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Research Article
Cost Effective Factor of a Midimew Connected Mesh Network

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Abstract
Background and Objective: Hierarchical Interconnection Network (HIN) is very much essential for the practical implementation of future generation Massively Parallel Computers (MPC) systems which consists of millions of nodes. It yields better performance with low cost due to reduction of wires and by exploring the locality in the communication\and traffic patterns. The main objective of this paper is to analyze the static cost effective factor of Midimew connected Mesh Network (MMN). **Materials and Methods:** A Midimew connected Mesh Network (MMN) is a HIN comprised of numerous basic modules, where the basic modules are 2D-mesh networks and they are hierarchically interconnected using midimew network to assemble the higher level networks. **Results:** This study, present the architecture of a MMN and evaluate the cost effective factor of MMN, TESH (Tori-connected Mesh), mesh and torus networks. The results shows that the cost effective factor of MMN was trivially higher than that of mesh and torus network. **Conclusion:** It was revealed that the proposed MMN yields a little bit high cost effectiveness factor with small diameter and average distance. Overall, performance with respect to cost effective factor with small diameter and average distance suggests that the MMN will be a promising choice for next generation MPC systems.

Key words: Massively parallel computers, hierarchical interconnection network, mesh network

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INTRODUCTION

The demand of computation power is increasing day by day and to fulfill this increasing demand of computation power researcher and scientists are trying in different ways. Initially the clock pulse of a single processor is increasing by reducing the gate width of individual transistors. Then multicore and many core processors for chip level concurrency is used to fulfill the increasing computational demand. And the multi nodes Massively Parallel Computer (MPC) system only possible solution to provide petaflops or exaflops level of computation power. Here each node consists of multicore or many core processors along with a router to route the packet in the neighboring nodes[1,2]. Interconnection network for MPC systems consisting numerous nodes should support all communication generated by the applications in an appropriate and efficient manner. Also the scalability of the MPC is increasing day by day. Therefore, in a very near future, MPC will be consisting of millions of nodes together to have the computing power at the level of exafloaps[3-6]. It is infeasible to connect such a huge number of nodes using conventional topologies. To construct the MPC systems consisting of such huge nodes, an appropriate custom interconnection is essential. For example, the fastest computer right now in the world (the Sunway TaihuLight-2 supercomputer (TOP500 2016) uses a five-level integrated hierarchy, connecting the computing node, computing board, super-nodes, cabinet, to the complete system[7,8]. By the elimination of the interconnection bottleneck, the overall inter-node communication and fault tolerance performances are significantly improves[9]. The topology of an interconnection network is an important design decision because it has noteworthy on an MPC system performance.

The hierarchical interconnection network is a credible alternative way in which several topologies integrated together. However, due to limited connectivity the higher level hierarchical interconnection networks do not draw the potential attention from the MPC industry community. Among the available hierarchical interconnection networks, various k-ary n-cube based hierarchical interconnection networks yield good performance[10-12]. A hierarchical interconnection network, which results good performance in all aspect is still need to be explored. A good interconnection network is designed around the capabilities and constraints of available technology.

The midimew network is a wraparound 2D-mesh network whereby one dimension is wrap-around like tori connected and the other dimension is wrap-around diagonally. A Midimew connected Mesh Network (MMN) is a hierarchical interconnection network which consisting of numerous Basic Modules (BM) whereby the BMs are 2D-mesh networks. The BMs are hierarchically interconnected for higher-level networks in a midimew fashion. The architecture of the MMN, its static and dynamic performances were studied in previous study. It was depicted that MMN possesses several pretty good features. These include constant node degree, small distance parameters (diameter and average distance), low cost and less number of wires required to connect the network[13]. The dynamic communication performance of the MMN under uniform traffic pattern using virtual cut through flow control and dimension order routing algorithm is shown better than that of other conventional and hierarchical interconnection networks[14]. In spite all of these research works, it is needed and important to study how eases the implementation of the proposed MMN. In this regard, packing density and message traffic density are two important parameters which statically show the implementability of a proposed interconnection network. The main focus of this paper is to study the density parameters such as packing density and message traffic density of the proposed MMN over other networks. The only demerit is long diagonal links which makes the routing algorithm complex[15].

The main objective of this study was to analyze the static cost effective factor of MMN and therefore the architecture of a MMN is presented and evaluated the cost effective factor of MMN, TESH, mesh and torus networks respectively.

MATERIAL AND METHODS

Interconnection of midimew connected mesh network: Minimal Distance Mesh with Wrap-around links (Midimew) is a 2D network, where one dimension is tori-connected and the other dimension is wrap-around connected in a diagonal fashion. This paper considered vertical direction as tori connection and horizontal direction as diagonal connection. An MMN is a hierarchical interconnection network, which consists of numerous clusters called BM. The BM is a 2D-mesh network and the higher level network is a midimew network. The BM refers to as a Level-1 network. The consecutive higher level network is built using a hierarchical fashion, i.e., immediate lower level network is used as sub-net modules of a higher level network. For example, Level-1 network is used as a sub-net module of Level-2 network; Level-2 is used as a sub-net module of Level-3 network and so on.

Basic module: The BM of an MMN is a 2D mesh network and in the exterior nodes of a 2D-mesh network, either one or two

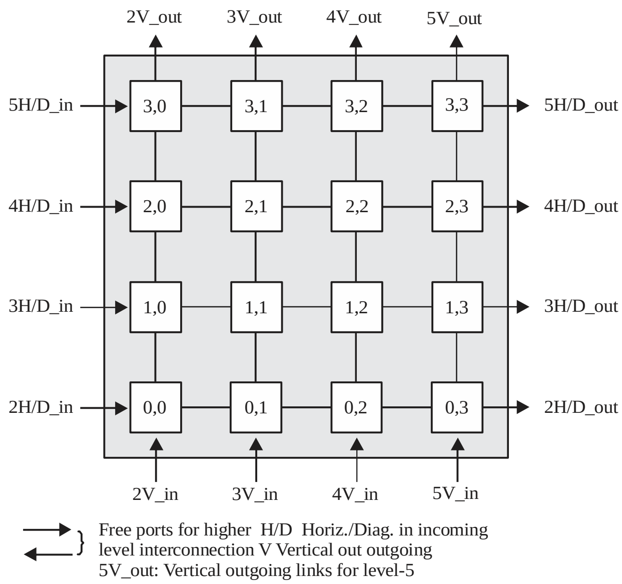

Fig. 1: Basic module of an MMN

(corner nodes) ports are not in used. These free ports used for higher level interconnection of MMN and also used some additional links in these free ports. These links were connected the logically adjacent BMs in a hierarchy for higher level interconnection. A $2^m \times 2^m$ 2D-mesh network consisting of 2^m rows and 2^m columns, i.e., the BM of a MMN have 2^{2m} nodes, whereby m is a positive integer. Due to better granularity, concentrated on m = 2 in this study. For course granularity, could be any values. A$2^2 \times 2^2$ i.e., (4×4) BM is portrayed in Fig. 1.

A $2^m \times 2^m$ BM has 2^{m+2} number of free ports at its periphery for higher level interconnection. As depicted in Fig. 1, a (4×4) BM has $2^{2+2} = 16$ free ports for higher level interconnection. Each free port is defined according to Level L($1 \leq L \leq 5$), direction (vertical, horizontal or diagonal) and flow direction (incoming or outgoing). Outgoing link was tied together with the corresponding incoming links to form the bidirectional links. These defined free links were used for the respective higher level interconnection.

Higher level network: As mentioned earlier, higher level of a MMN is a midimew network. Here, the vertical direction had toroidal connection and the horizontal direction had diagonal wraparound connections. Considering M =2 a Level-2 MMN was constructed by interconnecting $2^{2\times 2} = 16$ BMs as a midimew network. Similarly, a Level-3 MMN was constructed by interconnecting 16 Level-2 one and so forth. Each higher level interconnection used $4\times 2^q = 2^{q+2}$ free ports and their associated links, half of them, 2×2^q, free links for vertical toroidal interconnections and the rest of them, 2×2^q, free links for horizontal connections between adjacent BM and diagonal wraparound connection for end to end BMs. The parameter q is known as the inter-level connectivity, where q∈{0,1, ..., m}. Here, q = 0 and q = m lead to minimal and maximum inter-level connectivity, respectively.

The higher level interconnection of MMN considering is portrayed in Fig. 2. For q = 0, $4(2^0) = 4$ free ports and the links are used for each higher level MMN interconnection, 2 for the vertical toroidal connection and 2 for horizontal and diagonal connection. Out of these 2 links, one is used for incoming link and another one for used for outgoing link, i.e., a single link is used for vertical_in, vertical_out, horizontal_in or diagonal_in and horizontal_out or diagonal_out. Incoming and outgoing links between two logically adjacent nodes were tied together to form a bidirectional link. This scenario depicted in Fig. 2. Therefore, in general an MMN (m, L, q) is constructed using $2^m \times 2^m$ BM, L levels of hierarchy and q inter-level connectivity.

Using $2^m \times 2^m$ BM and above interconnection principle, the highest level MMN can be interconnected is $L_{max} = 2^{m-q}+1$. Therefore, considering m = 2 and q = 0 $L_{max} = 2^{2-0}+1 = 5$, that is, Level-5 is the maximum level of hierarchy. The number of nodes in a Level-L MMN is $N = 2^{2mL}$. Considering highest possible level of hierarchy, L_{max}, the maximum number nodes can be interconnected by an MMN (m, L, q) is $N = 2^{2m2^{m-q}+1}$. Considering m = 2and with minimum inter-level connectivity, the number of nodes is:

$$N = = 2^{2m2^{m-q}+1} = 2^{2\times 2(2^2+1)} = 2^{20} = 1,048,576$$

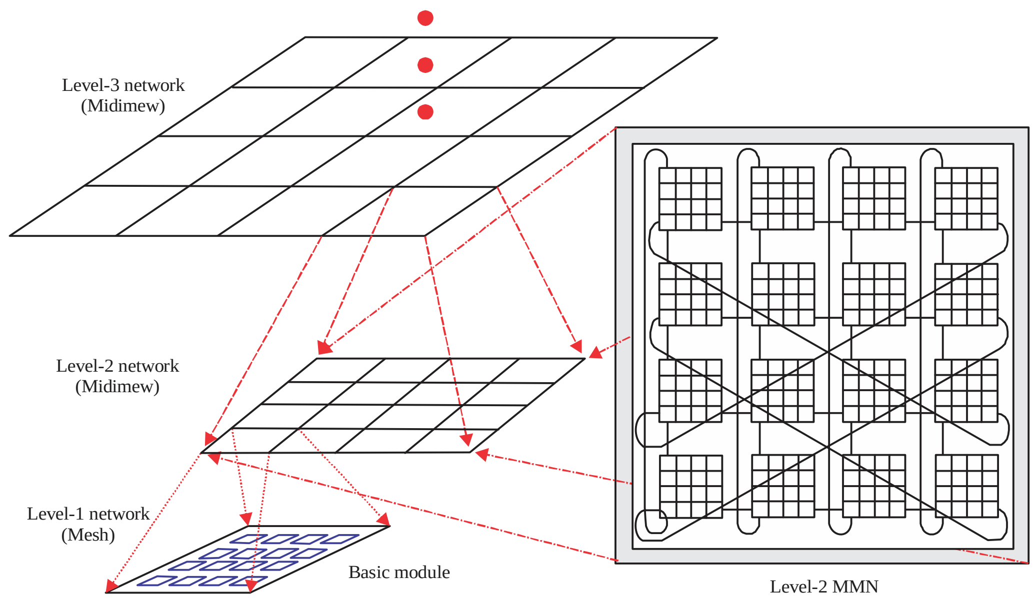

Fig. 2: Higher level network interconnection of an MMN

Table 1: Cost effective of Different interconnection networks

Network	Degree	Wiring complexity	Diameter	Average distance	Cost effective factor
2D-Mesh	4	480	30	10.67	0.8421
2D-Torus	4	512	16	8.00	0.8333
Tori-connected Mesh (TESH)	4	416	21	10.47	0.8601
Midimew connected Mesh Network (MMN)	4	416	17	9.07	0.8601

i.e., more than 1 million nodes can be interconnected to form a future generation MPC system.

RESULTS

Cost effectiveness analysis: Basically the real performance of an MPC system depends on various implementation issues and their underlying technology. However, before going into real implementation static evaluation is widely used to study the suitability of an interconnection network for an MPC system. The static performance metrics that characterize the performance and effectiveness of the proposed MMN with respect to cost effective factor is discussed and analyzed.

Cost effective factor: The actual cost of a massively parallel computer system is depending upon the cost of total number of nodes and the cost of total number of interconnecting links to interconnect the whole network. Also speedup and efficiency are two desirable properties of an MPC system. Therefore, Cost-Effective Factor (CEF)[16,17] can be a good characterization factor that analyzes the cost effectiveness of the MPC systems.

Let P denotes the total number of nodes and L denotes the total number of links of a MPC system. Now, let us we consider a system with all processors as well as the links have the identical cost. Let C_p corresponds to the cost of a processor, including the processing unit, control unit and memory module and also let C_L is the cost of a communication link. ρ is the ratio of cost of link to the processor, $\rho = \frac{C_L}{C_p}$. It is assumed that the cost of links is homogeneous as well as the cost of nodes are homogeneous, thus $0.1 \leq \rho \leq 1$. The minimum value of ρ is considered here to calculate the cost effective factor. G_P is the ratio of total number of links to total number of nodes:

$$G_p = \frac{\text{Total No. of links}}{\text{Total No. of nodes}}$$

The cost effective factor of different networks have been evaluated and tabulated in Table 1. It is shown that the cost effective factor MMN is trivially higher than that of mesh and torus network. It is tabulated in Table 1 that the cost effectiveness factor of MMN is equal to that of Tori-connected Mesh (TESH) network; however, the diameter and average distance are lower than that of TESH network. In another study, it is found that the zero load latency of the MMN is lower and the saturation throughput is higher than that of TESH network[14]. Therefore, MMN is a cost effective network in building the future generation massively parallel computers.

DISCUSSION

Some generalization: The distance between two nodes of a network is known as hop distance. This rough distance measurement is used to compare different networks to predict the network latency and throughput[18]. The hop distance between all distinct pairs of nodes using a shortest path algorithm is evaluated by computer simulation. The highest value among all the distances is called diameter and the average value of all the distances is called average distance[19]. It is shown in Table 1 that with slightly increase of cost, MMN yields low diameter and average distance. Both the diameter and the average distance of the MMN are lower than that of mesh and TESH networks and slightly higher than that of torus network.

Torus network has wrap-around connection of all end-to-end nodes and these wrap around links are providing alternative path for message transfer, which results low diameter and average distance, which in turns reduces cost effective factor. With the cost of these extra-long wrap-around links (which is 4 times higher than that of MMN), torus network results best performance in distance parameters and cost effective factor. It is to be noted that the length of long wire length of torus network is 211.20 cm whereas it is only 67.76 cm for the MMN, far lower than that of torus network[20,21].

$$CEF = \frac{1}{1+\rho \times G_P} \quad (1)$$

CONCLUSION

The architectural details of a MMN and its cost effectiveness have been discussed in this study. To show the superiority of the MMN, the cost effective factor for different networks such as mesh, torus and TESH networks were evaluated and compared with that of MMN. Combination of mesh and midimew network made the MMN as a simple hierarchical network. The diagonal wrap-around links improve the distance parameters of the MMN to that of other networks. It was also showed that the cost effectiveness of the MMN is trivially higher than that of mesh, torus and TESH networks. However, this little extra cost results small diameter and average distance than those of mesh and TESH networks. This study focused on the architectural structure and its cost effectiveness.

SIGNIFICANCE STATEMENTS

This present study discovered that the suggested MMN method produces batter cost effectiveness factor with minimum diameter and average distance. From the performance of the proposed system, it is suggested that the MMN method is promising choice for next generation MPC systems.

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