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Reliability Analysis of Fault Tolerant Irregular Triangle Multistage Interconnection Network

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Abstract

Multistage Interconnection Networks (MINs) interconnect thousands of various processors and memory modules. These Systems attract the researchers in various aspects such as performance parameters, reliability and routing. In this paper reliability of Irregular Fault Tolerant MIN named as Irregular Triangle has been discussed and compared with Theta Network.

Keywords: Irregular Fault Tolerant MIN, Design of MIN, Reliability.

Introduction

The MINs are used in important applications like ATM Networks, Weather Forecasting and in almost every field where instant response and complex calculations are required[7]. The MINs use more than one stage of small interconnection networks like Switching Elements (SEs)[1][9].Broadly there are two types of MIN namely static regular and irregular. If the MIN has same no of SEs in all the stages then it is called as regular MIN, otherwise it is called as irregular MIN. This paper compares the reliability analysis of a new class of Irregular Fault Tolerant MIN named as Triangle MIN with Theta Network(THN).

Design of Triangle MIN

The Network is an Irregular Multistage Interconnection Network, of size N*N. It has N sources and N destinations. The MIN consists of n stages ($n=\log_2 N$).

The network Comprises of two identical groups of switching elements (SEs), named as G0 and G1.Each group incorporates N/2 sources and N/2 destinations. Both the groups are connected to the N inputs through N multiplexers, and to the N outputs through N no. of demultiplexers. The switches in all the stages are of size 3*3 except the last one. The switches in the stages n-3,n-2 and n-1 have been connected to each other through links called as auxiliary links. These links are used when the SE in the next stage is busy or faulty. This makes the network more faults tolerant and reliable.

The Triangle network of size 2^n*2^n consists of (2m-2) stages where $m=\log_2(N/2)$.This network has (2^n -2) no. of switches of size 3*3 and 2^{n-1} no. of switches of size 2*2.Each source is connected to one switching element in each group with the help of multiplexers. The network of size 16*16 is shown in

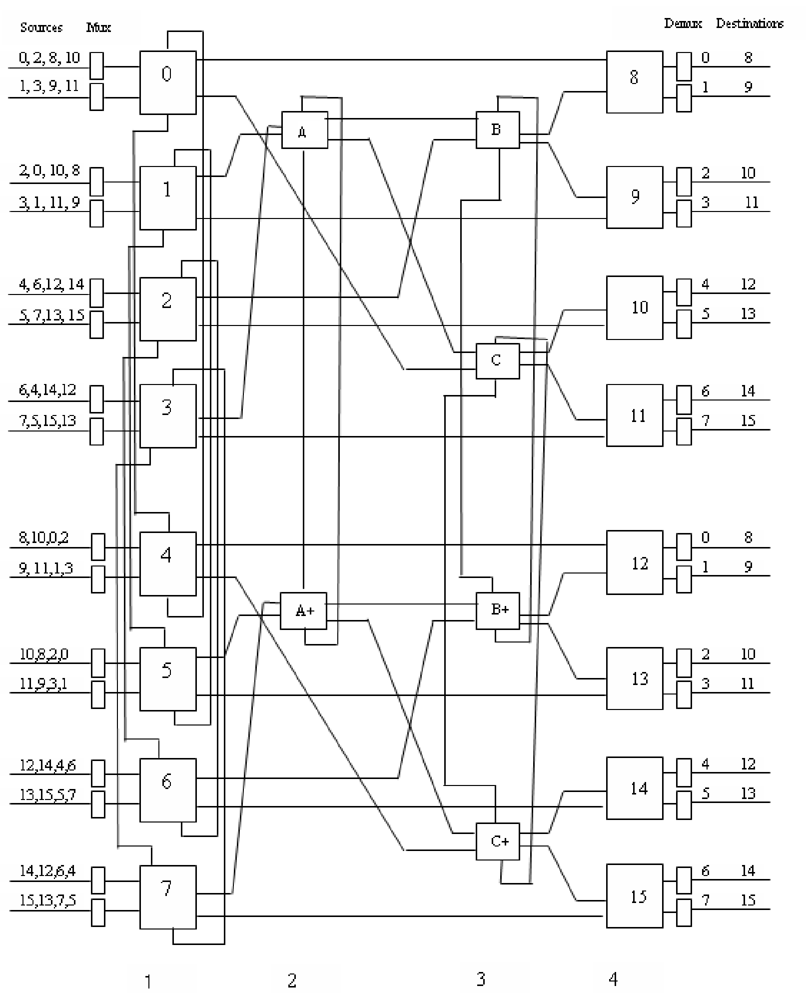

Figure 1: Design of Triangle MIN.

Redundancy Graph

The Redundancy Graph is a pictorial representation of the architecture of a MIN. It shows all the possible paths from every source to every destination. [6][7]

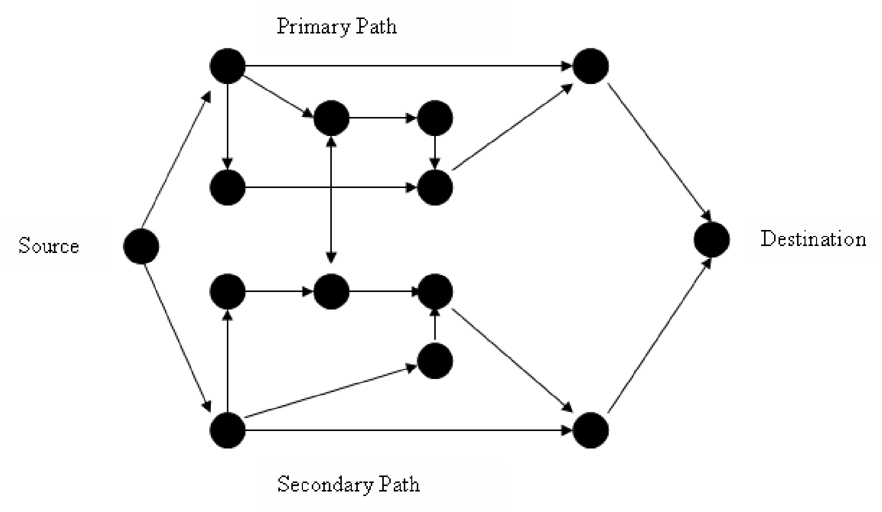

Figure 2: Redundancy Graph of Triangle MIN.

Experimental Results on Reliability Analysis

Reliability R(t) is the probability that the system does not fail in the interval (0,t).The network is assumed to be faulty if any source destination pair cannot be connected because of the presence of faulty components in the network.

The reliability can be measured in terms of MTTF [9] [4] i.e. Mean Time To Failure. It is defined as expected time elapsed before some source is disconnected from some destination.

Upper Bound Analysis

The network is operational if the critical set of switches is operational. The critical set is the set of k SEs, each from different module such that a failure occurs if all k SEs are faulty simultaneously. The expression for Upper Bound Reliability is [5] [3]

$f1= [1-[1-e\lambda_m t]^{2}]^{N/2}$

$f2= [1-[1-e\lambda_3 t]2]^{(N/2+N/4)}$

$f3= [1-[1-e\lambda_{2d} t]2]^{N/4}$

$f= \int (f1*f2*f3)\, dt$

$$MTTF = \int_0^{\infty} R_{UB}(t)\, dt$$

The table 1 depicts the Upper Bound analysis of Triangle Network and Theta Network. It is clear that Triangle Network has more Upper Bound for all sizes of Network. The figure 3 has been plotted with the values of Mean Time To Failure. The Triangle Network has better MTTF of Upper Bound as compared to Theta Network.

Lower Bound Analysis

In the Lower Bound Analysis the input side SEs and their corresponding multiplexers are considered as a series system and failure of any component leads to the failure of all three.[8][2]

The expression for Lower Bound Reliability is

$f1= [1-[1-e\lambda_{3m}t]^2]^{N/4}$

$f2= [1-[1-e\lambda_3 t]^2]^{(N/2+N/4)}$

$f3= [1-[1-e\lambda_{2d}t]^2]^{N/4}$

$f= \int (f1*f2*f3)\, dt$

$$MTTF = \int_0^\infty R_{LB}(t)\, dt$$

The table 2 presents the Lower Bound analysis of Triangle Network and Theta Network. The Triangle Network has more Lower Bound. The figure 4 shows that Mean Time To Failure of Triangle Network is better as compared to Theta Network.

Simulator

The reliability analysis has been calculated using Simpson's Trapezoidal Numerical Method simulator in c# in.Net platform.

Table 1: Comparison of Upper Bound Analysis.

switch size	Theta UB	Triangle UB
16*16	181400.2	190591.34
32*32	92415.56	117404.91
64*64	69389.29	77106.12
128*128	40654.23	52251.53
256*256	29765.38	36252.73
512*512	20876.91	27335.08
1024*1024	18552.89	20110.9

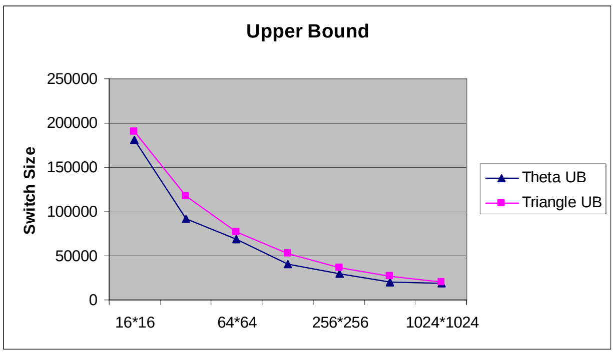

Figure 3: MTTF Comparison of Upper Bound.

Table 2: Comparison of Lower Bound Analysis.

switch size	Triangle LB	Theta LB
16*16	98440.49	90234.34
32*32	69120.2	56356.56
64*64	48386.57	39789.91
128*128	34253.58	30892.62
256*256	26713.97	19367.76
512*512	25060.09	17986.98
1024*1024	21590.34	15678.87

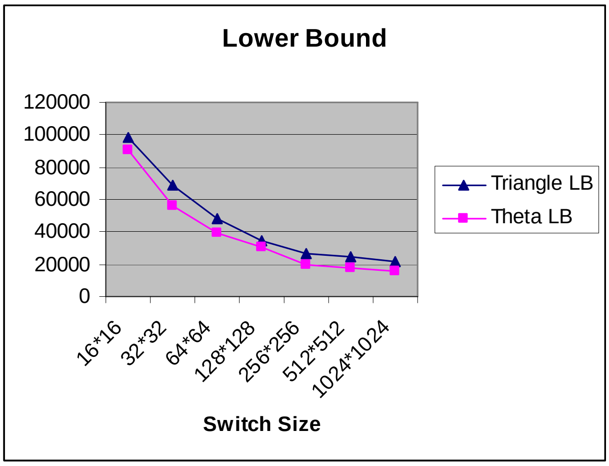

Figure 4: MTTF Comparison of Lower Bound.

Conclusion

The Fault Tolerant Irregular Triangle Multistage Interconnection Network is better as compared to the other discussed Network i.e. Theta Network. It has more Upper Bound and Lower Bound Reliability. Moreover Triangle Network has less cost as compared to Theta Network

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