Performance Analysis of Fault-Tolerant Irregular Baseline Multistage Interconnection Network

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Abstract - **In this paper an attempt has been made to analyze the characteristics of a new class of irregular fault-tolerant multistage interconnection network named as irregular modified augmented baseline network(IMABN).IMABN can provide 'Full access' capability in presence of multiple faults . Permutation passibility and Bandwidth Analysis shows that Proposed IMABN achieve a significant improvement over Modified Augmented Baseline Network (MABN).**

Keywords - **Multistage Interconnection Networks, Bandwidth, Irregular Modified Baseline Network.**

I. INTRODUCTION

With the present state of technology building multiprocessor system with hundreds of processors is feasible.A vital component of these systems is the interconnection network(IN) that enables the processors to communicate among themselves or with the memory units.Multipath nature of multistage interconnection networks become more popular. Many ways of providing fault-tolerance to multistage interconnection networks(MINs) have been proposed.The basic idea for fault-tolerance is to provide multiple paths between source-destination pair so that alternate paths can been used in case of faults. Sufficient work has been done on the regular type of MINs,but little attention has been paid to the irregular type of MIN.

In this paper, a new class of irregular fault-tolerant multistage interconnection network named as irregular modified augmented baseline network(IMABN) is proposed. In this paper we present methods of increasing fault-tolerance of an network by introducing the extra stage. Hence with the additional stage more paths available between each source and destination, as compared to existing network MABN. The proposed Irregular Modified Augmented Baseline Network(IMABN) is an Modified augmented baseline network(MABN) [10] with additional stage. In an IMABN, there are Six possible paths between any source-destination pair, whereas MABN has only Four. As we will see, IMABNs can achieve general goals for the design of fault-tolerant networks i.e. good permutation possibility, high bandwidth , simple control.

In the following section structure and design of existing network MABN and proposed network IMABN is described. Section III describes the Permutation Passibility of MABN and IMABN. Bandwidth analysis of MABN and IMABN is given in a section IV. Finally, some concluding remarks are given in section V.

II. STRUCTURE OF NETWORKS

A. MABN (Modified Augmented Baseline Network)

To construct an MABN of size N, two identical groups of N/2 sources and N/2 destinations need to be formed first. Each source is linked to both the groups via multiplexers. There is one 4 x 1 MUX for each input link of a switch in stage 1 and one 1 x 4 DEMUX for each output link of a switch in stage n-2. MABN consists of two identical sub-networks which are denoted by G^i. For example, in Figure 1, switches A, B, C, D belonging to stage 1 of a sub-network (G^i) form a conjugate subset, switches A and B form a conjugate pair, and switches A and C form a conjugate loop.
An MABN of size 16X16 is shown in Fig. 1.

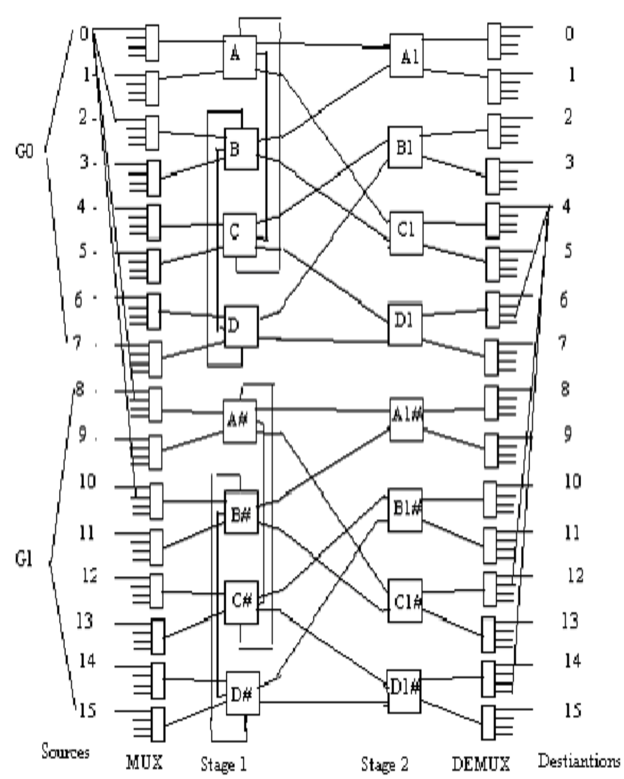

Figure 1 : An MABN of size 16 X 16.

B. IMABN (Irregular MABN)

IMABN (Irregular modified augmented baseline network) is a Modied Augmented Baseline Network with one additional stage, increase size of switch and more auxiliary links. To construct an IMABN of size N i.e. N sources and N destinations, two identical groups of N/2 sources and N/2 destinations need to be formed first. Each source is linked to both the groups via multiplexers. There is one 4 x 1 MUX for each input link of a switch in stage 1 and one 1 x 4 DEMUX for each output link of a switch in stage n-1. IMABN consists of two identical sub-networks which are denoted by G^i. For example, in Figure 2, switches A, B, C, D belonging to stage 1 of a subnetwork (G^i) form a conjugate subset, switches A and B form a conjugate pair, and switches A and C form a conjugate loop.Thus an IMABN of size N consists of N number of 4 x 1 MUXs, N number of 1 x 4 DEMUXs, and switches in the last stage of size 2 x 2, switches in the middle stage of size 5 x 5 and switches in the first stage of size 3 x 3. IMABN as its name suggest is an irregular network in which middle (additional) stage doesn't have equal number of switches as of other stages. The irregular topology of IMABN varies the number of switching elements encountered in the way of data transfer through an input-output pair depending on the path chosen, which makes the average rate of failure of the network less as compared to that of regular ABN and MABN.IMABN is a dynamically re-routable irregular MIN and provides multiple paths of varying lengths between a source-destination pair.

Observe that this construction procedure has two benefits. First, the network can tolerate the failure of any switch in the network. And, secondly it provides a topology which lends itself to on-line repair and maintainability, as a loop can be removed from any stage of the IMABN without disrupting the operation of the network. Since the sub-networks are identical, so the VLSI implementation of the network becomes simple. IMABN of size 16x16 is shown in Fig 2.

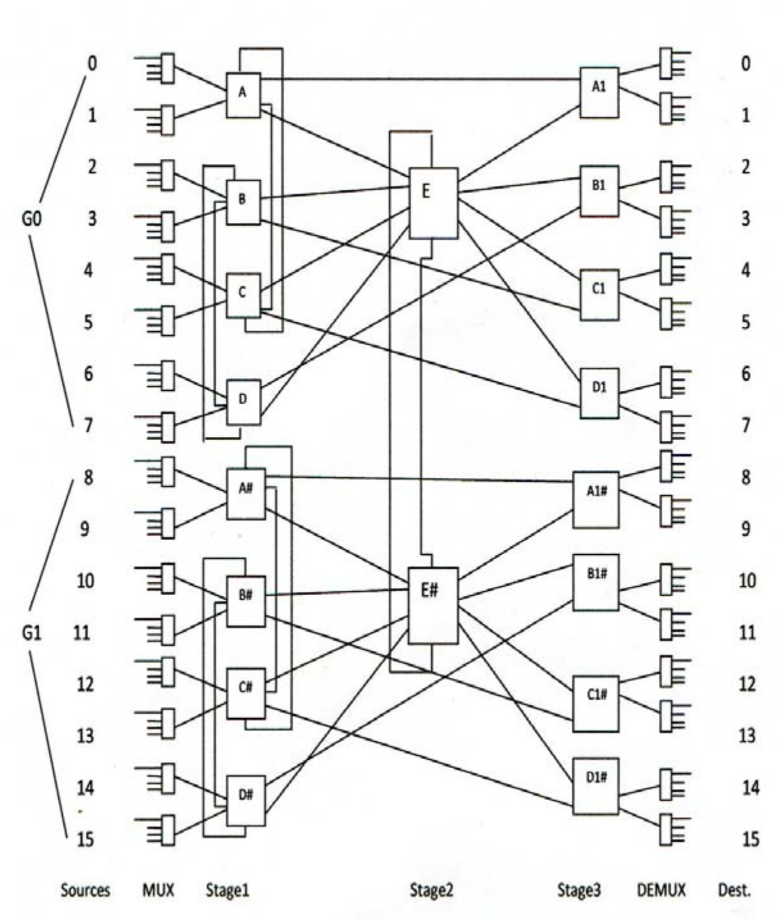

Figure 2: An IMABN of size 16 X 16

III. PERMUTATION PASSIBILITY

Permutation Passibility is one of the most important parameter to measure the performance of Interconnection Network. This parameter tells, how many number of requests appear at source side has successfully got matured, means how many of them has successfully reached their destinations. Different combinations of source destination pairs are selected and their path length is calculated for these networks, only if a request matures successfully. Unsuccessful requests are indicated by CLASH. The average path length is defined as the ratio of sum of the path lengths used in the successful requests to the total number of requests. FAULT indicates faulty component encountered while establishing path. So two cases have been considered, without faults and with faults.

A. MABN(Modified Augmented Baseline Network)

Results of Permutation Passibility Analysis done for existing regular network MABN gave us following results:

Total number of request appearing at source side =36
Total requests matured when no switch is failed =36
Total requests matured when switch is failed =32

Total path length when no switch is failed =81
Total path length when switch is failed =75
Average path length when no switch fails =81/36 = 2.25
Average path length when switch failed =75/32 = 2.34

B. IMABN(Irregular MABN)

Results of Permutation Passibility Analysis done for proposed irregular network IMABN gave us following results:

Total number of request appearing at source side =36
Total requests matured when no switch is failed =36
Total requests matured when switch is failed =35
Total path length when no switch is failed =94
Total path length when switch is failed =97
Average path length when no switch is failed =94/36 = 2.6
Average path length when switch is failed =97/35 = 2.77

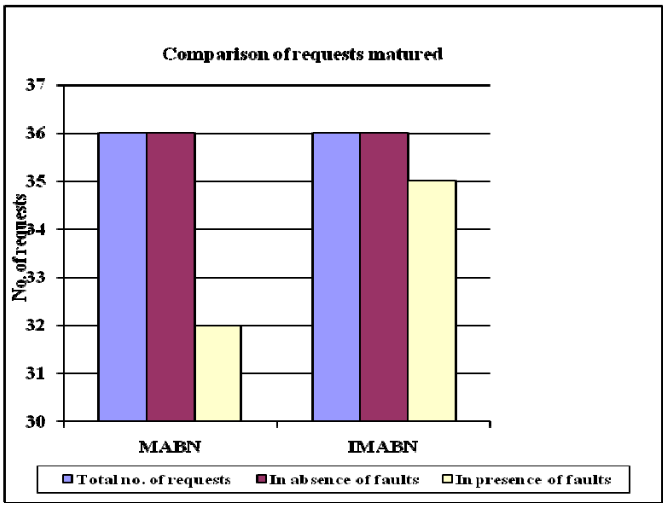

Figure 3 Comparison on the basis of number of requests matured

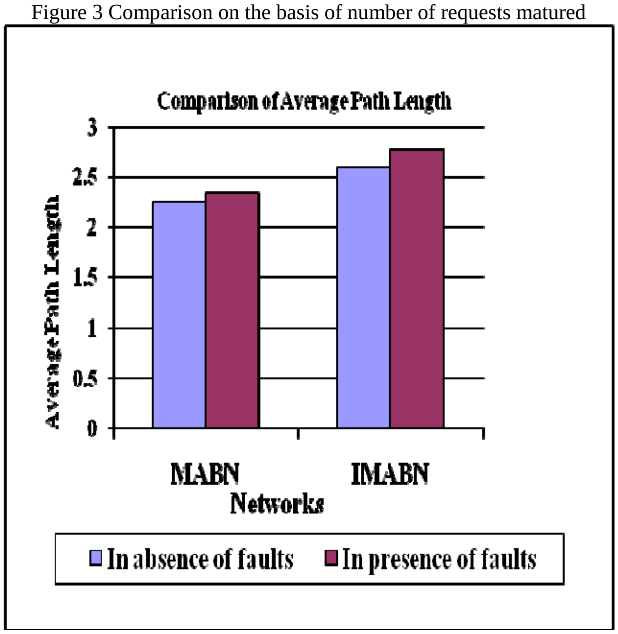

Figure 4: Comparison on the basis of average path length

From the data given above, it can be concluded that average path length of proposed network IMABN is greater than MABN. But there is significant improvement in number of requests successfully maturing at the destination side in case of IMABN. Main consideration in permutation possibility is how many requests get matured in presense of faults, the proposed irregular network IMABN gives better performance in this respect.

IV. BANDWIDTH ANALYSIS

Bandwidth (BW) is defined as the expected number of destination receiving requests in any given cycle . Thus it is the total number of requests matured. It is the most common performance parameter used in analyzing a IN .It is defined as the mean number of active memory modules in a transfer cycle of the IN. The term ”active” means a process is successfully performing memory operation (either read or write) in that memory module.

Bandwidth is given as :

$$BW = b^n p_n \quad \text{and} \quad p0=p$$

Where p_0 is the probability with which a processor generate a request.
Probability equation is given as : $1 - (1- p/b)^a$

Probability equations for MABN:

$p[1]=1-(1-p[0]/3)^3$

$p[2]=1-(1-p[1]/2)^2$

Probability Equations for IMABN

$p[1]=1-(1-p[0]/3)^3$

$p[2]=1-(1-p[1]/10)^5$

$p[3]=1-((1-p[1]/2)*(1-p[2]))^2$

Bandwidth of MABN and IMABN for different network size is shown in a Table I:-

TABLE I: BANDWIDTH OF MABN AND IMABN

P(Probability)	MABN	IMABN
0.1	1.509853	2.851672
0.2	2.851587	5.113012
0.3	4.042236	6.914852
0.4	5.097285	8.3574
0.5	6.030778	9.517707
0.6	6.855424	10.45525
0.7	7.582695	11.216118
0.8	8.222926	11.83617
0.9	8.785405	12.343417
1	9.278464	12.759828

Bandwidth comparison of MABN and IMABN is shown in Fig. 4:-

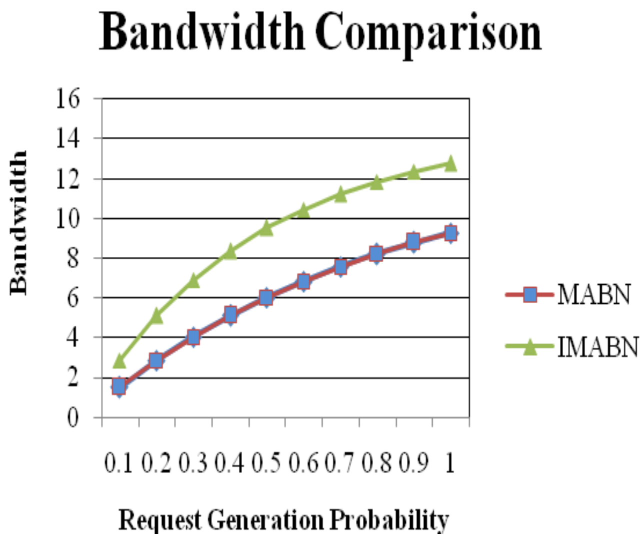

Figure 4: Bandwidth comparison of MABN and IMABN

From the above graph,it shows that bandwidth of proposed network IMABN is much higher than that of MABN.
Further, three more performance parameters namely probability of acceptance, throughput and processor utilization, are calculated based on bandwidth values.

A. *Probability of Acceptance(P_a)*

It is defined as the ratio of expected bandwidth to the expected number of requests generated per cycle. It is the probability that, in random-access environment, a request submitted by a source is accepted by destination without getting blocked by other requests in the network. It is given as:-

$$P_a = BW / (a^n . p)$$

Probability of Acceptance of MABN and IMABN is shown in a Table II:-

TABLE II: PROBABILITY OF ACCEPTANCE

P(Probability)	MABN	IMABN
0.1	0.943658	1.782295
0.2	0.891121	1.597816
0.3	0.842133	1.440594
0.4	0.796451	1.305844
0.5	0.753847	1.189713
0.6	0.714107	1.089089
0.7	0.677026	1.001439
0.8	0.642416	0.924701
0.9	0.610098	0.857182
1	0.579904	0.797489

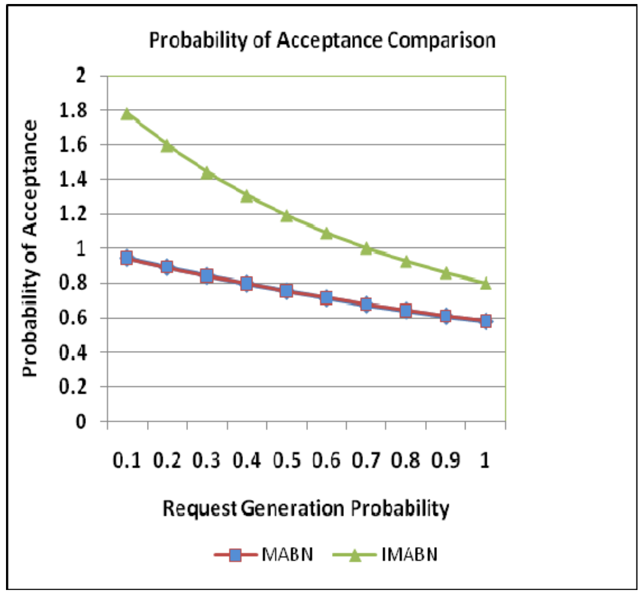

Figure 5: Comparative Probability of Acceptance of MABN and IMABN

Above graph shows that Probability of Acceptance of proposed network IMABN is almost double than MABN.

B. *Throughput(TP)*

Throughput means average number of cells delivered by a network per unit time.It is also defined as maximum number of traffic accepted by a network per unit time.It is given as:

$$TP = BW / (a^n . T)$$

Where BW = Bandwidth
a^n = size of the network
T = 0.285

Throughput of MABN and IMABN is shown in Table III:-

TABLE III: THROUGHPUT OF MABN AND IMABN

P(Probability)	MABN	IMABN
0.1	0.331108	0.625367
0.2	0.625348	1.121275
0.3	0.886455	1.516415
0.4	1.117826	1.832763
0.5	1.322539	2.087216
0.6	1.503382	2.292818
0.7	1.662872	2.459675
0.8	1.803273	2.595651
0.9	1.926624	2.70689
1	2.034751	2.798208

TABLE IV: PROCESSOR UTILIZATION OF MABN AND IMABN

P(Probability)	MABN	IMABN
0.1	3.311081	6.253667
0.2	3.12674	5.606373
0.3	2.954851	5.054716
0.4	2.794564	4.581908
0.5	2.645078	4.174433
0.6	2.505637	3.821363
0.7	2.375531	3.513821
0.8	2.254092	3.244564
0.9	2.140693	3.007655
1	2.034751	2.798208

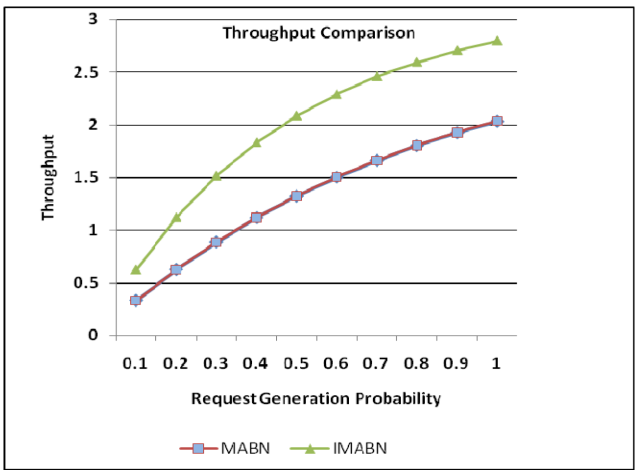

Figure 6: Comparative Thruoghput of MABN and IMABN

As shown in a graph,with the increase in the value of probability throughput values also increase.

C. Processor Utilization(PU)

It is the expected percentage of time, a processor is active doing internal computation without accessing the global memory. It is given as :

$$PU = BW / (a^n.p.\ T)$$

Where BW = Bandwidth

a^n = size of the network

T = 0.285

p = Probability value

Processor Utilization of MABN and IMABN is shown in Table IV.

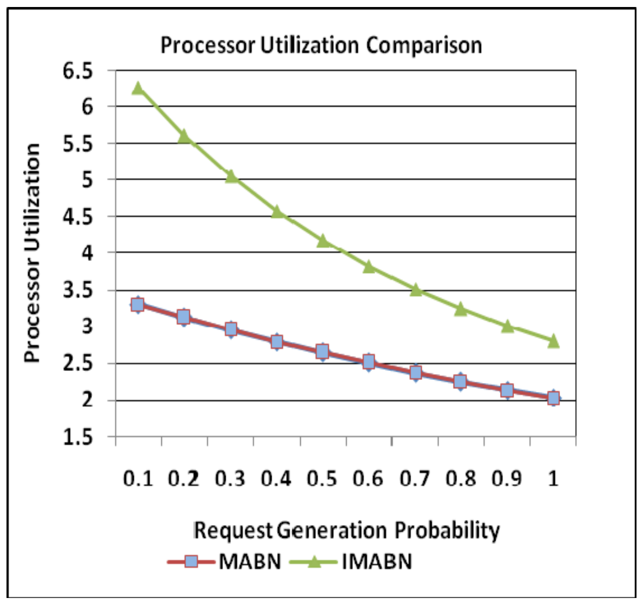

Figure 7: Comparative Processor Utilzation of MABN and IMABN

As we can seen from the graph above, processor utilization of proposed network IMABN is almost double than MABN.

V. CONCLUSIONS

In this paper, we proposed and analyzed new irregular Fault-tolerant multistage interconnection network named as Irregular modified augmented baseline network(IMABN).IMABN is dynamically re-routable and providing multiple paths of varying lengths between source and destination pairs. It has been found that

IMABN has six possible paths whereas in MABN has only four. Permutation Passibility and Bandwidth Analysis shows that proposed IMABN is better than MABN in all respects.

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