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FAULT TOLERANT HIERARCHICAL INTERCONNECTION NETWORK FOR PARALLEL COMPUTERS (FTH)

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***Abstract*:- In this paper we introduce a new interconnection network Fault Tolerant Hierarchical Interconnection network for parallel Computers denoted by FTH(k, 1).This network has fault tolerant hierarchical structure which overcomes the fault tolerant properties of Extended hypercube(EH).This network has low diameter, constant degree connectivity and low message traffic density in comparisons with other hypercube type networks like extended hypercube and hypercube. In this network we proposed the fault tolerant algorithm for node fault and also we introduce the hamiltonian Circuit for the proposed network FTH(k,2).**

Keywords:-Hypercube; fault tolerant; parallel algorithm; node fault;

1. INTRODUCTION

In different interconnection networking system the hypercube network is considered ideal for robust parallel system due to rich regular connectivity. In 1992, J. M. Kumar et al. proposed the extended hypercube(EH) interconnection network [1] which retains the positive features of k-cube at different level of hierarchies and proposes some additional advantage like less diameter and constant degree. This network is recursive in nature and has reduced diameter [2], low cost and constant degree. In EH the number of I/O ports for each PE and NCs is fixed and is independent of the size of the network. Is used for class hierarchies parallel algorithm like ASCEND and DECEND[1] algorithm. The utilization factor is also very high in comparisons with the normal hypercube. It contain improved diameter, cost factor reliability and improved fault tolerant nature [3] with robust to node fault. The FTH(k, l) can tolerate up to k + 1 link faults per PE , 2^k+k + 1 link faults per NC and two node faults for every k-cube of PEs or NCs. The use of spare nodes in every basic module of the facilitates reconfiguration [1] in the event of node faults and the presence of several alternate paths enables rerouting in the event of link faults.The hypercube multiprocessors are extensively used for a variety of applications as they have low degree of connectivity and diameter and are cost-effective. The fault tolerant extended hypercube topology is a hierarchical interconnection network of hypercube with improved cost factor and utilization factor. However, the extended hypercube topology is vulnerable to faults at the network controllers since there are parallel paths to route messages among modules.

The main drawback of the EH (k, l) is the existence of a single path from one level to another. On the other hand, the FTH (k, l), in addition to having a hierarchical and recursive structure, has two parallel paths between any

two levels. In this chapter, we discuss the architectural characteristics and the fault-tolerant capabilities of the FTH (k, 2) with fault tolerant algorithm; we also discuss the Hamiltonian circuit.

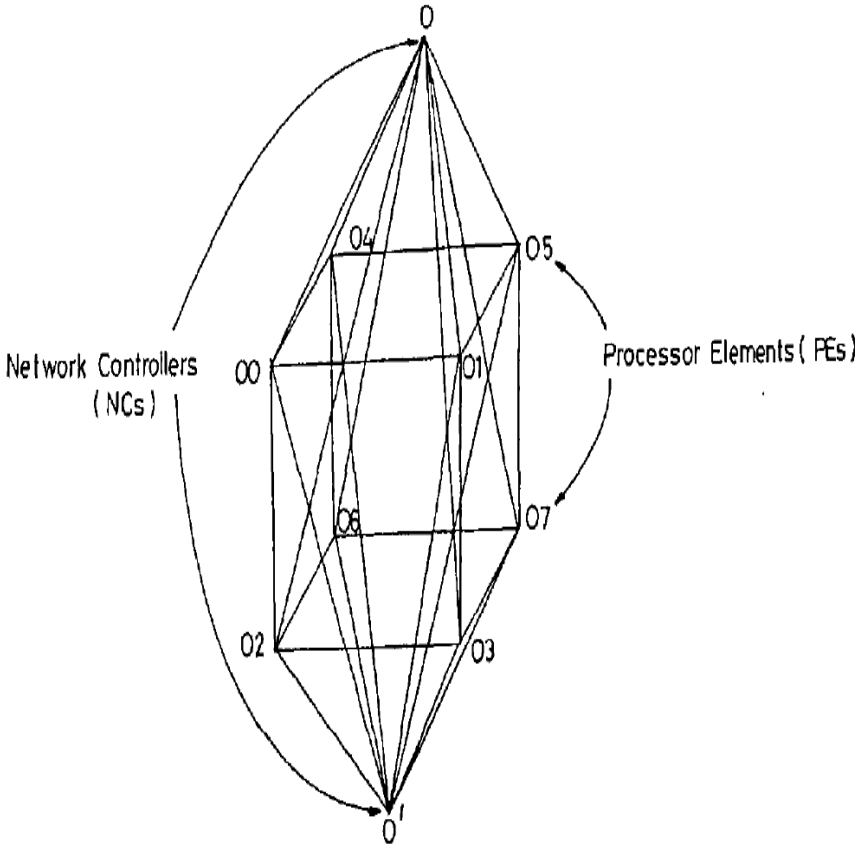

FIGURE 1.1 FTH (3, 1)

II .CONSTRUCTION:

FTH is constructed using basic building block of EH. Each basic building block represented by FTH(k, l) consist of hypercube of 2^k PEs ,2 network controller(NC) ,links from each PEs to NCs and additional links for interconnecting with basic building blocks .It is seen from figure 1.1 that there are cross links forming network among NCs and PEs.

Let $\sum = \{0,1,2,\ldots..2^{k-1}\}$.As shown in figure there are two NCs at highest level (l^{th} level)addressed by P_0 and P'_0 . For all level j,0<j<l ,there are two NCs addresses permutation on k-j symbols $i_1,i_2,\ldots\ldots i_{k-j}$ preceded by the number 0(zero), i.e.$P_{0i1,i2,\ldots\ldots i\ l-j}$ level zero addressed by $P_{0i1,i2,\ldots\ldots i\ l-j}.(i_1,i_2 \in \sum)$ is connected to two NCs, $P_{0i1,i2,\ldots\ldots i\ l-j}$ and $P'_{0i1,i2,\ldots\ldots i\ l-j}$ of level one. The addresses of all pairs of neighboring PEs differ in the last components. A node NC at level j, 0<j<l represented by $P_{0i1,i2,\ldots\ldots il-j}$ is connected to two parent nodes $P_{0i1,i2,\ldots\ldots i\ l-j-1}$ and $P'_{0i1,i2,\ldots\ldots i\ l-j-1}$. In addition NC at level j (0<j<k) with address $P_{0i1,i2,\ldots\ldots i\ l-j}$ is connected to 2^n child nodes at level j-1.There are three types of links in the FTH (k, l).(i) The EH links connecting nodes of the hypercube(ii) The EH links forming 2^k ary tree network with NCs.(iii) The cross link forming the network among NCs and PE.

III. ARCHITECTURE OF FTH:

In this section, we discuss the hierarchical structure of the FTH [5] and present a scheme for addressing the nodes of the FTH. We refer to the PEs and NCs in general as nodes. The basic module of the FTH comprises of a k-cube of PEs and two NCs as shown in fig. Each PE is connected to both the NCs by separate links and hence there are (k + 2) parallel paths between any pair of PEs. There are a total of [2^k + (k/2)] links in the basic module. The structure of the basic module of the FTH is suited for hierarchical expansion. The basic module represented by FTH (k, l) has two levels of hierarchy, viz., 2^k PEs at the zeroth level and two NCs at the first level. The k-cube of PEs is referred to as the FTH (k, 0). In general, an FTH (k, l) has (1+ 1) levels of hierarchy and the NCs are used for inter module communication while the PEs handle intra-module communication. An FTH (k,2) is constructed by connecting 2^k . The FTH (k,2) comprises of 2^k k-cubes of PEs at the zeroth level, two k-cubes of NCs at the first level and four NCs at the second level.In general an FTH (k, l) (1 is the degree of the FTH), comprises of 2^l NCs at the lth level, 2^{l-1} k-cubes of NCs at the (l-1) st level……$2*2^{(l-1)k}$ first level and 2^{k*l} PES at the zeroth level. The FTH is a 2^l rooted 2^k ary tree of height l, with additional horizontal links which form k-cubes at all levels. A node at level j (0 < j < 1) in an FTH is connected to its neighbors: k siblings at level j, 2^k children at level (j-1) and two parents at level (j + 1). In contrast, the FTH is a single rooted 2^k ary tree with height l and a node at level j (0< j < l) is connected to k siblings, 2^k children at level (j-1) and one parent at level (j +1). The connectivity of node in an FTH is greater than that of the FTH and hence we have more parallel paths in the FTH. Propositions related to parameters of FTH (k, l).

Proposition 1:-

The degree connectivity of PE, NC ,at level 1,NC at level j(1<j< l)) and NC at level l are (k+2),(2^k +k+2),(2^k + k+ 3) and 2^{k+1} respectively.

Proof**:-**

In an FTH (k, l) the PEs are at the lowest (zero) level of hierarchy. Each PEs belonging to EH (k, 1) is directly connected to n-neighboring PEs and two NCs [6] at the next higher level. Thus the degree of PEs in FTH (k, l) is (k+2). This amounts its degree to 2^k +k+2. Now NCs at level 1<j<l is connected to 2^k +1 . NCs at its just lower level ,k NCs at its level and two NCs at its next higher level .Thus the degree of a NC at level 1<j<l is 2^k +k+3 . As a NC at highest level is connected to two 2^k NCs at its just lower ,the degree connectivity of the NCs at highest level is $2+2^k=2^{k+1}$

Proposition 2:-

The diameter of FTH (k, l) is n+2[l-1], where k is the diameter of the hypercube (HC).

Proof:-

Considering two nodes A and B, they are either in the same EH or in different EH.

Case (i)

Suppose A and B are in the different hypercube. Then the distance between A and B is at most k.

Case (ii)

Suppose A and B are in different hypercube. Let us choose a node C in the hypercube that contains A. By previous case the distance between A and C is almost k. B and C can be connected by cross links through NCs at 1,2,3,…..,(k-1) levels. Thus the shortest path between B and C has a distance 2(l -1).Hence the distance between A and B is almost k+2(k-1).FTH (k, l) consists of (l+1) hierarchical levels and hence l-hops are needed between the PEs (at the lowest level) and the NC (at the highest level). Thus any PE of FTH(k, l-1) needs (l-1) hops to reach the kth kevel. Now the problem reduces to determine the number of nodes and their corresponding distance from this NC to all other NCs and PEs except the chosen EHC (k, l-1) .Choose one PE of FTH (k, l-1),two NCs one from each k-cube at $(l-1)^{th}$ level. we call these two NCs as source NCs at $(l-1)^{th}$ level. We call these two NCs as source NCs at $(k-1)^{th}$ level.

Now NCs at k^{th} level from these two source NCs at distances 1 or 2. The source NCs can be reached from source PE by (l-1) hops. Since there are 2(k+1) NCs at distance l from the considered source PE of FTH(k, l-1),the sum of their distances from source PE is equal to 2(k+1)l. Excluding these NCs the total number of NCs at $(l-1)^{th}$ level from two source NCs at a distance 2 is equal to $2(k^{th}$ -k-1).Thus the sum of their distances from source PE is equal to $2(k^{th}$ -k-1)(k-1+2)= $2(k^{th}$ -k-1)(k+1).Distances of PEs under (2^k (k-1)) NCs from the source PE[11].

Since there are (2^k -(k+1)) NCs and each NC contain $2^{(l-1)n}$ PEs, The sum of their distances from source PE is equal to (2^k -(k+1)) $2^{(l-1)k}$. Further NCs at a distance one from source NC also contain each $2^{(l-1)k}$ PEs.And distance of a PE from source PE=(l-1+1+l-1)=(2l-1).

IV. IMPLEMENTATION OF FAULT TOLERANT ALGORITHM:

In an FTH(k,l) the DESCEND/ASCEND class of algorithms can be executed in O(log N) parallel steps and the PEs of the EH do not perform data transfer operations of other PEs. The Algorithm can be used to implement DESCEND in the FTH(k, l), where n=k*l. However, as the connectivity of the FTH (k, l) is not equal to log N, the basic operation OPER (m, h;T[m], T[m +2^h) is not as straight forward as it is in the case of a hypercube. In the EH, for 0≤h<k, each pair (T[m], T[m +2^h]) is separated by a single link of the k-cube, whereas for k≤h<n, each pair (T[m],T[m+2^h]) separated by an extended link of the EH(k, l).

The basic operation OPER is performed log N = n times: for an EH(3,2) with 2^6 PEs, OPER is performed six times, i.e. for h - 5 step - 1 until 0.We define OPERS[12] a modification of the basic operation OPER as, OPERS(m,q;H[m],H[m +2^q]), where q = (k*j)+h. OPERS is equivalent To pardo[14] for all pairs separated by 2^q OPER(m,q;T[m],T[m+1])

Algorithm1.1 for fault tolerant hypercube

1.Procedure FTH DESCEND

2. for j =l-1step -1 until j=0

3. for each HC(k,j Dj=$b^j_{k-1}b^j_{k-2}$…….b^j_0

4. for h←k-1 until h=0

5. for each m;0≤m<z; where

$z=2^k-1$

6. if $bit_h(m)=0$ AND j=0

7. then OPERS(m,q;H[m],H[m+2^{q+1}])

8. m=h;

9. else

10. OPER(m,h;T[m],T[m+h])

11. end else;

12. end for;

13. end for;

14. end for;

15. end FTH DESCEND

V.HAMILTONIAN CIRCUIT FOR FAULT TOLERANT NETWORK:

A. For FTH (3, 1)

In this case, we are looking for a Hamiltonian circuit in the FTH (k, l). First, We consider an FTH (k, l) comprising of a k-cube and two NCs, a total of 2^k +2 nodes. The PEs are addressed by the two-digit numbers whereas the NCs are represented by 0 and 0'.In the FTH(3,1) the Hamiltonian path starts at 0, then covers the eight 2^k nodes and then finally ends with 0, if some node fault are there ,then the total network will suffered. But in this FTH(3,1) if some node fault present then the alternate NC is there for communication. Here all the nodes are connected with both 0 and 0'.

The bellow one is the Hamiltonian circuit for FTH (3,1).

$P_0 \rightarrow p_{00} \rightarrow p_{01} \rightarrow p_{03} \rightarrow p_{02} \rightarrow p_{06} \rightarrow p_{04} \rightarrow p_{05} \rightarrow$

$p_{07} \rightarrow p_0$

By the same procedure in FTH (3,1) we can start our processing by One NC and also end with that NC. Also we can say in both the cases we start from $P_0$and end with P_0. And every nodes are reached on Hamiltonian Circuit at least once.

B. For FTH (3, 2)

$P_0 \rightarrow P_{00} \rightarrow P_{000} \rightarrow P_{001} \rightarrow P_{003} \rightarrow P_{002} \rightarrow P_{006} \rightarrow P_{004} \rightarrow P_{005} \rightarrow P_{007} \rightarrow P'_{00} \rightarrow P'_{01} \rightarrow P_{017} \rightarrow P_{015} \rightarrow P_{014} \rightarrow P_{016} \rightarrow P_{012} \rightarrow P_{013} \rightarrow P_{011} \rightarrow P_{010} \rightarrow P_0 \rightarrow P_{03} \rightarrow P_{030} \rightarrow P_{031} \rightarrow P_{033} \rightarrow P_{032} \rightarrow P_{036} \rightarrow P_{034} \rightarrow P_{035} \rightarrow P_{037} \rightarrow P'_{03} \rightarrow P'_{02} \rightarrow P_{027} \rightarrow P_{025} \rightarrow P_{024} \rightarrow P_{026} \rightarrow P_{022} \rightarrow P_{023} \rightarrow P_{021} \rightarrow P_{020} \rightarrow P_{02} \rightarrow P_{06} \rightarrow P_{060} \rightarrow P_{061} \rightarrow P_{063} \rightarrow P_{062} \rightarrow P_{066} \rightarrow P_{064} \rightarrow P_{065} \rightarrow P_{067} \rightarrow P'_{06} \rightarrow P'_{04} \rightarrow P_{040} \rightarrow P_{041} \rightarrow P_{043} \rightarrow P_{04} \rightarrow P_{046} \rightarrow P_{044} \rightarrow P_{045} \rightarrow P_{047} \rightarrow P_{04} \rightarrow P_{05} \rightarrow P_{050} \rightarrow P_{051} \rightarrow P_{053} \rightarrow P_{052} \rightarrow P_{056} \rightarrow P_{054} \rightarrow P_{055} \rightarrow P_{075} \rightarrow P'_{05} \rightarrow P'_{07} \rightarrow P_{070} \rightarrow P_{071} \rightarrow P_{073} \rightarrow P_{072} \rightarrow P_{076} \rightarrow P_{074} \rightarrow P_{075} \rightarrow P_{077} \rightarrow P_{07} \rightarrow P_0$

Also in case of FTH(3,2) the same procedure will follow means the traversing will started from p_0 and end with p_0 .And all other nodes are reaches only once in coverage.

VI.RECONFIGURATION TECHNIQUE AND USE OF SPARSE NODE:

In this section, we discuss use of spare PEs and NCs [8] in the event of node faults. The FTH with spare nodes is called an augmented FTH..

The augmented FTH (3, l) consists of two Additional PEs, that's are , 0X and 0Y Spare node 0X is connected to NC 0 whereas 0Y is connected to NC 0'**.** Spare node 0X and 0Y can be used if any of the PEs of the k-cube is found to be faulty. For example, if node 0Z of the k-cube is faulty then all tasks originally meant for 0Z can be assigned to 0Y after isolating 0Z**.** The direct links of the faulty node 0Z are replaced by the extended links via 0'.

Similarly, each k-cube can tolerate one more processor fault as spare node 0X can take over. This scheme is illustrated in fig. spare PEs for every FTH (k, l) can be extended to an FTH (k, l). The method suggested above is cost-effective as the degree of connectivity of PEs is not altered while the degree of connectivity of the FTH (k, l) is increased by one. Further, as we have two NCs for every k-cube of nodes (PEs as well as NCs), the system can tolerate h e NC fault per k-cube. In general, a node at level j is connected to two nodes at level j + 1.

In effect there are (k + 2) parallel paths for intra module communication and two parallel paths for inter module communication.

VII. CONCLUSION

The proposed network "Fault tolerant hierarchical interconnection network for parallel computer" is a new interconnection network with highly fault tolerant nature. This network overcomes the poor fault tolerant nature of extended hypercube. It's having a hierarchical recursive structure with various robust properties. From the proposed network the Hamiltonian Circuit [1] of FTH (3,2) and also FTH (3,1) are also find out. Also we proposed an fault tolerant broadcasting algorithm to overcome node fault.

VIII. FUTURE WORK

We aim to cluster all the same nodes (all 64 PEs) and 2 NC of the proposed network in two different group using CHAMELEON the multiphase hierarchical clustering algorithm and also think to implement the broadcasting algorithm using neural network.

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