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PERFORMANCE EVALUATION OF LOAD BALANCING STRATEGY ON VARIANTS OF MULTIPROCESSOR INTERCONNECTION NETWORKS

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ABSTRACT
A Multiprocessor System (MS) is a single computer incorporating a number of independent processors that work together to solve a given problem. In MS, a suitable Multiprocessor Interconnection Network (MIN) is an integral part of any high-performance parallel system. MINs play an important role in the overall performance of the system for better load balancing. Deciding the appropriate network is an important issue in the design of parallel and distributed systems. The performance of a multiprocessor system can be characterized by communication delay, distribution of load among the processors and scheduling overhead. Load Balancing (LB) is the phenomena of distributing the approximately equal amount of workload of the tasks so that all processors kept busy all the time in order to prevent the average time of processors. In this paper, variants of MINs are studied and performance of networks is compared by on different parameters such as nodes, degree, diameter, bisection width, average node distance, message traffic density and cost. Then, we find out best network among all Interconnection network (ICN) on the basis of different parameters. In the simulation study, our previous works ITSLB is compared and superior performance is shown with the considered parameters under study on the variant of multiprocessor interconnection networks and experimental results have been reported accordingly.

KEYWORDS: Multiprocessor system, MIN, Load balancing, LIF

I. INTRODUCTION

In the era of computer field, there are so many current and emerging applications. In order to meet all the computational requirements, there is a promising approach that is parallel processing. However, there are some problems which are not handled by parallel processing that is the problem like designing a parallel algorithm, partitioning of the application into tasks, scheduling the task, coordinating synchronization and communication. The emergence of ICNs is the direct result of rapid change in technology and increasing demand for massive parallelism. As ICN governed a vital role in the architecture of large-scale high-performance computing system. ICN with a large number of processors emerged in order to cope up with increasing demands for more power of computing and to solve the giving problem in parallel processing. The cube-based ICN has gained much popularity in past few years due to its large bandwidth and the high degree of fault tolerance. ICN is considered as an undirected graph where edges correspond to the bisectional communication links and vertices correspond to the processors. ICN is commonly used in multiprocessors systems, networks of workstation, deep space communication and parallel multicomputer. ICN can be static as well dynamic. In static ICN, connections are established among nodes to form a fixed network whereas, in dynamic ICN, connections are established as per need. In order to establish connections between inputs and outputs, switching elements are used. Almost all systems can be differentiated by its ICN topology.

Scheduling is the process of assigning the tasks onto the processors, for its execution. Scheduling and its allocation governed a great importance from system's potential point of view, as if scheduling failed, gain from parallelization can be offset and true potential of the system will exploit. Scheduling is done in order to meet the goal to minimize the completion time from any parallel application through proper allocation of the task onto the processors. There are two types of scheduling such as static and dynamic. A schedule which is done at compile time is usually static scheduling and in which data dependencies between the tasks, processing time, synchronization requirements and communication time are known in advance that is before its execution, is usually static scheduling. However, these all characteristic of a parallel program like data dependencies, communication time and processing time are unknown before program execution. The motive of the dynamic scheduling is to minimize scheduling overhead along with minimization of compile time. Load Balancing is the phenomena of distributing the approximately equal amount of workload of the processors so that all processors kept busy all the time in order to prevent the ideal time for processors. The aim of LB algorithm is to sustain the load to each processing element (PE) such that all the PEs becomes neither underloaded nor overloaded that means each PE moderately has equal load at any instant during execution time to achieve the maximum performance of the system. In other words, the distribution of loads to the PE (i.e., PE is the combination of ALU and CU) is basically known as load balancing problem. In a system with several processors, there is a maximum option that few processors will be ideal, underloaded and other will be overloaded. Therefore, the proper design of an LB algorithm may notably improve the performance of the system. Since DS already defines is viewed as a set of computing and communication resources shared by login users. The load balancing issue becomes important when the required for computing power increases. The major principle of LB is to improve the performance of a distributed system through an application load [2].

In this paper, our contributions are as follows: to study of the performance analysis of various multiprocessor interconnection networks is presented. The performance is compared by considering cube type architectures on different parameters, then we find out best network among all Interconnection network (ICN) on the basis of different parameters. Further, we apply our previous strategy used named as ITSLB algorithm on considered MINs for performance evaluation on ICN [1,3,4].

Rest of the paper is classified as follows: in section 2, it describes the literature review and working ITSLB algorithm which is compared with best founded INC. In section 3 presents the experimental results of this work. In section 4, it finally shows the concluded paper.

II. LITERATURE REVIEW

Massively parallel processing (MPP), governed a vital role in the era of supercomputing. And in this regards, interconnection networks has assumed crucial and active role in MPP. As ICNs supports communication amongst some active processing elements. MPP mitigates the problem technical hindrances and this improves the performance level. The efficiency and the success of any multicomputer system totally depend on ICNs as ICN(s) governed an active and crucial role in MPP, by providing communication among the processors. ICN has a great impact on speed of execution of the multicomputer system, cost, bandwidth, routing, and reliability and broadcasting, there are performance matrices in order to decide the suitability of the network. In multiprocessor environment, ICN is the backbone. Basically ICN has a key role in parallel computing system for its performance. That's why various ICN topologies designed in order to get optimal solution in term of desired performance multiprocessor network. The importance of ICNs can be enlighten by the fact that, some ICN(s), are used to optimizing connection complexity and communication, in order to get economical solution, which is effective too. Performance matrices like degree, broadcasting, cost, scalability and diameter etc. are depends on the type of ICN used. In a parallel machine, transferring of machine is done from source node to selected destination node by an ICN completion of this task should be within small latency and should support transfer as much as possible. And an ICN should be economical purchase too. ICN comprises of links, network interfaces and switches. Switches and links help in transferring the information from source to destination node. An ICN is categorized differentiated by its routing switching strategy, its flow control phenomena, algorithm and its topology. An ICN helps in exchanging the information among various processors in the parallel system. As ICN is made up of switching elements and topology helps in connecting switching elements like processors, memories and other switches etc. There are two types of ICN that is static network as well as dynamic network. In static ICN, connections are point to point among neighboring nodes and these point to point connections are fixed whereas in dynamic ICN, there are no fixed neighboring nodes. Load Balancing is the phenomena of spreading or distributing the equal amount of work among the tasks so that all tasks kept busy all the time, in order to prevent idle time of tasks. The goal of load balancing algorithm is to maintain the load to each processing element such that all the processing elements becomes neither overloaded nor idle that means each processing element ideally has equal load at any moment of time during execution to obtain the maximum performance (minimum execution time) of the system. Distributed system can be viewed as a collection of computing and communication resources shared by active users. When the demand for computing power increases, the “Load Balancing (LB)” problem become important. The purpose of load balancing is to improve the performance of a distributed system through an application load. The concept of LB is applied in two algorithms namely Dynamic Load Balancing Strategy (DLBS) and Independent Tasks Scheduling with Load Balancing (ITSLB) algorithms. Working of DLBS algorithm initiates with generation of random tasks in multiprocessor scheduler model, which are allocated to various processors in haphazard fashion [3]. The scheduler calculates the load on each and every processor (LEP), total load on the system and ideal load (IL) required for each processor. And then determines the overloaded, underloaded and moderate processors by comparing with the IL. After determining maximum overloaded (MOL) and maximum underloaded (MUL) processor, scheduler checks for connectivity in Folded crossed cube (FCC) network. If connectivity exists between MOL and MUL, execution time starts and migration of load takes place from MOL to MUL until the processor become moderate. Then scheduler again determines MOL and MUL and migration takes place and this step is repeated for all possible connections among processors until the processors become moderates and the execution time ends. ITSLB algorithm proposed for scheduling of n number of independent tasks (IT) for heterogeneous distributed system, where all the IT generated randomly and allocated to the n number of processors. This algorithm was applied on Folded crossed cube (FCC) ICN in order to get optimal result in the form of smaller diameter. Hence FCC proved as the best ICN as compared to others MIN(s) in term of diameter. This algorithm used load balancer scheduler in order to fulfill the requirements or request of the clients by server. Load balancer allocates all the tasks to the processors as per the capability and capacity of the processors for doing that particular task in order to complete the client's request in an efficient manner. After the allocation of the jobs to the processors, scheduler calculates LEP, total load and IL for each processor. Then load balancer determines overloaded (OL) and underloaded (UL) processors. Then after determining MOL and MUL processors, load balancer migrates the tasks from MOL to MUL processors in order to moderating the processors after checking connectivity (CC) between MOL and MUL. Thus by this process of migration from MOL to MUL all the processors of FCC ICN gets moderates in order to give optimal performance in term of Load imbalance Factor(LIF), Migration time, speed up, Makespan and resource utilization. In this paper, we study the performance analysis of various interconnection networks is presented. The performance is compared by considering cube type architectures on different parameters, then we find out best network among all Interconnection network (ICN) on the basis of different parameters, after that we applies ITSLB algorithm on best founded ICN and in the end we may comparison between ITSLB algorithm on FCC and ITSLB algorithm on founded ICN [1,3,8].

Working of DLBS

Step 1:-Generate random tasks
Step 2:-Scheduler calculates the load on each processor, total load and ideal load
Step3:- Finds the maximum overloaded (MOL) and maximum underloaded (MUL) processor
Step 4:-Checks connectivity between MOL and MUL in FCC network
Step 5:-Starts execution time.
Step 6:-Migration of load takes place from MOL to MUL processor
Step 7:-Repeat steps 3 -6 until processors become moderate.
Step 8:-Ends execution time.

Working of ITSLB

Step 1:- Generates random ETC matrices.
Step 2:- Sort ETC of all tasks in ascending order.
Step 3:- Calculates LEP, TL, IL of the system.
Step 4:- Determines Overloaded, underloaded and moderating processors then also determined MOL and MUL from the set of OL and UL respectively.
Step 5:- Checks connectivity between MOL and MUL in FCC network.

Step 6:- Migration time start.
Step 7:- If connectivity exists between MOL and MUL then migration will take place from MOL to MUL by using two strategies that is Max-Max and Min-Max.
Step 8:- Migration and Mapping.
Step 9:- Determine next MUL and repeat steps 5 to 8.
Step 9:- Migration time ends.
Step 10:- Repeat steps 4 to 8, until MOL and MUL are not empty.

Performance Matrices of Interconnection Network

There are various parameters used in multiprocessor interconnection networks such as

1. Nodes (N): The basic unit which is used in the computer field is called node for examples, mobile, printer and personal computer. In a MIN, nodes play a crucial role as the performance and the complexity of any system relies on a number of nodes. The number of nodes is directly proportional to the complexity and the performance of the system due to this reason the number of nodes should be optimal.
2. Node Degree (d): The connectivity between different nodes in an ICN is known as the degree of a network. The number of connection needed at each node is called the degree of ICN. Degree in a network reflects the complexity of the network. So, lesser degree shows lower the complexity. The degree of a node is directly proportional to the cost. Therefore in order to reduce the cost, degree of the node should be low.
3. Diameter (D): The largest distance between two nodes in an ICN is called diameter. Thus diameter is a maximum shortest distance between the destination node and source node in any network. The diameter is directly proportional to the performance of an ICN. The attractive and desirable properties for any ICN is lesser diameter due to a lesser diameter, an ICN can have optimal routing steps with a higher degree.
4. Cost: Cost is an important parameter as an ICN should always be economically effective along with higher performance, cost should be reduced in order to get an optimal result. Cost is the product of the degree of node and diameter. At the time of analyzing the performance of ICN, cost is widely considered and evaluated. Cost=degree*diameter
5. Bisection Width (BW): Minimum number of edges which should be removed for the purpose of division of ICN exactly into two halves is called the bisection width of any ICN. High bisection width is considered better performance for an ICN because bisection width is directly proportional to the performance of an ICN. Bisection width should be higher from fault tolerance of an ICN's point of view.
6. Latency: Interval of time between response and stimulation is called latency. Meaning of latency is time, therefore, the time takes place for carrying out packets from source to destination, and this time is latency. Thus for transferring of particular elementary unit needed sometime and this required time is latency. Ping and trace route are those popular tools which can be used to measure latency. Term delay can also be used for latency. Therefore, latency is the delays occurred in the processing of network. Unit of latency is hours, minutes, second, nanosecond or clock period.
7. Average Node Distance (AND): The mean distance between different pairs of nodes present in an ICN is called average distance. If average distance is small then it facilitates small communication latency. Overall delay in a system network can be determined by the average distance of the network. It conveys actual performance of ICN.
8. Link (E): It is also known as edges and it is denoted by E. edges are responsible for the connection between nodes. Thus, links connect communication and nodes between nodes in an interconnection network.
9. Reliability: Reliability is the ability of a system to perform and maintain its functions in routine circumstances, as well as hostile or unexpected circumstances.
10. Message Traffic Density (MTD): This characteristic of ICN can be defined by $\rho \equiv dN/ E$ Where N is the total number of nodes and E is the total number of communication links. There is an assumption that each node is transferring the information to the nodes at the distance on the average. Message traffic density is the good measure in order to evaluate the traffic handling of messages in the ICN. Performance of an ICN can be analyzed by the ability of an ICN to handling the traffic of messages.
11. Fault Tolerance: Fault tolerance is the characteristic which makes the system for continuous operation in a proper manner even in the case of some failure of its components. Thus, fault tolerance is that configuration

which protects the network from failure because of some errors. Therefore, for a better performance of an ICN, fault tolerance of a network should be high and the system should be designed in such a way that it makes possible for the system to do functions on a continuous base even in the presence of some faults or errors. Fault tolerance of any graph is a maximum number of vertices which can be removed from it only when a graph is still connected.

12. Extensibility: It is the characteristic of an ICN which helps in taking out the large sized system from the small-sized system along with few changes in node's configuration. Therefore, extensibility is that minimum increment through which expansion of the system is possible in a beneficial manner that is system can be expanded for the useful purpose. However, this expansion of the system should be linear for avoiding unnecessary complexity of the system [5].

Interconnection Networks

There are various interconnection networks studied in this paper such as Hypercube (HC) interconnection network is a network which has four processors. It is a binary type n-cube network based multiprocessors. In this network, nodes are connected by a bidirectional asynchronous communication link. The major issue of this network is that number of communication links, is directly proportional to the total number of nodes [21]. Folded Hypercube (FHC) is a standard form of hypercube, along with few extra links, which has established between its nodes. In this network each node is connecting to that unique node which is farthest from it [8]. Hierarchical Cubic Network (HCN) are in the also form of hypercube where there clusters are connected in a complete discipline [20]. Dual cube (DC) interconnection network reduces the issue regarding increasing number of links in large scale hypercube network and also with possessing others desirable properties of the hypercube ICN [9]. Meta cube (MC) is used to high performance parallel computer. MC has an efficient routing and also easy broadcasting. In MC, millions of nodes can be connected along with 6 links per node in this network [11]. Necklace Hypercube are attached at each two adjacent nodes of network. It has also some other additional desirable properties such as scalability of hardware and efficient layout of the network. Length of the necklace may be variable may be fixed [2]. Folded Dual cube (FDC) interconnection network is made from DC and folded hypercube ICN. In this interconnection network nodes are connected with each other, which is farthest from it. This ICN reduces diameter and cost [10]. Double Loop Hypercube (DLHC) is that interconnection topology, which is scalable. This kind of topology proves the better ICN topology in terms of properties and performance of communication [18]. Folded Meta cube (FMC) is that interconnection network which possessed some desirable properties of both ICN that is FHC as well MC and those desirable properties are reduced diameter, cost and easy efficient broadcasting [12]. Tori connected torus network (TCTN) is a hierarchical ICN, which gives a high performance for massively parallel computer systems. The algorithm is used in TCTN is deadlock free routing algorithm, which used four virtual channels and analysis the dynamic communication performance of the networks, under uniform as well non-uniform traffic patterns [19]. Symmetrical Tori Connected Torus Network (STCTN) has lower diameter and average distances but the fault tolerance is equal to TCTN [22]. Linearly Extensible Cube (LEC) is an interconnection network, which can grow linearly. LEC has some positive features of an ICN like it has small diameter, has high scalability, and has high connectivity and also maintained constant node degree without affecting by increases the size or number of nodes. LEC requires lesser number of nodes to provide smaller diameter [13]. Linearly Extension Arm (LEA) network gives two links to the two different processors and also receives two links form two distinct processors. Scalability of LEA is also very high [14]. Linearly Extensible Tree (LET) is a binary type interconnection network. LET has lesser diameter, constant degree of nodes and average path length etc. [15]. KCube is the combination of two graphs that is hypercube as well Kautz digraph where Kautz digraph and hypercube graph proves as regular. Balance Varietal Hypercube (BVHPC) is a hybrid of two ICNs that balance hypercube and varietal hypercube [9]. Linear crossed cube (LCQ) interconnection network grows linearly in the cube form. LCQ also helps to mitigate the complexity of hypercube architecture [18]. Twisted Hypercube (THC) having similar structural complexities as hypercube consists. It consist some attractive properties of hypercube and thus improves communication times by minimizing the diameter. THC can reduce diameter without affecting degree of nodes but rooting gets more complicated.

Uses of ICN over LB

- Load balancing is the allocation of the work of a single application to processors at run-time so that the execution time of the application is minimized. In order to achieve this purpose, load balancing algorithms require various network parameters to make decisions for effective load balancing.
- ICN facilitates load balancing algorithms in estimating network parameters (packet loss and delay) to be used in decision making. Thus the process of load balancing depends on network characteristics. For instance, many load balancing techniques rely on determining the availability of a server before attempting to set up a connection.
- ICN is used to tune the delay dependence module of various load balancing strategies.
- Network parameters have an important role to play in the operation of a load balancer and load balancing algorithms. As Load balancing is examined from various angles, for example, static and dynamic load balancing or global and local policies for load balancing. The role of network parameters is dominating in these classifications of load balancing. For example, dynamic load balancing algorithms can provide a significant improvement in performance over static algorithms.

III. EXPERIMENTAL RESULTS

In order to simulate and compute the performance of ITSLB (Max-Max) and ITSLB(Min-Max) strategies, tasks are generated and allocated on various ICNs such as HC, FHC, FCC, LCQ, LEA, HCN, MC, FDC. These strategies have been evaluated and compared performances on matrices such as node, degree, diameter, average node distance and message traffic density. The experimental result shows two observations.

1. Observations

- Observing that KCube has a higher number of nodes whereas HC has lesser number of nodes.
- Observing that LCQ has a smaller diameter while MC has a higher diameter.
- Observing that LEA, LET, LEC and LCQ have constant degree.
- Observing that LCQ has lesser average node distance.
- Observing that TH has lesser message traffic density.

There are some performance matrices like diameter, nodes, degree, average node distance and message traffic density of various ICN such as HC, FHC, MC, FMC, DC, FDC, HCN, TH, LCE, LCA, LCT, LCQ, BVHC, DLHC and KCube..The curves are plotted for each parameter of ICN.

The number of nodes in a multiprocessor network plays a vital role by virtue of which the performance of the system is evaluated. Higher the number of nodes, higher is the system performance but the complexity increases. Figure1 shows that complexity of network which higher as the number of level increases and KCube has a higher number of nodes which could not show KCube in Figure 1 and HC has lesser number of nodes. When the performance of interconnection network is evaluated and compared on the basis of the diameter which is an important performance metric. The degree in a network is defined as the number of connections required at each node. As shown in Figure 2, LEC, LEA, LET and LCQ has constant degree which is a promising property and advantageous too. However, the demerits of other interconnection networks such as DC, HC, FDC and TH etc. has lower degree in the beginning but degree of LEC, LEA, LET and LCQ will still have constant degree which can be higher. The diameter of a network is the measure of the largest distance between two nodes. As we can see in Figure 3, LCQ has the smaller diameter. However, MC interconnection network is not present in Figure 3 because of its higher diameter. The mean distance between different pairs of nodes present in an ICN is called average distance. In Figure 4 comparison is done on the basis of average node distance, LCQ interconnection network has the lesser average node distance. Message traffic density is the good measure in order to evaluate the traffic handling of messages in the ICN. Now, in Figure 5, message traffic density of different interconnection network is compared and evaluated so finding is that message traffic density decreases with increasing number of processors. TH has lesser message traffic density. Observation 1 has been depicted Figures 1 to 5.

2. Observations

We have used two strategies namely ITSLB (Max-Max) and ITSLB (Min-Max) in all those ICNs in which LIF has been calculated at 8, 16 and 32 nodes where number of processors kept fixed and number of tasks is varying as

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shown in Figure 6 to Figure 8. We have considered 1000 to 100000 tasks for experimental results. In Figure 6, ITSLB (Max-Max) gives best LIF on FHC interconnection network followed by LCQ interconnection network. However, when we see in overall performance, ITSLB (Min-Max) gives best LIF on FCC interconnection network followed by LCQ interconnection network. So, FCC is best interconnection network for balancing the load on ICN. The value of LIF given by ITSLB (Min-Max) on FHC is best and which is followed by LCQ interconnection network as shown in figure 7. As we can see in Fig 8, both schemes ITSLB (Max-Max) and ITSLB (Min-Max) are performing better on MC interconnection network on account of LIF for all considered batch size.

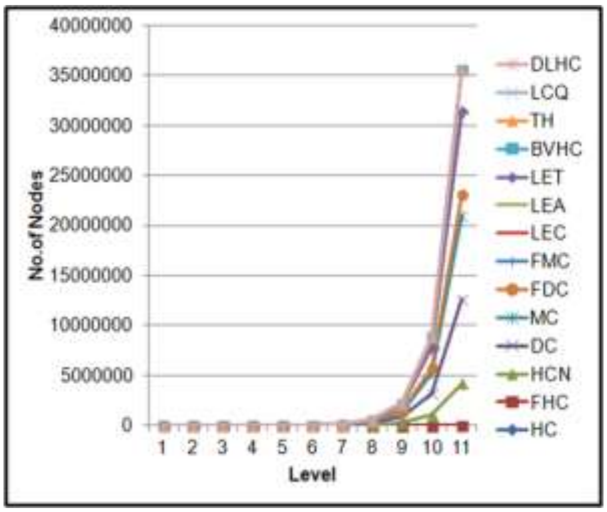

Figure 1. Comparison of Nodes on Various ICN

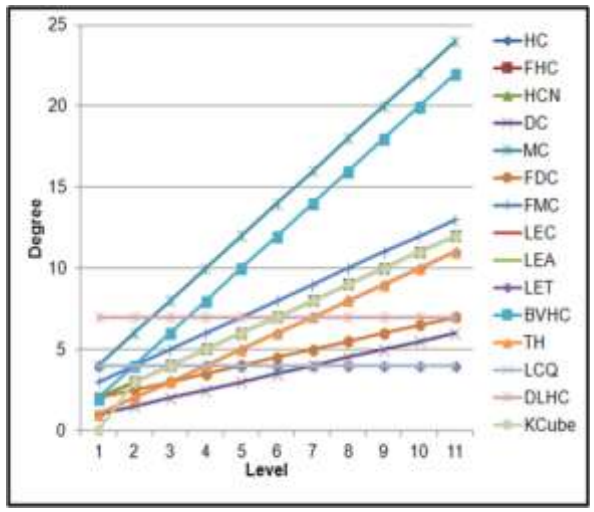

Figure 2. Comparison of Degree on Various ICN

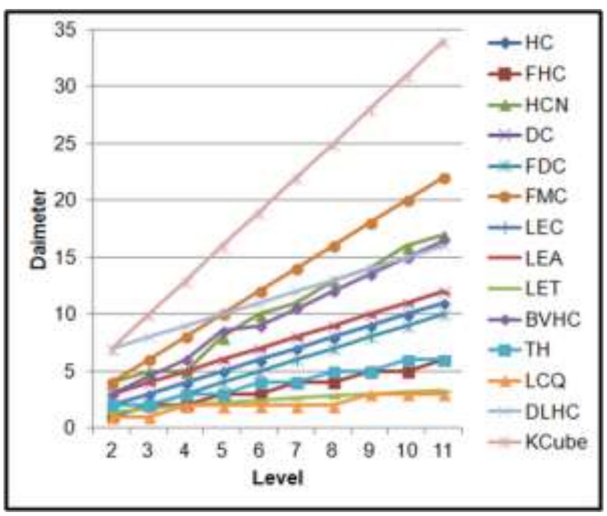

Figure 3. Comparison of Diameter on Various ICN

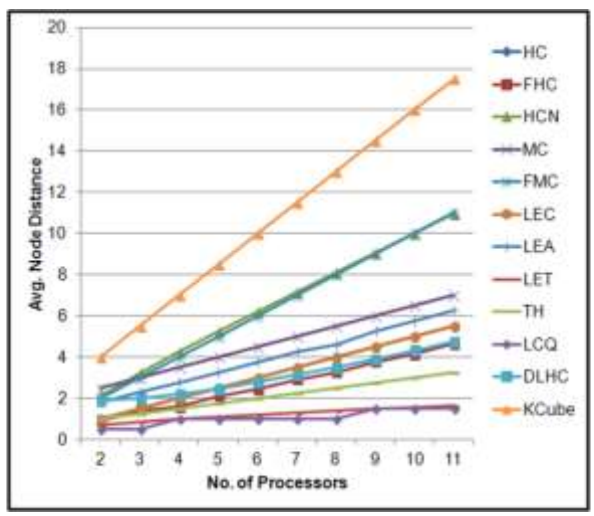

Figure 4. Comparison of AND on Various ICN

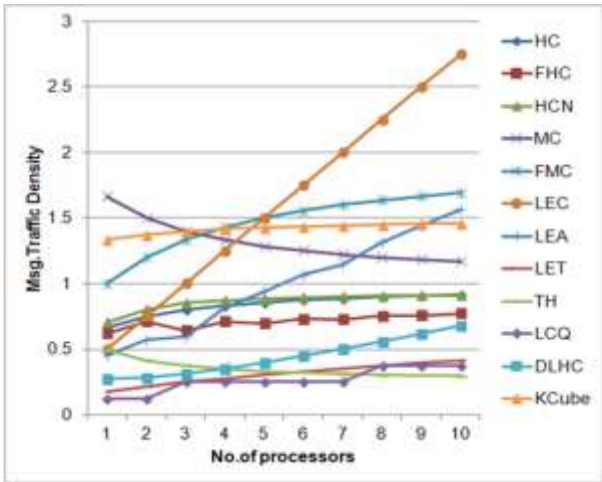

Figure 5. Comparison of MTD on Various ICN

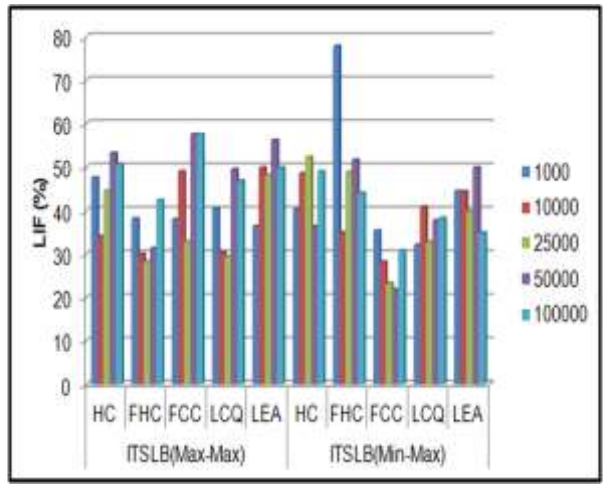

Figure 6. LIF for 8 nodes

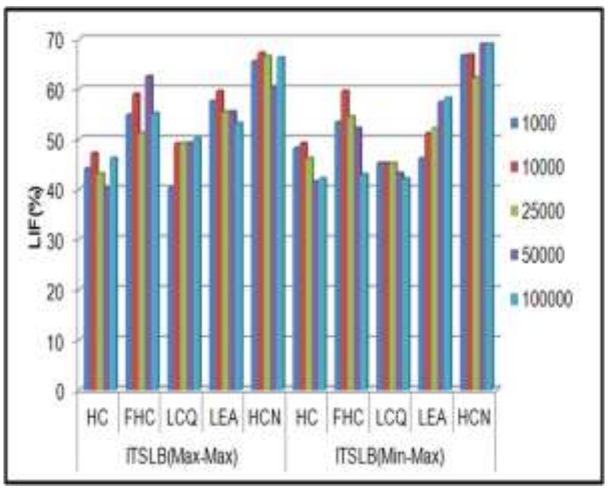

Figure 7. LIF for 16 Nodes

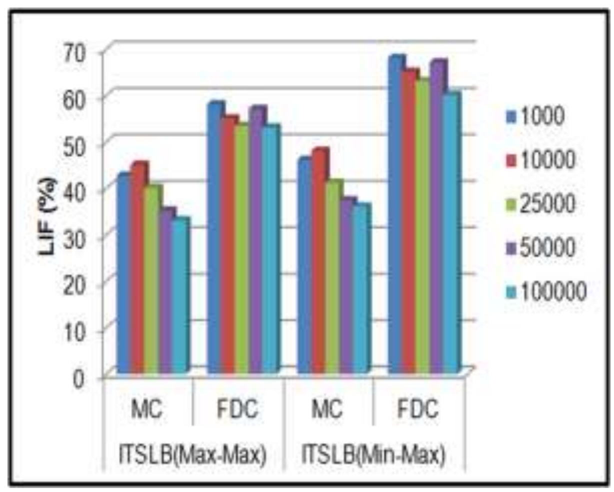

Figure 8. LIF for 32 Nodes

IV. CONCLUSIONS

In this paper, performances of various interconnection networks such as HC, FHC, MC, FMC, DC, FDC, HCN, TH, LCE, LCA, LCT, LCQ, BVHC, DLHC and KCube have been compared and evaluated in terms of various performance matrices such as diameter, node, degree, message traffic density and average node distance. The comparative study of cube-based, as well as linearly extensible architectures is made. LCQ has the smaller diameter, constant degree and lesser average node distance but MC has a high diameter so because of this MC interconnection network is not present in Figure 2, whereas KCube is better in terms of the number of nodes. TH has lesser message traffic density. As shown in the experimental study, by using ITSLB (Max-Max) and ITSLB (Min-Max) at 8, 16 and 32 nodes, the value of LIF on FCC is found to be best at 8 nodes even after increasing number of tasks. Similarly, the values of LIF on LCQ and MC are better at 16 and 32 nodes respectively.

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