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Analysis of Fault Tolerance in Hypercube

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Abstract:- Multiprocessor systems which afford a high degree of parallelism are used in variety of applications. The extremely stringent reliability requirement has made the provision of fault-tolerance an important aspect in the design of such systems. This paper presents a new technique called wormhole technique to route the message for multiprocessor systems. It emphasizes the concept of fault tolerance in n-dimensional hypercube. Worn hole switching technique is considered for forwarding the data from source to destination, faulty nodes are detected and the path of transfer of packets from source to destination is rerouted.

Keywords: Fault tolerance, wormhole switching, hyper cube, shortest path algorithm

I. INTRODUCTION

A variety of routing algorithms have been proposed for Hypercube systems in the past[1], [2], [3]. However, most of these algorithms are not suitable for routing messages when nodes fail in hypercube. There has also been a number of fault-tolerant routing strategies proposed in previous research [4],[5],[6],[7],[8],[9].Gorden and Stout[6] proposed an approach called "sidetracking" to route messages in hypercube with faulty nodes. A message is derouted to a randomly chosen fault-free neighbouring node when there exists no link available for advancing the message. However, routing failures may occur although such probability is low and excessive message delay may rise. Chen and Shin[5] developed and analyzed a routing scheme based on depth-first search in which back tracking is required when all forward links are blocked by faulty components. In this method, the time overhead required is relatively excessive when the number of faults is small. To avoid routing to the same node, every message must carry information indicating the dimensions already traversed. A simplified version of the method that tolerates fewer faults was presented in [4].

The issue of deadlock freeness is not specifically considered in the above schemes. Lee and Hayes[7] proposed a different fault tolerant routing strategy which is based on the concept of Unsafe nodes. In this method, each node only has to keep simple information about the state of its neighbours. This method lead to communication difficulties, excessive delays, the time delay incurred at each node is small. This showed that a message can be routed via a path of length no greater than two plus the Hamming distance between source and destination of the message. As long as the Hypercube is not fully unsafe, which is guaranteed that the number of faults is no more than Γ n/2 □ in n-cube. In [8], concept of safety level, which is enhancement of safe node is implemented for reliable broad casting in hyper cubes. Extensive survey of routing algorithms for hypercube systems can be found in [10],[11]. Many fault tolerant routing algorithms like wormhole routing which achieve deadlock freeness for Hypercubes were proposed in the past.

In this paper, a similar approach is used. We propose wormhole routing techniques and apply to Multiprocessor Interconnection Networks (MIN'S) like Hypercube and study how the fault tolerance is achieved in the network.

II. ASSUMPTIONS

A. *Assumptions:*

a. The nodes are imperfect whereas the links are perfect.
b. The nodes failure is statistically independent of each other.
c. Initially the distance between each node is same.

III. ARCHITECTURE DESCRIPTION

A. *Hypercube:*

Hypercubes are loosely coupled parallel processors based on the binary n-cube network and introduced under different names like binary cubes, cosmic cubes etc. An n-cube parallel processor consists of 2^n processors, each provided with its own sizable memory and interconnected with n neighbours.

An *n*-dimensional hypercube(so called *binary n-cube)* can be modelled as a graph H_n with the node set V_n and edge set E_n, where $| V_n | = 2^n$ and $| E_n | = n*2^{n-1}$. The 2^n nodes are distinctly addressed by *n*-bit binary numbers, with values from 0 to 2^n -1. Each node has link at *n* dimensions, ranging from 1(lowest dimension) to *n* (highest dimension), connecting each node to *n* neighbouring nodes. N edge connecting nodes $X=x_n x_{n-1}\ldots x_1$ and $Y=y_n y_{n-1}\ldots y_1$ is said to be at dimension *j* (or to be the *j* th-dimensional edge) if their binary addresses $x_n x_{n-1}\ldots x_1$ and $y_n y_{n-1}\ldots y_1$ differ at bit position *j* only, i.e. $x_j \neq y_j$. An edge in H_n can also be represented by *n*-character string with one hyphen (-) and n-1 binary symbols {0,1}. For example in a H_4, the string 00-1 denotes the edge at dimension 2, connecting nodes 0001 and 0011.

So, in an n-dimensional Hypercube(Q_n) the edge connectivity can be given as follows.

*Definition 1:*In Q_n, two vertices u and v are adjacent if the hamming distance between them is 1.

$$(u,v)€ Q_n \text{ if } H(u,v)=1$$

Figure 1 shows a hypercube of dimension 3.

Any multiprocessor system would allow for its processors to exchange data between all of its nodes. The data is transferred between the processors along a path consisting of possibly small number of nodes. In hypercube, the minimum distance between a pair of vertices (u,v) is equal to the number of bits in which they differ, which is their hamming distance.

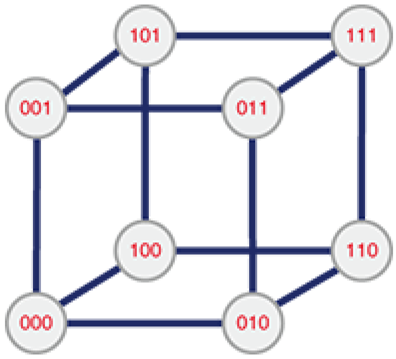

Figure 1.Hypercube (n=3)

IV. FAULT TOLERANT ROUTING STRATEGY

A. Wormhole switching:

It avoids the need for large buffer space. In wormhole switching, a packet is transmitted between the nodes in units of flits, the smallest unit of a message. The header of the message contains all the necessary routing information and all the other flits contain the data elements. The flits are transmitted through the network in a pipelined fashion. All the trailing flits follow the header flits.

Let the time taken for a packet to get delivered from source to destination be ‘t’ seconds.

If there is faulty node at distance ‘one’ in the established path, the time taken to send packet from source to destination is

t+X+dt (1)

d is the distance from neighbouring node of faulty node to destination.

X is the time taken to identify faulty node and to reach neighbouring node.

If the faulty node is at distance ‘two’ from source node, the time taken to send message from source to destination is

2t+X+dt (2)

If the faulty node is at distance ‘n’ from source node, the time taken to send message from source to destination is

nt+X+dt (3)

To route a packet from source to destination, initially virtual circuit path has to be established using shortest path algorithm. Now, in the established path, if any faulty node occurs, then the packet will be sent to the neighbouring node and virtual circuit has to be re-established from neighbouring node of faulty node to destination.

V. RESULTS AND DISCUSSIONS

The proposed approach has been applied to evaluate the fault tolerance of various dimensional Hypercube for the purpose of comparison. Results for various node failures located at different distances have been computed and plotted in Figs. From the plotted graphs, it can be observed that in case of HC, as the distance of the faulty node increases from source, the time taken for a packet to reach destination increases.

Figure 2.1 shows the comparison between the failure nodes and time when n=1.

Figure 2.2 shows the comparison between the failure nodes and tie when n=2.

Figure 2.3 shows the comparison between the failure nodes and time when n=3.

Figure 2.4 shows the comparison between the failure nodes and time when n=4.

Figure 3 shows the comparison between n and d when n,d varies from 1 to 4.

Table I Comparison between nodes and distance

	d=1	d=2	d=3	d=4
n=1	10.8	15.8	20.8	25.8
n=2	15.8	20.8	25.8	30.8
n=3	20.8	25.8	30.8	35.8
n=4	25.8	30.8	35.8	40.8

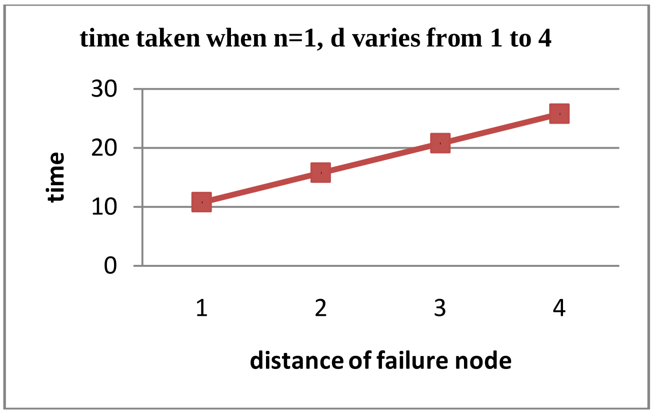

Figure 2.1: Time taken when n=1, d varies from 1 to 4

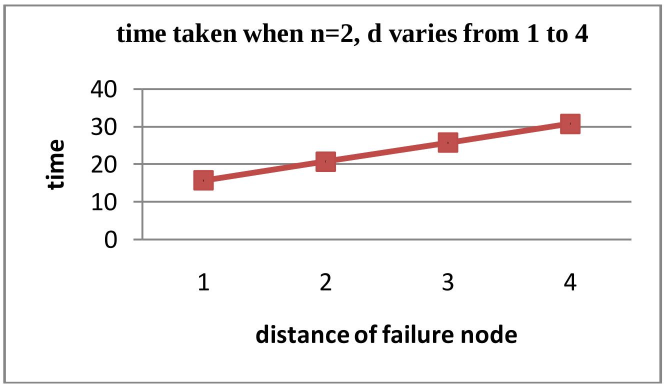

Figure 2.2: Time taken when n=2, d varies from 1 to 4

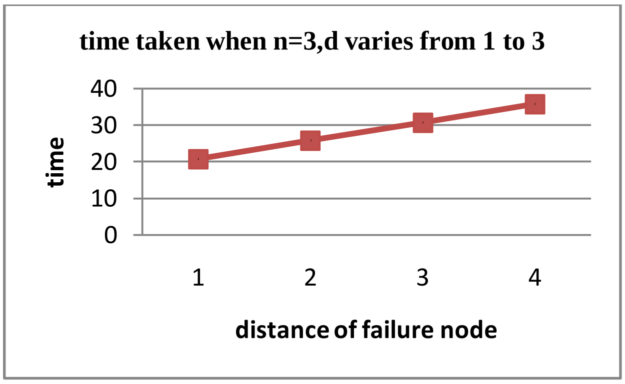

Figure 2.3: Time taken when n=3, d varies from 1 to 3

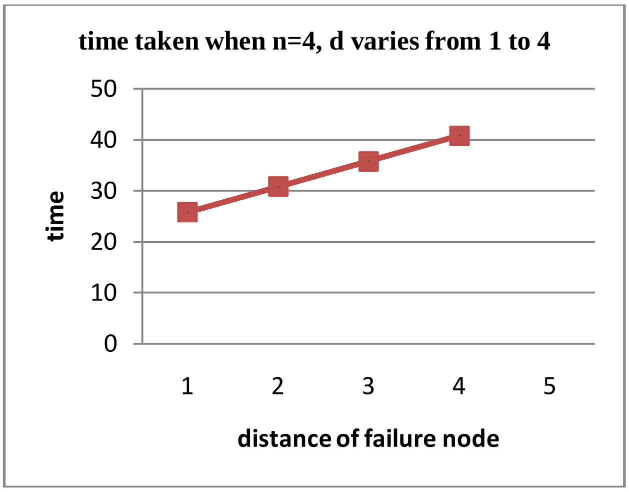

Figure 2.4: Time taken when n=4, d varies from 1 to 4

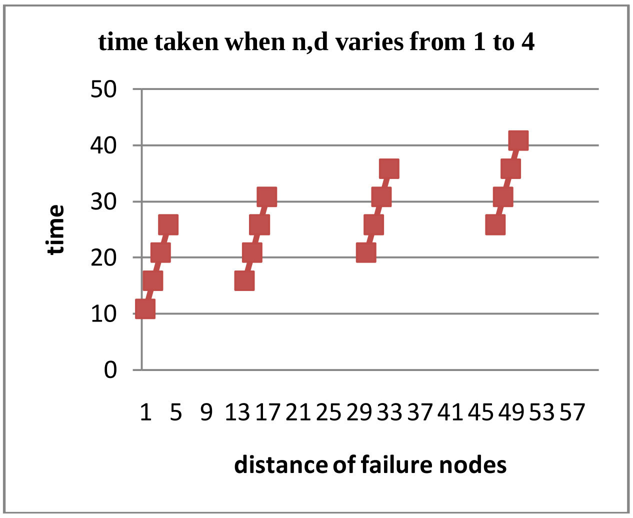

Figure 3: Time taken when n,d varies from 1 to 4

VI. CONCLUSION

In this paper, the fault tolerance of various dimensional Hypercube are compared and the results for various node failures located at different distances have been computed and plotted. It has been observed that as the distance of the faulty node increases from source, the time taken for a packet to reach destination increases.

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