ON A CLASS OF MULTISTAGE INTERCONNECTION NETWORK IN PARALLEL PROCESSING

[£]SANDEEP SHARMA, [β]DR. P.K.BANSAL and [£]DR. KARANJIT SINGH KAHLON

[£]Guru Nanak Dev University Amritsar, [β]MIMIT ,Malout PUNJAB,INDIA

Abstract:
Parallel processing is an efficient form of information processing system, which emphasizes the exploitation of concurrent events in the computing process. To achieve parallel processing it's required to develop more capable and cost-effective systems. In order to operate more efficiently a network is required to provide low latency and be able to handle large amount of traffic. Multistage Interconnection Network [1] plays a vital role on the performance of these multiprocessor systems. This paper introduces an irregular class of fault tolerant Multistage Interconnection Network (MINs) named as New Four Tree (NFT) Network. A NFT network can provide a "full access" capacity in presence of multiple faults. Performance measures show that NFT achieve a significant improvement over other popular existing irregular MINs like FT [7] [20], QT [19] and MFT [20].

Keywords:
Interconnection networks; A New Fault Tolerant multistage ; Four Tree Network; Multistage Interconnection Network; Dynamic MINs; Modified Four Tree Network; permutation passable.

1. Introduction

Today is the era of parallel processing and building of multiprocessor system with hundred processors is feasible. A vital component of these systems is the Interconnection Network (IN) that enables the processor to communicate themselves or with memory units. Multistage Interconnection Network is a low cost network, which interconnects N inputs with N outputs and has $\log_2 N$ switching stages. Each stage consists of 2x2 switching elements with or without loop depends upon the regular or irregular class of network. MIN's have been extensively used in the design of parallel and distributed systems [3].

In this paper we propose a new irregular fault tolerant multi-stage interconnection network. The paper is organized as follows: Section 2 describes the construction procedure of NFT network. Section 3 describer the analysis of permutation passable of existing and proposed networks. Section 4 discusses the path length of both new as well as existing networks. Fault tolerance aspects are discussed in section 5. The cost effectiveness of NFT network is analyzed in section 6. Finally conclusions are given in Section 7.

2. Construction of NFT Network

A New Four Tree (NFT) network of size NxN has 2 $\log_2 N/2 - 1$ stages. Both stage i and stage (2n-3) have exactly 2^{n-i} switches where i=1 and n=4. The stage i and 2n-4 have exactly 2^{n-3} switches where i=2. The middle stage has 2^{n-2} switches. A NFT network being an irregular network supports multiple paths of different path lengths. Every 3x3 SE in a stage forms a loop with the corresponding numbered 3x3 SE of other sub-network in the same stage. Every source and destination is connected to both the subgroups by means of multiplexers and demultiplexers. The advantage of this network is that if both switches in a loop are simultaneously faulty then even some sources are connected to the destinations. NFT network is not only the cost effective in comparison to existing FT ,QT and MFT networks but the performance measure in terms of permutation and path length are also better. NFT network of size 16x16 is illustrated in Fig (1).

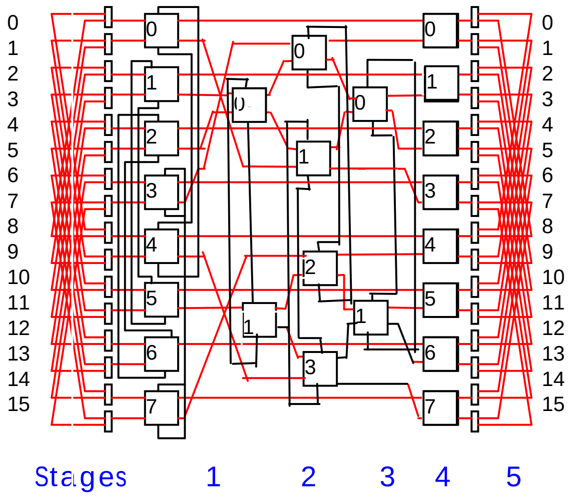

Fig.1. New four Tree Multistage Interconnection Network of Size N=16

Manuscript received May 5, 2008
Manuscript revised May 20, 2008

3. Permutation Passable

A one to one correspondence between source to destination is called Permutation [19][11]. The request always passes from the most suitable path available. If such path is busy then the request is passed through an alternate path. If no alternate path is available then the request has to be simply dropped or said to have clashed. One of the major aspects of permutation parameter is that it varies with path length.
To find out this parameter for a network, it is assumed that source and destination is represented by:

$$\begin{cases} S_i \ (\text{ where } i = 0,1,\ldots\ldots N-1) \\ D_i \ \ \text{where } i = 0,1,\ldots\ldots N-1) \end{cases}$$

Permutation can be evaluated in two ways:

3.1 Identity Permutations

A one-to-one correspondence between same source and destination number is called Identity Permutation. In terms of source and destination this can be expressed by:

$(S_0 \to D_0), (S_1 \to D_1) \ldots\ldots\ldots\ldots (S_{n-1} \to D_{n-1})$

3.2 Incremental Permutations

Incremental means that each source is connected to destination in a circular chain is represented as:

$(S_0 \to D_4), (S_1 \to D_5) \ldots\ldots\ldots\ldots (S_{n-1} \to D_3)$

For Example:

Source (0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15)
Destination (4 5 6 7 8 9 10 11 12 13 14 15 0 1 2 3)

There are two cases to find out the permutations
(i) Non Critical Case: if a fault is present in a single switch
(ii) Critical Case: If the switches are faulty in a loop
Probability of issuing a request is 1.0.

3.3 Permutation Analysis of NFT, QT, FT and MFT Networks

The identical permutations of all the networks are almost same, but there is lot of variations in incremental permutations. The results are shown as:

Fault		Total path length	Total no of request passes	Average path length	% Passable of requests
WITHOUT		32	8	4	50
MUX		32	8	4	50
S0	A*	32	8	4	50
S0	B*	16	4	4	25
S1	A*	24	6	4	37
S1	B*	16	4	4	25
S2	A*	24	6	4	37
S2	B*	16	4	4	25
S3	A *	32	8	4	50
S3	B *	16	4	4	25
S4		32	8	4	50
DEMUX		32	8	4	50

Table 1. Incremental permutation measures of NFT

*A – Non critical Case *B – Critical Case

Fault		Total path length	Total no of request passes	Average path length	% Passable of requests
WITHOUT		40	8	5	50
MUX		40	8	5	50
S1	A*	35	7	5	43
S1	B*	30	6	5	37
S2	A*	30	6	5	37
S2	B*	20	4	5	25
S3	A*	30	6	5	37
S3	B*	20	4	5	25
S4	A *	30	6	5	37
S4	B *	20	4	5	25
S5		35	7	5	43
DEMUX		40	8	5	50

Table 2. Incremental permutation measures of FT & QT Networks (all cases)

Fault	Total path length	Total no of request passes	Average Path Length	% Passable of requests
WITHOUT	20	4	5	25
MUX	20	4	5	25
S1 A*	20	4	5	25
S1 B*	20	4	5	25
S2 A	15	3	5	18
S2 B	10	2	5	12
S3 A	10	2	5	12
S3 B	**0**	**0**	**0**	**0**
S4 A	15	3	5	18
S4 B	10	2	5	12
S5	20	4	5	25
DEMUX	20	4	5	25

Table 3. Incremental permutation measures of MFT

It has been analyzed from tables 1, 2 & 3 that incremental permutation passable of NFT is better than existing FT, QT and MFT in terms of path length and no of successful passes of requests.

4. Path Length

For a given source to destination pair, there are multiple paths of different path length in a network exists. The algorithm for the allocation of path length [7] gives the information about different possible paths between source –destination pair.

Let the source S and destination D be represented in binary code as

$S = S_{n-1} \ldots\ldots\ldots S_1 . S_0$
$D = D_{n-1} \ldots\ldots\ldots D_1 . D_0$

4.1 Path length algorithm:

If $[(S_{n-2} \Theta D_{n-2}) + (S_{n-3} \Theta D_{n-3}) + \ldots (S_1 + D_1)]$ is Zero
('Θ' represents an exclusive –or and '+' represents an OR operation)

then
minimum path length is 2 and all paths of different lengths are possible i.e 4,6,. (2x-2), (2x-1).

Else
If $[(S_{n-2} \Theta D_{n-2}) + (S_{n-3} \Theta D_{n-3}) + \ldots (S_2 \Theta D_2)]$ is zero then
all paths of length equal or greater than 4 are possible
else
:
:
if
If $[(S_{n-2} \Theta D_{n-2}) + (S_{n-3} \Theta D_{n-3}) + \ldots (S_p \Theta D_p)]$ is zero

{where 1<=p<=(n-2)}

then
all paths of length equal to or greater than 2p are possible

else
path of length 2x-1 (i.e longest path) is possible only.

Network	Average Path Length without and with single switch Fault
FT	Log_2N+1
QT	Log_2N+1
MFT	Log_2N+1
NFT	Log_2N

Table 4. Path length comparison

5. Fault Tolerance

Fault tolerance is the ability of an interconnection network to continue operating in the presence of single or multiple faults. The comparison of Permutation clearly indicates that NFT can work in critical condition, whereas previous networks like FT and QT are single switch fault tolerant. The capability of NFT is better in comparison to MFT because of its path length.

6. Cost - effectiveness

To estimate the cost of network, one common method is to calculate the switch complexity with the assumption that the cost of a switch is proportional to the number of gates involved, which is roughly proportional to the number of 'cross points' within a switch [10][7]. For example 2x2 switches has 4 units of hardware cost whereas 4x4 has 16 units. For multiplexers and demultiplexers, we roughly assume that each of K: 1 or 1: K demultiplexers have k units of cost. In this way the following MINs are compared:

Network	Cost
FT	$9.75\ 2^{n+1}$-54
QT	$9.75\ 2^{n+1}$-54
MFT	$9.75\ 2^{n+1}$-36
NFT	$9.75\ 2^{n+1}$-72

Table 5. Comparison of cost-effectiveness

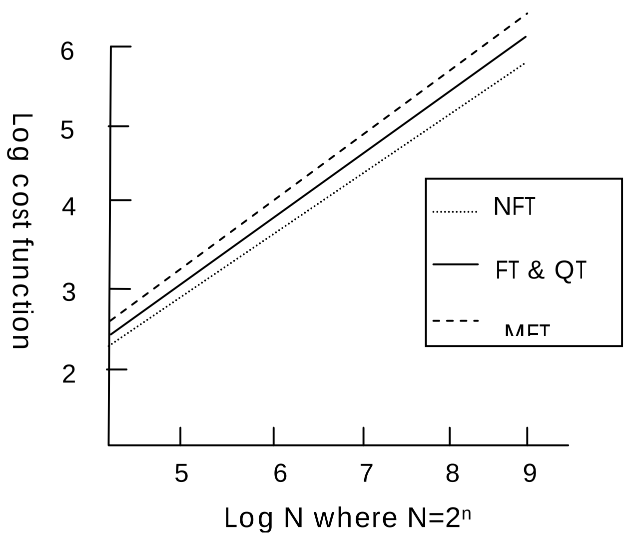

Fig.2. Log Cost function versus log N

Figure 2 shows the variation of cost function with the size of networks. From the graph and table 8 it is clear that NFT network is more cost effective than other fault tolerant irregular networks and that the advantage becomes more significant as the network grows.

7. Conclusion

In this paper a new irregular fault tolerant Multistage Interconnection Network called NFT has been proposed and analyzed. Multiple pats are guaranteed in NFT MIN. NFT shows better performance in terms of permutation passes than existing irregular FT, QT and MFT Networks. It has also been observed from tables 4 & 5 that the new proposed network NFT has lesser cost and has better average path length in comparison to existing networks.

References

[1] G.B. III Adams, D.P. Aggarwal, H.J Siegel, "A survey and comparison of fault-tolerant multistage interconnection network", IEEE Computers, pp. 14-27,June 1997.

[2] Y.Yang,J.Wang , Y.Pan , " Permutation capability of optical multistage interconnection network ", Journal of parallel and Distributed computing , pp.60,2000.

[3] K.V Arya, R.K.Gosh. "Designing a new class of fault tolerant Multistage Interconnection Networks" Journal of Interconnection Network vol 6, No. 4 (2005) pp.361-382.

[4] Shen, J.P., 1982, "Fault tolerance analysis of several interconnection networks "Proceedings of International conference on Parallel Processing ", pp.102-112.

[5] P.K.Bansal, K. Singh, R.C. Joshi, and G.P. Siroha, "Fault tolerant double tree network", Proceedings of International Conference IEEE INFOCOM, pp. 462-468 , April 1991.

[6] P.K.Bansal, K. Singh, R.C. Joshi, and G.P. Siroha, "Fault tolerant Augmented Base Line Multistage Interconnection Networks", IEEE TENCON, pp. 205-208, 1991.

[7] P.K.Bansal, K. Singh, and R.C. Joshi, "Routing and path length algorithm for a cost-effective four-tree multistage interconnection network", International Journal of Electronics, Vol. 73, pp. 107-115,1992.

[8] R.Potapalli Yashovardhan, P. Aggarwal Dharma, "On the design of efficient Multistage Interconnection Network", IEEE Trans. computers, 1996.

[9] Bhuyan Laxmi N., Qing Yang, Agrawal Dharma P., "Performance of Multiprocessor Interconnection Networks", IEEE Trans. Computer, Vol. 22, pp. 25-37, Feb 1989.

[10] Patel, J.H., "Performance of processor-memory interconnection for multiprocessors." IEEE Transaction on computers, 30,pp. 771-780,1981.

[11] M. Cutler, Y. Shiloach, "Permutation Layout", IEEE on Networks, Vol. 8, pp. 253-278,1978.

[12] K. Hwang, F.A. Brigges, “Computer Architecture and Parallel Processing”, McGraw Hill, Computer Organization and Architecture, 1984.
[13] Shirakawa Isao, “Some comments on Permutation Layout”, IEEE on Networks, Vol. 10, pp. 179-182,1980.
[14] C.P. Kruskal, M. Snir, “Performance of Multistage Interconnection networks for multiprocessors”, IEEE Transactions on Computers, Vol. C-32, pp. 1091-1098, Dec. 1983.
[15] J.H. Patel, “Processor – Memory Interconnections for multiprocessors”, IEEE Computers, pp. 168-177,1979.
[16] A.K. Somani, N.H. Vaidya, “Understanding Fault-Tolerance and Reliability’’, Computer, Vol.30, No.4, April 1997.
[17] K.S. Trivedi, J.T. Blake, “ Multistage Interconnection Reliability” IEEE Trans. Computers, vol 38, no. 11, pp 1,600 – 1,604. Nov. 1989.
[18] P.K.Bansal, Kuldip Singh and R.C. Joshi, “Routing and Path Length algorithm for a cost- effective four-tree multistage interconnection network ”, International. J.Electronics, Vol. 73,No.1, pp 107-115,1992.
[19] J.Sengupta, P.K.Bansal “Performance of regular and irregular dynamic MINs”IEEE TENCON 99 vol 1, pp 427-430,1999.
[20] Sandeep Sharma, P.K.Bansal, “A new fault tolerant Multistage Interconnection Network ”, IEEE TENCON’02 , vol 1, pp 347-350,2002.

Vitae

Sandeep Sharma received his M.E. degree in Computer Science from TIET,INDIA in 2000 and his B.E in Computer Engineering from Pune University, INDIA in 1994. His area of interest is parallel processing, Multistage Interconnection Network, fault tolerance and load balancing algorithms).He has two journal papers to his credit. He is the member of IEEE forum committee.

Prof. P.K.Bansal received his PhD and M.E in Electronics from the IIT Roorkee, INDIA. He is working as principal in an engineering institute MIMIT Malout, INDIA. His area of interest is parallel and distributed computing. He has many research papers on his name. He is life time member of Computer Society of India.

Prof. Karanjeet Singh Kahlon received his PhD degree from the Guru Nanak Dev University Amritsar, INDIA. He is working as professor in the faculty of computer Science and engineering. His area of interest is parallel and distributed computing using Java. He has ten journal papers to his credit. He is member of International Association of Engineers, Singapore.