On Permutation Capabilities of Fault Tolerant Multistage Interconnection Networks

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Abstract

In this paper permutation capabilities analysis of fault tolerant [1] Multistage Interconnection Networks have been presented. I have examined some popular FT(Four Tree)[8], MFT(Modified Four Tree)[2], PHI(Phi Network)[11], NFT(New Four Tree)[4], IFT(improved Four Tree)[5], IASN(Irregular Augmented Shuffle)[14] and IIASN(Improved Irregular Augmented Shuffle)[3] networks which are irregular in nature[11].Permutation capabilities are measured in terms of incremental and identical basis by introducing various faults at the different stages of the networks.

Keywords: *Multistage Interconnection Network, Permutation, IIASN, Four Tree Network, NFT, THN, IFT*
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1. Introduction

Research on Interconnection Networks is a broad field, where most results have been achieved for a multitude of regular networks, particularly in multiprocessor systems. A large number of regular interconnection networks models have been proposed in the last twenty years for large scale parallel processing system. With the introduction of interconnection networks into system area networks such as clusters of workstations, research on irregular networks became a point of interest. One of the most irregular networks is the Internet. When the numbers of switches at different stages in a network are not alike then such networks are called Irregular Networks. The wiring flexibility of irregular networks is promising, any number of routing nodes can be inserted into the network, and the system manager does not need bother about the maintenance of the regular structure. The limitation of regular network is to provide equal number of switches if one has to insert a new stage which is a very costlier process. Furthermore, methods for irregular networks are also applicable to regular networks, allowing usage of the same method in any interconnection network topology. In the past years, several irregular class of multistage interconnection networks have been proposed on behalf of static routing and dynamic routing. The main purpose of this paper is to conduct the survey of some popular multipath irregular fault tolerant networks which are constructed by using express links. Performance analysis in term of permutation passable of a network is carried out in this paper.

The rest of the paper organized as follows. Section 2 discusses about permutation passable. Section 3 discusses the identical permutation passable of considered MINs. Section 4 discuses the Incremental Permutation passable of considered MINs. Finally conclusions are given in Section 5.

2. Permutation

A one to one correspondence between source to destination is called Permutation [2][9][13] [15][16]. 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 or blocked. One of the major aspects of permutation parameter is that it varies with path length.

To find out this parameter for an Interconnection Network, it is assumed that source and destination is represented by:

$$S= s_{i-1,}\ldots\ldots\ldots\ldots\ldots, s_{1,} s_0$$

$$D= d_{i-1,}\ldots\ldots\ldots\ldots\ldots, d_{1,} d_0$$

The methods which are considered in this paper to evaluate the permutation are:

- Identical Permutation
- Incremental Permutation

2.1 Identical Permutation

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

$(S_0 \text{->} D_0), (S_1 \text{->} D_1) \ldots\ldots\ldots\ldots (S_{n-1} \text{->} D_{n-1})$ for NxN Network where $N=2^n$.

For Example:

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

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

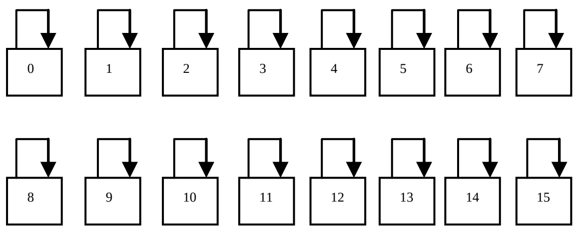


Fig. 1 Identical permutation pairs

2.2 Incremental Permutation

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

$(S_0 \text{->} D_{n-12}), (S_1 \text{->} D_{n-11}) \ldots\ldots\ldots\ldots (S_{n-1} \text{->} D_{n-13})$

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)

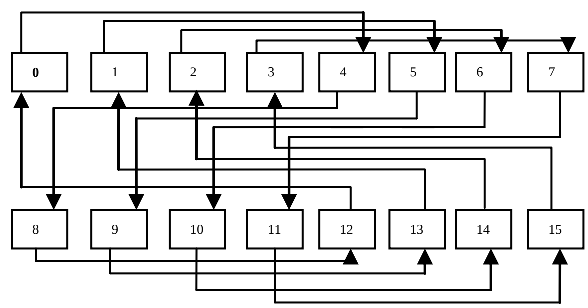


Fig. 2 Incremental permutation pairs

The physical connections in figure 1 and 2 are based on when a group of sources $(s_{0,}\, s_1.., s_{n-1})$ wants to communicate with its destinations $(d_0, d_1, \ldots. d_{n-1})$ simultaneously.

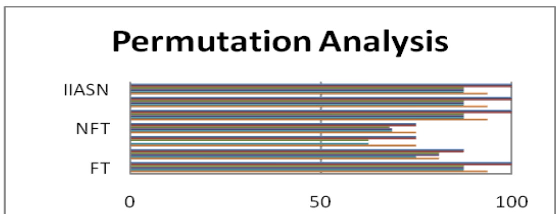
Two cases have been considered in this paper to find out identical and incremental permutations.

- Non Critical Case: If a single switch fault occur
- Critical Case: If a fault occurs in a conjugate loop

3. Identical Permutation Analysis

To evaluate the results of identical permutations, we have considered two cases non-critical (single switch failure) and critical (two switches failure in a loop) as discussed earlier. The identical permutation results are evaluated in both critical and non critical case by checking the following conditions:

- Without fault
- Multiplexer failure
- Switch failure at stage 1
- Switch failure at middle stage
- Switch failure at last stage
- Demultiplexer failure



	FT	MFT	PHI	NFT	IFT	IASN	IIASN
without	100	87.5	75	75	100	100	100
mux	100	87.5	75	75	100	100	100
first	87.5	81	62.5	68	87.5	87.5	87.5
middle	87.5	81		68.7	87.5	87.5	87.5
last	87.5	75	62.5	68.7	87.5	87.5	87.5
demux	93.75	81	75	75	93.75	93.75	93.75

Fig. 3 Identical Permutations Passable Analysis with and without Fault at Various Stages in Non Critical Condition

The results of degradation of request passing in a Network in the presence and absence of fault are as shown in figure 3. The above results show that almost all the Networks produced the same results when a single switch fault occur at first , middle and last stages. PHI Network does not contain any middle stage (empty in fig. 3) and the rest of its stages are compared with other Networks stages. The switches of first and last stages are directly attached with MUX and DEMUX to bypass the request if any clash or fault occurs, but it is shown from above graph that almost all the Networks blocked the request if such kind of fault occurs.

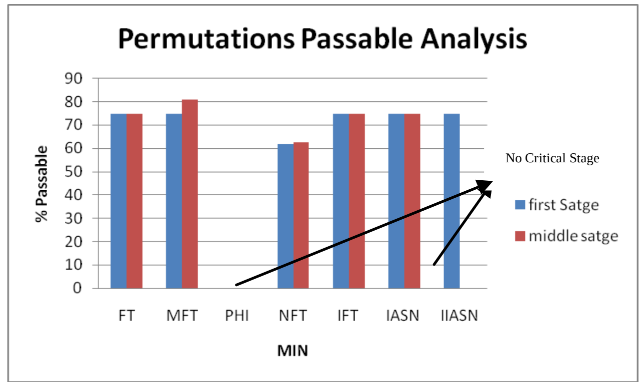
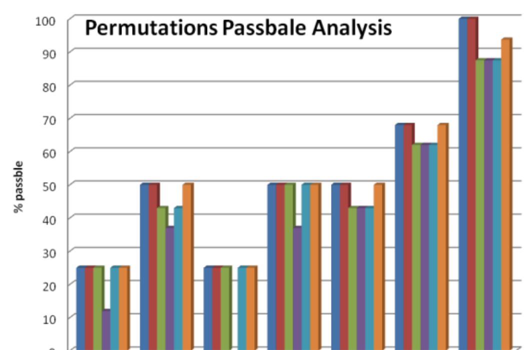


Fig. 4 Identical Permutations Passable Analysis at Various Stages in Critical Condition

The figure 4 shows that request pass percentage of critical case is lesser in comparison to non critical case. The Network like PHN does not have any express link in the first stage and also does not have any central stage. Similarly no express links have been used in central stage of IIASN Network.

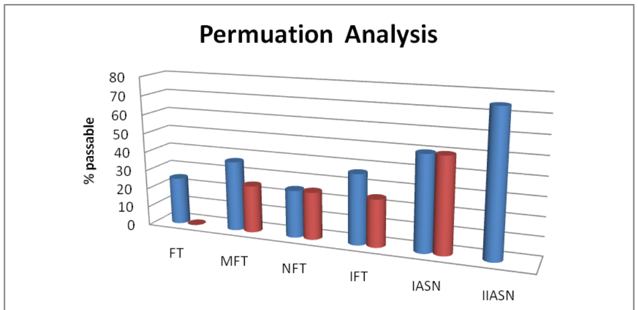
4. Incremental Permutation Analysis



	FT	MFT	PHI	NFT	IFT	IASN	IIASN
without	25	50	25	50	50	68	100
mux	25	50	25	50	50	68	100
first stage	25	43	25	50	43	62	87.5
middle stage	12	37		37	43	62	87.5
last stage	25	43	25	50	43	62	87.5
demux	25	50	25	50	50	68	93.75

Fig. 5 Incremental Permutations Passable Analysis with and without Fault at Various Stages in Non Critical Condition

The above analysis from figure 5 shows that average path length of all considered MINs remains almost constant in the presence and absence of faults. It is also concluded from the analysis that most of the Network used more path length in comparison to path length used in identical permutation. The reason of more path lengths is because of lesser direct cross connection between considered sources to destination for the sample chosen for incremental permutation. The number of successful requests passes from different sources to their destinations in the presence and absence of fault is shown in figure 5. The evaluated result clearly indicates that the pass percentage of requests is lesser when a fault occurs in middle stage switch. The degradation in pass percentage is because of more clashes and lesser unique paths.



	FT	MFT	NFT	IFT	IASN	IIASN
first Satge	25	37	25	37	50	75
middle satge	0	25	25	25	50	

Fig. 6 Incremental permutations Passable Analysis of Various Stages in Critical Condition

The average path lengths result computed shows that the success rate of passing the a request from different sources to destinations is decreased by more than 50% in comparison to identical permutations (non critical case) and is almost 25% lesser in comparison to incremental permutation (non critical case).The results shown in figure 6 shows that number of request passes in FT Network is almost zero when a critical fault occurs at middle stage of it.

5. Conclusions

In this paper Permutation Passable analysis which is the biggest factor to consider the network has been analyzed by introducing some faults. The identical permutation passable results in non critical case of FT, IASN, IFT and IIASN networks are 100% when the network is fault free and there is only 12.5 % degradation when a single switch fault occurs in any stage. These results are quite better than MFT, ZTN and NFT networks. The graph shows that the average path length consumed by IIASN in the presence and non presence of fault is much better than others compared networks. The result of identical permutation in critical condition is also comparable in the case of IIASN network. On the other hand the incremental permutation in non critical case of IIASN is much better than other existing considered networks. The result evaluated from the case considered shows that 100% request are granted in IIASN in comparison to 68% in IASN and 25-50% for other networks when network is fault free. The results of IIASN network remain same as of identical permutation when single switch fault occur in any stage. The result of NFT (25%) and IFT (37%) are much better than FT (0%) in incremental permutation in non critical case when centre stage switch faulty in a loop.

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