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Fault Tolerance in Torus-Butterfly Interconnection Network

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***Abstract*—Topology interconnection network Torus - Butterfly is a new Cartesian product interconnection network. It is cartesian product of Torus and Enhanced-Butterfly interconnection network. This topology has the properties of constant degree, small diameter and a smaller network cost. This paper discuss fault tolerance in the Torus-Butterfly interconnection network. The fault tolerance parameter is also one of the important parameters that need to be evaluated to determine the effetiveness of interconnection networks.**

Keywords*— *Torus-Butterfly, degree, diameter, network cost, fault tolerance

I. Introduction

Model (topology) of interconnection networks is an important part for parallel processing or distributed system [1]. Zhang [2] states that a good model of the interconnection network must have the symmetry properties, measured (scalable), has a small diameter, and also has a constant and a limited degree [3, 4]. In practice it is more desirable that the network model has a high connectivity and a smaller diameter. Connectedness is widely used to measure the fault-tolerance capacity of the network [5]. this paper, discuss the fault tolerance in this Torus-Butterfly interconnection network.

II. Definition and Notation

This part gives definition and notation use in this paper

Definition 1: A graph G = (V, E) is called connected if for any two nodes of a graph G there is always the path that connects the second node [6].

Definition 2: The degree of a node $x \in V_G$, denoted by deg (x), is connected arc from x to nodes $y \in V_G$, $y \neq x$ [7].

Definition 3: The diameter of the connected graph G (V_G, E_G) is the maximum distance of all pairs of vertices [8].

Definition 4: Fault tolerance vertices of a graph is not directed connectivity measured by the vertices of the graph. A graph G is said to have a connection node, if the graph G remains connected when there is a node failure (faulty).In other words if there are as many different paths between any two nodes.

The existence of different pathways (parallel) between pairs of nodes is also one of the important things in interconnection networks. In this connection it is clear that the vertices of a graph G can not exceed the maximum degree of vertices in G. A graph is said to maximally fault tolerant if connectedness concluded with the degree of vertices of the graph.

Definition 5: If G = (V_1, E_1) is the Torus interconnection network model of size *ml* and H = (V_2, E_2) is the Enhanced Butterfly interconnection network model dimension n, then the Torus-Butterfly interconnection network model, denoted as TB (m, l , n), is the Cartesian product of Torus and Enhanced Butterfly, with m and l is the size of Torus interconnection network model and n is the dimension of the Enhanced Butterfly interconnection network model. This is true for $n \geq 3$, $m \geq 2$ and $l \geq 2$ [9]

Lemma 1: The degree of each node in the Torus -Butterfly interconnection network model is 9 [9].

Lemma 2: The diameter of the interconnection network Torus-Butterfly TB (m, l, n) is $= \max \{ \lfloor m/2 \rfloor, \lfloor l/2 \rfloor \} + n$ [9].

From the above degree and diameter of Torus-Butterfly interconnections network formula, the following network cost: of Torus-Butterfly interconnection network model is
$9 (\max \{\lfloor m/2 \rfloor, \lfloor l/2 \rfloor\} + n)$ [9].

Table 1, 2 and 3 give the comparion of degree, diameter and network cost of three models of interconnection networks, that is Hyper-Butterfly (HB), Torus Embedded Hypercube (TH) and Torus-Butterfly (TB).

Table 1. Degree comparison of three models of interconnection network

Network Type No. of processor	HB (*k, n*)	TH(*16,16,k*)	TB(*m,l,n*)
512	7*	5**	9***
1024	8*	6**	9***
2048	9*	7**	9***
4096	10*	8**	9***
8192	11*	9**	9***
16384	12*	10**	9***

32768	**13**	**11**	**9*** **

Source : * : [10], **: [11], ***: [9]

Table 2. Diameter comparison of three models of interconnection network

Network Type No. of processor	**HB (*k, n*)**	**TH(*16,16,k*)**	**TB(*m,l,n*)**
512	7*	17**	5***
1024	8*	18**	6***
2048	9*	19**	8***
4096	10*	20**	8***
8192	11*	21**	12***
16384	12*	22**	12***
32768	15	23	20***

Source : * : [10], **: [11], ***: [9]

Table 3.Network cost comparison of three models of interconnection network

Network Type No. of processor	**HB (*k, n*)**	**TH(*16,16,k*)**	**TB(*m,l,n*)**
512	49*	136**	45***
1024	64*	144**	54***
2048	81*	152**	72***
4096	100*	160**	72***
8192	121*	168**	108***
16384	144*	176**	108***
32768	195	184	180***

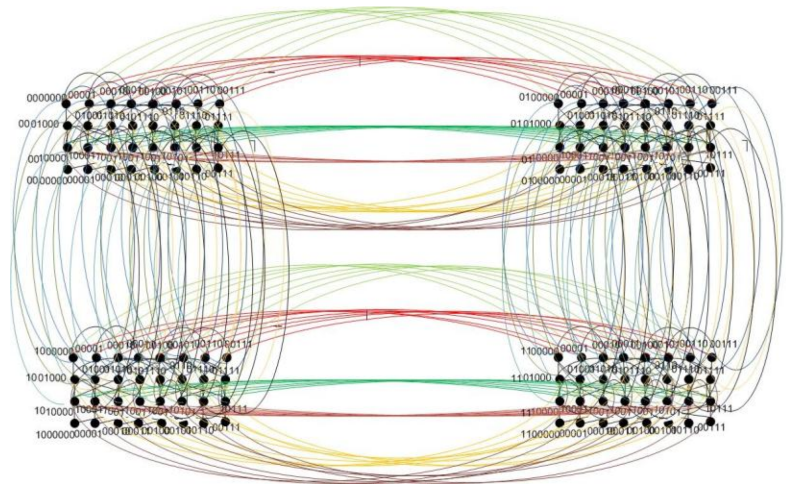

Figure 1: Torus-Butterfly Interconnection Network TB(2, 2, 3) [12].

From figure 1, nodes in the torus-Buttefly interconnection network can be represented as binary digit. For example nodes 0000000, 010000, 0101001 etc.

III. Results and Discussions

The results of this discussion is determination of the parameters of Fault Tolerance in Torus-Butterfly interconnection network topology.

Lemma : Among the two nodes TB there are 9 different node Paths.

As an illustration, 9 different node path will be obtained. Suppose from node to node 0001001 0000000 there will be nine different paths, namely:

1. 0000000→0001001
2. 0000000→0100000→0100001→0001001
3. 0000000→0010100→0001100→0001001
4. 0000000→1000000→1010001→1001001→0001001
5. 0000000→0100000→0101001→0100001→0000001→0001001
6. 0000000→1100000→1000000→1000010→0000001→0001001
7. 0000000→0001000→0010000→0010001→0001001

8. 0000000→0100000→0100010→0000001→0001001

9. 0000000→0000010→0001010→0010000→0010001→000 1001

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IV. Conclusion and Future Work

In Torus-Buttrfly interconnection network topology, there are 9 different node paths. So its have 9 possibility to send message along this 9 path. It means when we have faulty on 1 path to send messange, we still have 8 paths possibility to send message along this 8 paths. So also if still 2 path faulty to send messages, still have 7 paths possiblity to send messages along this 7 paths.

For future work it can be evaluated the optimal routing from source to destination node .

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