 simulation tool is used to build the topology and used to produce different traffic set-up using an exponential traffic generator tool [7]. Packets are transmitted at a constant rate during ON period, and during OFF period no packets are transmitted. The most important network performance metrics like delay, throughput are analyzed with the help of this traffic generator for varying buffer sizes and traffic generation rates. In [7], packet delay model is also presented, where several different parameters are considered for packet delay, and so many factors are used to deriving the packet delay.

Torus is a good interconnection structure due to better symmetry and less value of average delay [8]. Based on torus and taking advantage of high process level, it is possible to design a new topology to meet high communication performance requirements that many-core processors present, and to suit a great variety of traffic patterns.

In [9] a topology called xtorus is presented, and analyzes it by theoretical analysis as well as experimental simulation analysis. In this analysis, the mesh, xmesh, and torus are also compared using GEM5 simulation tool. The result of simulation shows that the xtorus topology has better values for parameters viz. network diameter, path diversity, delay, and throughput.

A model that uses queuing theory is discussed in [10] to analyze behavior of the traffic of Spidergon NoC. Simulations are performed to validate the model for average latency for variable message lengths and different traffic rates.

3. PERFORMANCE METRICS

The performance of any system needs to be evaluated on certain criteria, these criteria then decide the basis of performance of any system. Such parameters are known as performance metrics [11]. The three types of performance metrics used to evaluate performance of CBR over UDP and FTP over TCP in this paper are described below:

A. Throughput

The throughput is the measure of how fast we can actually send data through the network. It is the measurement of maximum amount of information delivered from source to destination in per time unit in the network. It is desirable to have a network with high throughput.

Unit – Mbps (Mega bits per second)

B. Average Delay

This is the average time delay consumed by data packets to propagate from source to destination. This delay includes the time elapsed from when the message transmission is initiated until the message is received at destination. A network with minimum average end to end delay offers better speed of communication.

Unit – sec (Seconds)

4. DATA TRAFFIC AGENT AND TRAFFIC APPLICATION

Data traffic agent and traffic application that takes the responsibility to transport the data in the network are of different types and offer different characteristics in the network [12] [13]. The two types of traffic agents and traffic applications used in this paper are as follows:

A. FTP over TCP

In such a traffic scenario, TCP represents the traffic agent and FTP represents the traffic application which transports TCP data. Here TCP is a transport layer protocol and FTP is an application layer protocol. This scenario offers connection oriented transmission environment, where communication occurs in phases, namely, connection establishment, data transmission, connection termination.

B. CBR over UDP

This type of traffic implies traffic agent of UDP type and traffic application CBR. Here, the former is a transport layer protocol and latter is application layer protocol. It offers transmission of data at constant bit rate and does not communicate in phases, and traffic moves in one direction from source to destination without any acknowledgement from destination.

5. STRUCTURAL DESCRIPTION

The interconnection architectural model has an (m × n) torus network of switches. The switches have a slot, in which resources can be connected. Resources like a processor, a memory block, a custom hardware or some other peripheral device fits into the slot. Suppose that switches have buffer devises to control data traffic in the network. The architecture of the torus (4x4) model is shown in the figure- 1with 16 nodes.

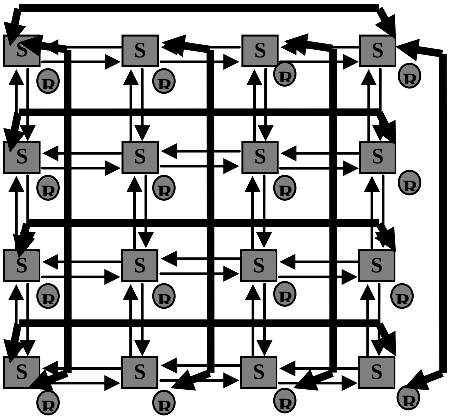
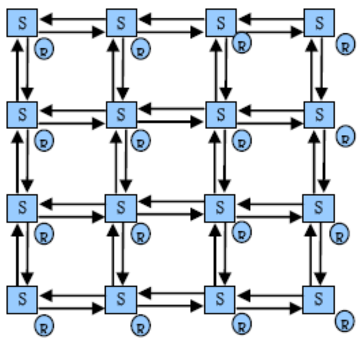


Fig. 1. 4 x 4 Torus Interconnection Architecture

A 4 x 4 two-dimensional torus topology was modeled and simulated. This topology is also applicable for higher dimensions.



The three basic elements in the topology are the switches, resources and links. A communication path connecting the switches is made up of links. Every node is connected by bidirectional point-to-point links.

6. PERFORMANCE ANALYSIS

We have developed a simulation model for torus interconnection using NS2 simulation tool. It is a discrete event driven network simulation tool. Tcl scripting language is used for designing the network and also for simulating the network model. The standard existing routing algorithm is used for data transmission. We have modeled 4x4 Torus network. Every node is connected with bidirectional point-to-point serial links. The link bandwidth is set to 1 Mb and latency is set to 10 ms. All packets are generated using Constant Bit Rate or FTP traffic.

The following table specifies the parameter values used for simulation.

Table 1 Parameters for Simulation

Parameters	Values	
	CBR over UDP	***FTP over TCP***
Traffic Application	CBR	FTP
Traffic Agent	UDP	TCP
Channel	Wired	Wired
Network Size	16-node (4x4)	16-node (4x4)
Routing Protocol	Distance Vector (Dynamic Routing)	Distance Vector (Dynamic Routing)
Simulation Time	5 Second	5 Second

We have designed two different scenarios. In the first scenario we evaluated the performance of torus network in an ideal condition, where we assume no link failure. The time window of simulation is fixed for 4.5 seconds.

In the second scenario, we assume link failure environment for a particular time. A single link between any two nodes along the path from source to destination is down for a fixed time. The time of link down is 1.0 second and link up is 2.0 second after the starting of simulation. A link cannot be used in any direction, when it is down. This fact was discussed in [14] and is reasonable, because a single wire is used to implement bidirectional links.

In these situations, simulation model uses two different packet generation traffics for transmission. And finally we compare the performance of network for average delay, throughput and packet loss, for two different traffics CBR over UDP and FTP over TCP in these different scenarios.

7. SIMULATION RESULTS AND DISCUSSION

The results of simulation for both the scenarios are presented in this section.

In the first experiment packet has been sent from source node(0) to destination node(10) in Torus interconnection. Here we used CBR over UDP, in which acknowledgement facility is not available. The results of the simulation analysis are calculated using event trace files generated during simulation.

Table 2. Observations for Throughput

Sr. No.	Architecture	Average Throughput
1	Mesh	.668054
2	Torus	.668059
3	DMesh	.716135
4	DTorus	.716135
5	XMesh	.709267
6	XTorus	.709267

In using CBR application we found that source node has generated 488 packets and destination node has received the same number of packets in 0.052485 seconds.

Table 3. Observations for Average Delay

Sr. No.	Architecture	Average Delay
1	Mesh	.057635
2	Torus	.057634
3	DMesh	.031530
4	DTorus	.031533
5	XMesh	.045232
6	XTorus	.045233

Like first experiment, packets have been sent from source node(0) to destination node(10) in Torus interconnection network. But here we used FTP over TCP for packet transmission, in which acknowledgement facility is available. In using FTP application we found that source node has generated 748 packets and destination node received the same number of packets in 0.058124 seconds.

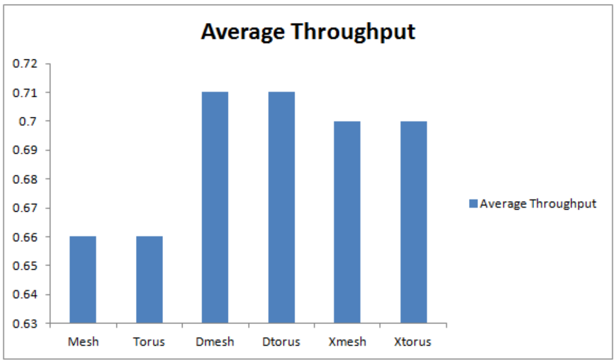


Fig. 4. Average Throughput Comparison Analysis

Above graph for comparing results of average delay under CBR and FTP shows that FTP traffic takes .005639 seconds and .006485 seconds extra time to complete the transmission than CBR traffic in scenario-1 and scenario-2 respectively. By seeing the results it is clear that it takes more time in FTP traffic application than CBR to complete the transmission in both scenarios.

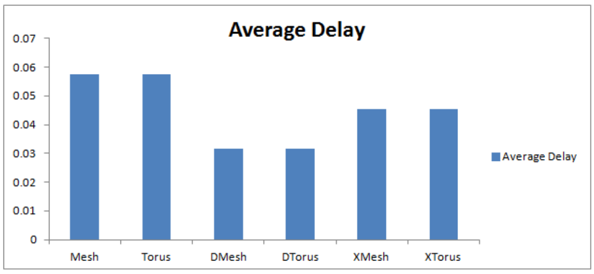


Fig. 5. Average Delay Comparison Analysis

When results are analyzed for throughput, it can be observe from the above graph, that FTP traffic produced higher throughput values than CBR traffic in both the scenarios.

8. CONCLUSION

Our paper concludes that DMesh and DTorus network architecture are best as compare to Mesh, Torus, XMesh and XTorus topologies. This is because of the increased average throughput and decreased average delay, which results in-increased data packet transfer speed, less latency and decrement in congestion. It also leads to the increment in the number of links, thus increasing the overall cost of the network which limits its usage to network on chips, hence increasing the overall performance of the chips.

But for cost effectiveness purposes DMesh and DTorus can't be used, so we prefer Mesh or Torus network architecture in the construction of LAN, SAN, etc. where network performance is not our primary concern.

These experiments and results are performed for a single link failure under two different traffic applications CBR and FTP. In future we will perform the same experiment for multiple link failure, and we will also use parallel communications between more than one source and destination pairs.

9. REFERENCES

[1] Thurber, Kenneth J., "Interconnection networks: a survey and assessment," in Proceedings of the ACM national computer conference and exposition, 1974.

[2] Ding, Zhu., "Adaptive Hybrid Switching Technique for Parallel Computing System," PhD dissertation, University of Pittsburgh, 2006.

[3] Duato, Jose., "Interconnection networks [electronic resource]: an engineering approach," Morgan Kaufmann, 2003.

[4] Xu, Junming, "Topological structure and analysis of interconnection networks," Springer Publishing Company, Incorporated, 2010.

[5] Dally, Bill, "Enabling technology for on-chip interconnection networks," in IEEE International Symposium on Networks-on-Chip (NOCS), 2007.

[6] S. Suboh, M. Bakhouya, S. Lopez-Buedo, and T. El-Ghazawi., "Simulation-based approach for evaluating on-chip interconnect architectures," SPL Proceeding, pp. 75–80, 2008.

[7] Mubeen, Saad, "Evaluation of source routing for mesh topology network on chip platforms," PhD disertation, Jönköping University, 2009.

[8] Wang Wei, Qiao Lin, et al, "Performance Analysis of the 2-D Networks-on-Chip," Journal of computer research and development, vol. 46, no. 10, pp. 1601-1611, 2009.

[9] Liu Yu-hang, Zhu Ming-fa, Wang Jue, Xiao Li-min, Gong Tao, "Xtorus: An Extended Torus Topology for On-Chip Massive Data Communication," 26th IEEE International Parallel and Distributed Processing Symposium Workshops & PhD Forum, pp. 2061-2068, 2012.

[10] M. Moadeli, A. Shahrabi, W. Vanderbauwhede, and M. Ould-Khaoua, "An analytical performance model for the Spidergon NoC," in Proceedings of the 21st International Conference on Advanced Information Networking and Applications, pp. 1014-1021, 2007.

[11] Vikas Singla, Parveen Kakkar, "Traffic Pattern based performance Comparison of Reactive and Proactive Protocols of Mobile Ad Hoc Networks," International Journal of Computer Applications, vol. 5, no. 10, 2010.

[12] Bijan Paul, Md. Ibrahim, Md. Abu Naser Bikas, "Experimental Analysis of AODV & DSR over TCP & CBR Connections with Varying Speed and Node Density in VANET," International Journal of Computer Applications, vol. 24, no. 4, 2011.

[13] Y-R. Sun, S. Kumar, and A. Jantsch, "Simulation and evaluation of a network-on-chip architecture using NS-2," Proceedings of the IEEE NorChip Conference, 2002.

[14] M.E. Gomez, P. Lopez, J.Duato, "A Memory-Effective routing Strategy for regular Interconnection Networks", in Proceeding of International Parallel and Distributed Processing Symposium., 2005.