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Performance Comparison of IMABN-2 and MALN-2 in Faulty and Non-Faulty Network Conditions

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ABSTRACT

In this paper, we have compared the performance of IMABN-2 and MALN-2. To compare the performance, data packets were passed via both networks in faulty and non-faulty environments. Results show that MALN-2 performs better than the IMABN-2. Cost of IMABN-2 and MALN-2 is also compared with other existing MINs.

General Terms

Interconnection Networks.

Indexing terms

Interconnection Networks, Performance, Cost, Throughput.

Academic Discipline And Sub-Disciplines

Physical Sciences.

SUBJECT CLASSIFICATION

Computer Science and Engineering.

COVERAGE

Computer Architecture.

TYPE (METHOD/APPROACH)

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INTRODUCTION

Various researchers already done sufficient work on regular Interconnection networks (INs) [1-3] and irregular topologies were out of limelight [4-10]. Therefore, in this paper, two Fault–tolerant Irregular networks, Modified Augmented Baseline Multi–stage Interconnection Network (IMABN-2) and Modified Alpha Network (MALN-2) have been compared with existing INs based on Normalized Throughput and Cost.

Based upon the topology a Dynamic MIN can be regular, irregular, and hybrid.

Definition 1: Any network is regular if the number of switching elements (SEs) in different stages of the network is same.

Definition 2: Any network is regular if the number of SEs in different stages of the network is different.

Definition 3: Any network is Hybrid if the network possesses the regular as well as irregular topology.

Before moving to next section, let us have a look on the symbols which are used throughout the paper. Symbol table (1) presents all the symbols and their meaning.

Table 1. Symbol Table

Symbol	Meaning of symbol
SE	Switching Element
MSE_1	Main SE of stage 1
SSE_1	First alternate SE of stage 1
TSE_1	Second alternate SE of stage 1
MSE_5	Main SE of stage 5
SSE_5	First alternate SE of stage 5
TSE_5	Second alternate SE of stage 5
SE-i	SE i
SE-j	SE j
SE-k	SE k
SE-l	SE l
SE-m	SE m
SE-n	SE n
SE-o	SE o
SE-p	SE p
Dp	Data packets
NFIMABN-2	Non Faulty IMABN-2
FIMABN-2	Faulty IMABN-2
NFMALN-2	Non Faulty MALN-2
FMALN-2	Faulty MALN-2

IMABN-2

Irregular Modified Augmented Baseline Network (IMABN–2) [9] is an irregular interconnection network with two extra stages. This network has N sources and N destinations. Here N is size of network. It has {$(\log_2 N)+1$} stages. In figure 1, S, D, M and DM represents the source address, destination address, multiplexers and demultiplexers respectively. In the same way S_1, S_2 , S_3 , S_4 and S_5 represents the first stage, second stage, third stage, fourth stage and fifth stage respectively.

The first and last stage of network has N/2 SEs in each stage. The second and fourth stage consists of {(N/4)–1} SEs in each stage whereas third stage has N/8 SEs. This network has 16 multiplexers of size 2 x 1 at source side and 16 demultiplexers of size 1 x 2 at destination side.

In first stage, the size of each SE is 2 x 3 and each SE of this stage is connected with 2 multiplexers, 3 SEs of second stage. In second stage, the size of each SE is 8 x 2 and each SE of this stage is connected with the SEs of first stage and third stage as shown in figure 1.

In the same way, the third stage consists of SE of size 3 x 3 and these SEs are connected with the SEs of second stage and fourth stage. In the fourth stage, the size of each SE is 2 x 8 and each switch of this stage is connected with the SEs of third stage and fifth stage. Finally, in the last stage, the size of SE is 3 x 2 and each SE of this stage is connected with the SEs of fourth stage and demultiplexers as shown in figure 1. The IMABN–2 is a two–switch fault tolerant network in first, second, fourth and fifth stage and single switch fault tolerant network in third stage.

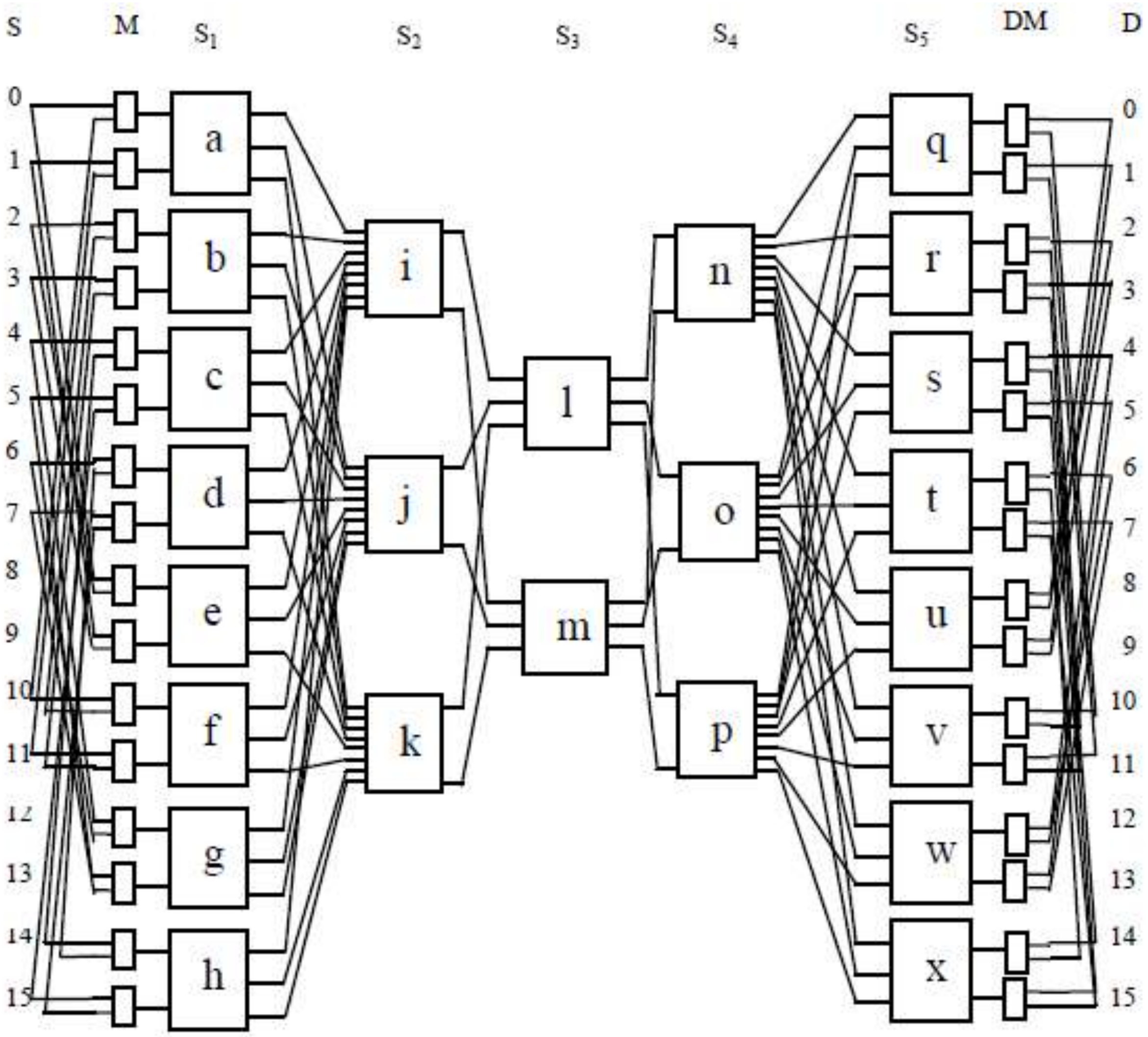

Figure 1. IMABN–2

Routing Algorithm of IMABN–2

Routing algorithm of IMABN-2 is a generalized algorithm and it is applicable on every network size. Initially, source sends the request to the multiplexer of IMABN-2. Multiplexer sends the request to appropriate SE of first stage. In first stage, each source is connected with MSE_1, SSE_1, and TSE_1. According to the algorithm, data packets will be collected by the SE which is non-faulty. If all the SEs are faulty or busy than data packets will not reach at the given destination. Further, the algorithm has these four functions:

1. Stage-2(Source, Destination)
2. Stage-3(Source, Destination)
3. Stage-4(Source, Destination)
4. Stage-5(Source, Destination)

In all these functions, the data packets will search the non-faulty SE. If non-faulty SE is not found than data transmission process will be stopped otherwise data packets will be reached to the given destination through demultiplexer.

Algorithm_IMABN-2

Input: *Source, Destination*
Output: *Data packets reached successfully or drop the request*

BEGIN

1. **if** *Request arrives at first stage*
2. **if** *MSE_1 == FTBY*
3. *SSE_1*

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else *Stage-2 (Source, Destination)*
if *SSE_1 == FTBY*
TSE_1
else *Stage-2 (Source, Destination)*
if *TSE_1 == FTBY*
Drop the request.
else *Stage-2 (Source, Destination)*

Stage-2(Source, Destination)
if *SE-i == FTBY*
SE-j
else *Stage-3(Source, Destination)*
if *SE-j == FTBY*
SE-k
else *Stage-3 (Source, Destination)*
if *SE-k == FTBY*
Drop the request.
else *Stage-3(Source, Destination)*

Stage-3 (Source, Destination)
if *SE-l == FTBY*
SE-m
else *Stage- 4 (Source, Destination)*
if *SE-m == FTBY*
Drop the request.
else *Stage- 4(Source, Destination)*

Stage-4(Source, Destination)
if *SE-n == FTBY*
SE-o
else *Stage-5(Source, Destination)*
if *SE-o == FTBY*
SE-p
else *Stage-5 (Source, Destination)*
if *SE-p == FTBY*
Drop the request.
else *Stage-5 (Source, Destination)*

Stage-5(Source, Destination)
if *MSE_5 == FTBY*
SSE_5
else *Receive data packets on MSE_5 and send to the given destination*
if *SSE_5 == FTBY*
TSE_5
else *Receive data packets on SSE_5 and send to the given destination*
if *TSE_5 == FTBY*
Drop the request
else *Receive data packets on TSE_5 and send to the given destination*
END

MALN-2

Modified Alpha Network-2 (MALN–2) [10] is an irregular fault–tolerant interconnection network. It has (log2N)+1 stages hence, it has one extra stage as compare to MALN network. This network has 16 sources and 16 destinations. In figure 2, S, D, M and DM represents the source address, destination address, multiplexers and demultiplexers respectively. In the same way S1, S2, S3, S4 and S5 represents the first stage, second stage, third stage, fourth stage and fifth stage respectively. The first and last stage of network has N/2 SEs in each stage.

The second and fourth stage consists of N/8 SEs in each stage whereas third stage has only a single SE. This network has 16 multiplexers of size 2 x 1 at source side and 16 demultiplexers of size 1 x 2 at destination side. In first stage, the size of each SE is 2 x 3 and each SE of this stage is connected with 2 multiplexers, 2 SEs of second stage and 1 SE of third stage. In second stage, the size of each SE is 8 x 2 and each SE of this stage is connected with the SEs of first stage and fourth stage. In the similar way, the third stage consists of SE of size 8 x 8 and this switch is connected with the SEs of first stage and fifth stage. In the fourth stage the size of each SE is 8 x 2 and each switch of this stage is connected with the SEs of second stage and fifth stage. Finally, in the last stage, the size of SE is 3 x 2 and each SE of this stage is connected with the SEs of third and fourth stage and demultiplexers. The MALN–2 is a two switch fault–tolerant interconnection network.

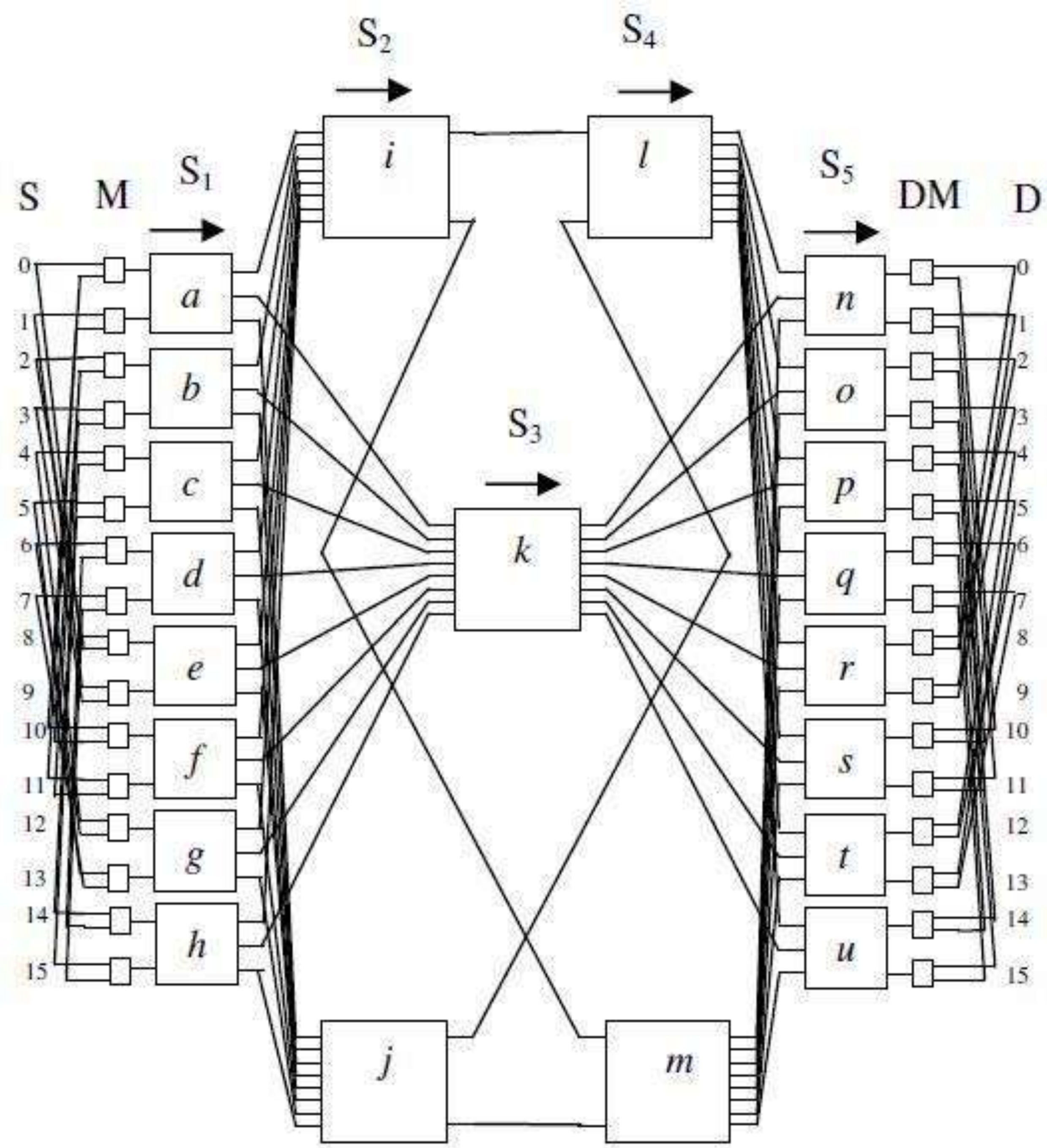

Figure 2. MALN–2

Routing Algorithm of MALN–2

Routing algorithm of MALN-2 is a generalized algorithm and it is applicable on every network size. Initially, source sends the request to the multiplexer of MALN-2. Multiplexer sends the request to appropriate SE of first stage. In first stage, each source is connected with MSE_1, SSE_1, and TSE_1. According to the algorithm, data packets will be collected by the SE which is non-faulty. If all the SEs are faulty or busy than data packets will not reach at the given destination. Further, the algorithm has these four functions:

1. Stage-2(Source, Destination)
2. Stage-3(Source, Destination)
3. Stage-4(Source, Destination)
4. Stage-5(Source, Destination)

In all these functions, the data packets will search the non-faulty SE. If non-faulty SE is not found than data transmission process will be stopped otherwise data packets will be reached to the given destination through demultiplexer.

Algorithm_MALN-2

Input: *Source, Destination*
Output: *Data packets reached successfully or drop the request*

BEGIN
1. **if** *Request arrives at first stage*
2. **if** MSE_1 == *FTBY*
3. SSE_1
4. **else** *Stage-3 (Source, Destination)*
5. **if** SSE_1 == *FTBY*
6. TSE_1
7. **else** *Stage-3 (Source, Destination)*
8. **if** TSE_1 == *FTBY*
9. *Drop the request*
10. **else** *Stage-3 (Source, Destination)*

Stage-2(Source, Destination)
1. **if** *SE-i == FTBY*
2. *SE-j*
3. **else** *Stage-4(Source, Destination)*
4. **if** *SE-j == FTBY*
5. *Drop the request*
6. **else** *Stage-4(Source, Destination)*

Stage-3(Source, Destination)
1. **if** *SE-k == FTBY*
2. *Stage-2 (Source, Destination)*
3. **else** *Stage-5(Source, Destination)*

Stage-4(Source, Destination)
1. **if** *SE-l == FTBY*
2. *SE-m*
3. **else** *Stage-5(Source, Destination)*
4. **if** *SE-m == FTBY*
5. *Drop the request*
6. **else** *Stage-5(Source, Destination)*

Stage-5(Source, Destination)
1. **if** MSE_5 == *FTBY*
2. SSE_5
3. **else** *Receive data packets on* MSE_5 *and send to the given destination*
4. **if** SSE_5 == *FTBY*
5. TSE_5
6. **else** *Receive data packets on* SSE_5 *and send to the given destination*
7. **if** TSE_5 == *FTBY*
8. *Drop the request*
9. **else** *Receive data packets on* TSE_5 *and send to the given destination*

END

PERFORMANCE EVALUATION PARAMETERS

In this section, we have explained all the performance parameters which are used in our simulation.

Link Capacity (L_C)

The number of data packets transmitted from a node to another node in a unit time is the capacity of the link.

Average throughput (Th_{avg})

"It is the average number of packets accepted by all destinations per network cycle [1]. This metric is also referred to as bandwidth [1]." Formally, Th_{avg} can be defined as:

$$Th_{avg} = \lim_{u\to\infty} \frac{\sum_{i=1}^{u} n(i)}{u} \qquad (1)$$

where *n(i)* denotes the number of packets that reach their destinations during the *ith* time interval.

Normalized throughput (Th)

"It is the ratio of the average throughput Th_{avg} *to network size N* [1]*."* Formally, *Th* can be expressed by:

$$Th = \frac{Th_{avg}}{N} \qquad (2)$$

Cost of IMABN-2 and MALN-2

Cost of IMABN-2 can be calculated as follows:

Total number of 2×3 SEs=8, cost=48,

Total number of 8×2 SEs=3, cost=48,

Total number of 3×3 SEs = 2, cost =18,

Total number of 2×8 SEs = 3, cost =48,

Total number of 3×2 SEs = 8, cost = 48,

Total number of 2:1 multiplexers =16, cost = 32 and

Total number of 1:2 demultiplexers =16, cost = 32.

Therefore, Total cost of IMABN–2 is 274 units. The cost of IMABN is 282 units and therefore, proposed interconnection network is cheaper than IMABN and it has more alternate paths with double switch fault tolerant capacity. In a generalized form, we have obtained the cost of various MINs and also derived a cost formula for IMABN-2. These formulas are as follows:

$$Cost_{ALPHA} = \left(\frac{N}{2}\right) \times \left[9log_2\left(\frac{N}{2}\right) + 7.5 \right] \qquad (3)$$

$$Cost_{MALN} = \left(\frac{N}{2}\right) \times \left[9log_2\left(\frac{N}{2}\right) + 3 \right] \qquad (4)$$

$$Cost_{ASEN-2} = (3N) \times [\ 1.5log_2(N) - 1\ ] \qquad (5)$$

$$Cost_{IASEN} = (3N) \times [\ \{1.5log_2(N)\} - 20\ ] \qquad (6)$$

$$Cost_{IMABN-2} = \{(16N) + 18\} \qquad (7)$$

Here $Cost_{ALPHA}$ [2], $Cost_{MALN}$ [2], $Cost_{ASEN-2}$ [3], $Cost_{IASEN}$ [3] and $Cost_{IMABN-2}$ are the cost of ALPHA [2], MALN [2], ASEN-2 [3], IASEN [3] and IMABN-2 respectively. The cost comparison is shown in figure 3. When we have to send the data from any source to any destination through IMABN-2 then simultaneously, it can sustain at least 2-faulty switching elements during data transmission. However, the other networks (shown in graph) are only able to send the data in single switch faulty situation.

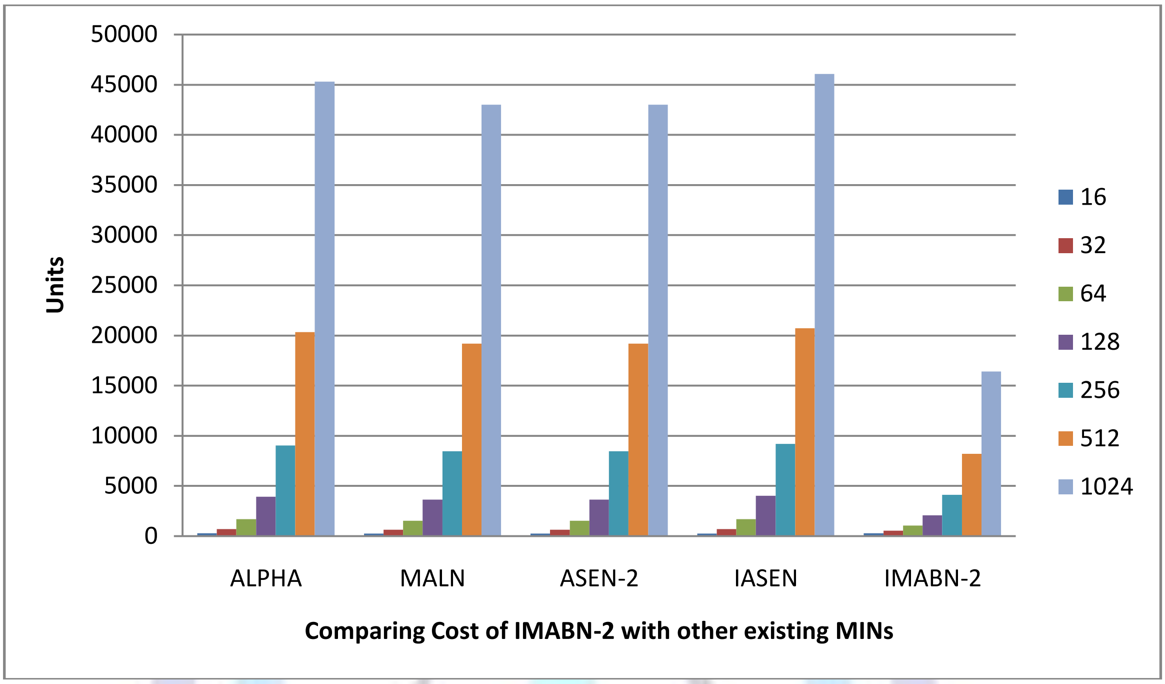

Figure 3. Comparison of IMABN–2 with existing network based on Cost

Cost of IMABN-2 can be calculated as follows:

Total number of 23 SEs = 8, cost = 48

Total number of 82 SEs = 2, cost = 32

Total number of 88 SEs = 1, cost = 64

Total number of 28 SEs = 2, cost = 32

Total number of 32 SEs = 8, cost = 48

Total number of 2:1 multiplexers = 16, cost = 32

Total number of 1:2 demultiplexers = 16, cost = 32

The total cost of MALN–2 is 288 units and the cost of MALN is 240 units. The proposed network is little more costly as compare to MALN however, it is double switch fault–tolerant and every source address of this network is able to send its request to any destination in faulty situations.

In a generalized form, we have obtained the cost of various MINs and also derived a cost formula for MALN-2. These formulas are as follows:

$$Cost_{MALN-2} = \{(14N) + \left(\frac{N}{2}\right)^2\} \quad (8)$$

Here $Cost_{MALN-2}$ is the cost of MALN-2. The cost comparison is shown in figure 4. Although MALN-2 is costly network however, it has better fault sustainability as compared to other existing MINs.

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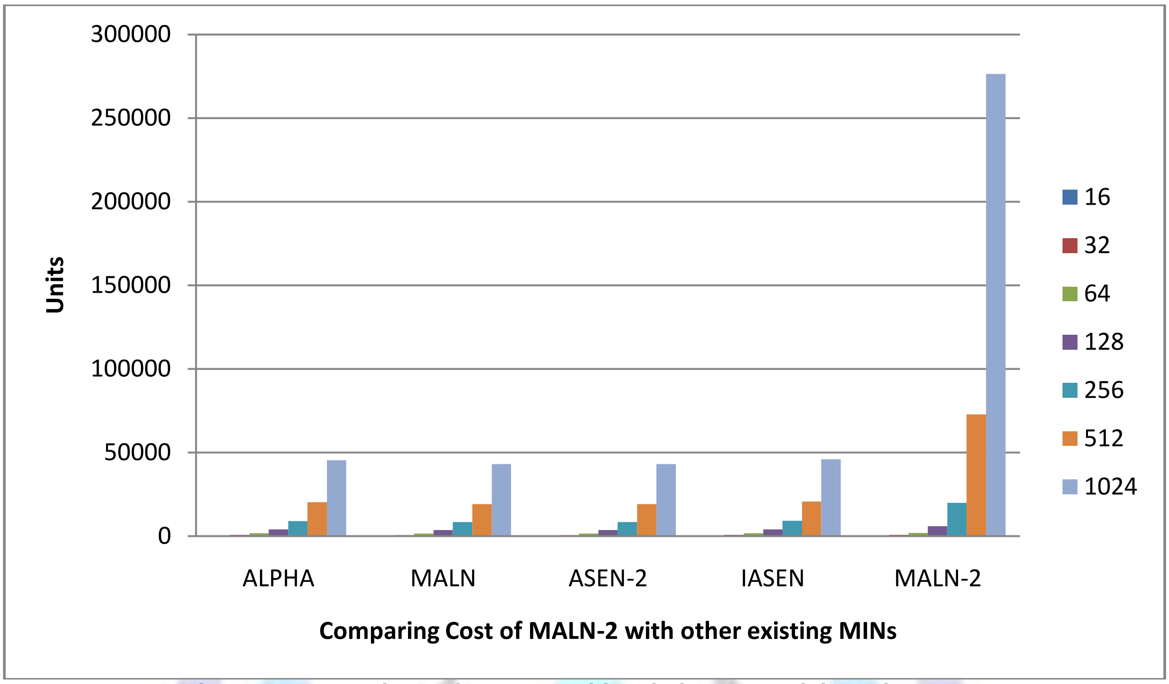

Figure 4. Comparison of MALN–2 with existing network based on Cost

PERFORMANCE COMPARISON OF IMABN-2 AND MALN-2

To evaluate the performance, we have used all the formulas which are discussed in section 3. In this simulation β is the load factor and it is assumed to be β = 0.1, 0.2, …, 0.9, 1.The performance of IMABN-2 and MALN-2 is analyzed in faulty and non-faulty network conditions. The term "faulty" indicates that single switching element is faulty in every stage simultaneously. Further, we have compare the performance of both networks for network size N = 16, 32, 64, and 128. On the basis of link capacity, we have calculated the average throughput for each load factor separately. The table (2) shows the average throughput in faulty and non-faulty network conditions.

Table 2: Average throughput of IMABN-2 and MALN-2

β	L_C (dp/ms)	NFIMABN-2(Th_{avg})	FIMABN-2(Th_{avg})	NFMALN-2(Th_{avg})	FMALN-2(Th_{avg})
0.1	50	8.33	4.54	12.5	5.55
0.2	75	12.5	6.81	18.75	8.33
0.3	100	16.66	9.09	25	11.11
0.4	125	20.83	11.36	31.25	13.88
0.5	150	25	13.63	37.5	16.66
0.6	175	29.16	15.90	43.75	19.44
0.7	200	33.33	18.18	50	22.22
0.8	225	37.5	20.45	56.25	25
0.9	250	41.66	22.72	62.5	27.77
1.0	300	50	27.27	75	33.33

Figure 5–8 shows the performance comparison of IMABN-2 and MALN-2 for network size N = 16, 32, 64, and 128 in faulty and non-faulty conditions. In all these figures, we can see that MALN-2 is better than IMABN-2 in terms of normalized throughput.

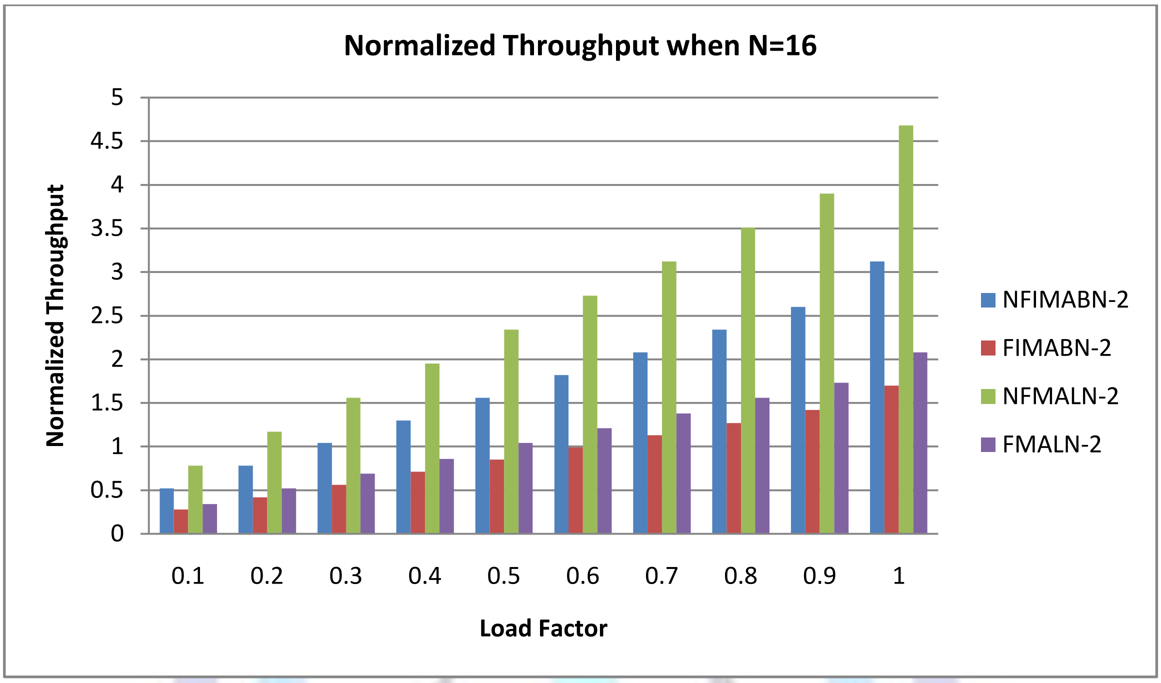

Figure 5. Performance Comparison of IMABN-2 and MALN–2 when N=16

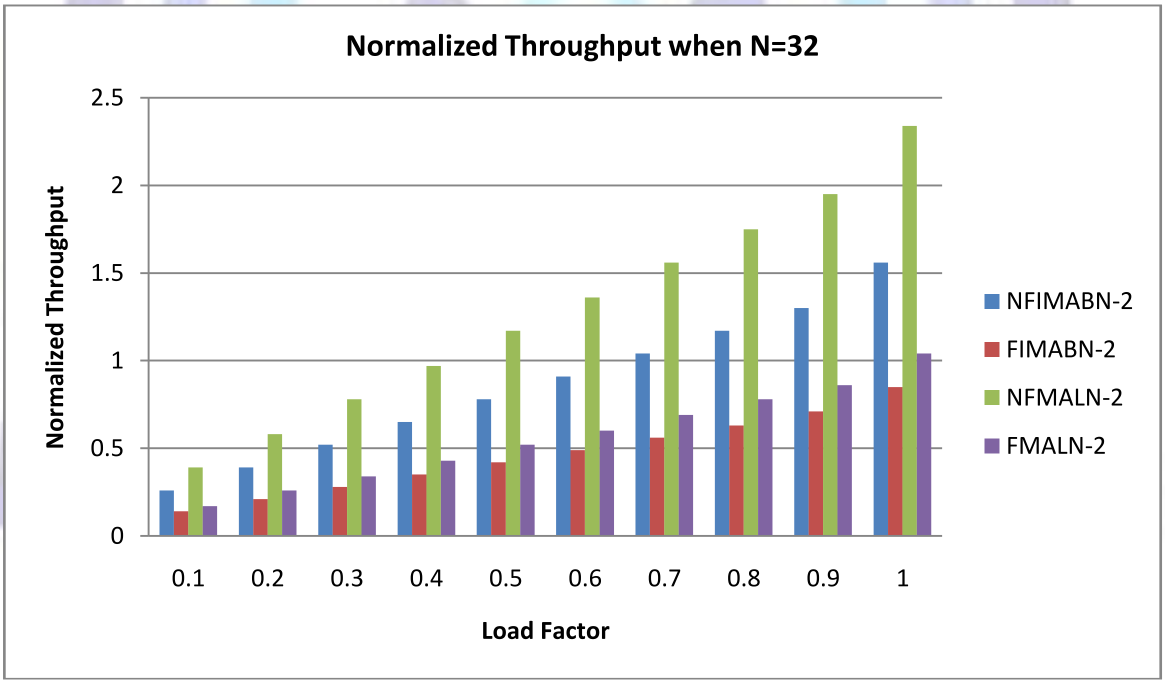

Figure 6. Performance Comparison of IMABN-2 and MALN–2 when N=32

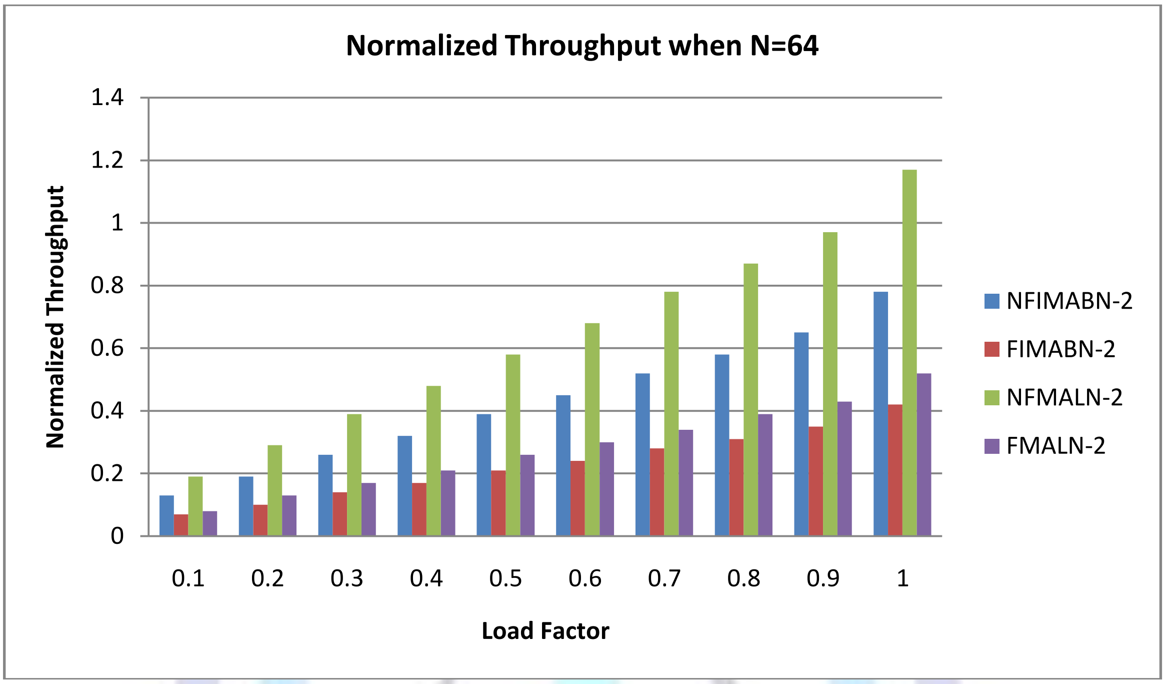

Figure 7. Performance Comparison of IMABN-2 and MALN–2 when N=64

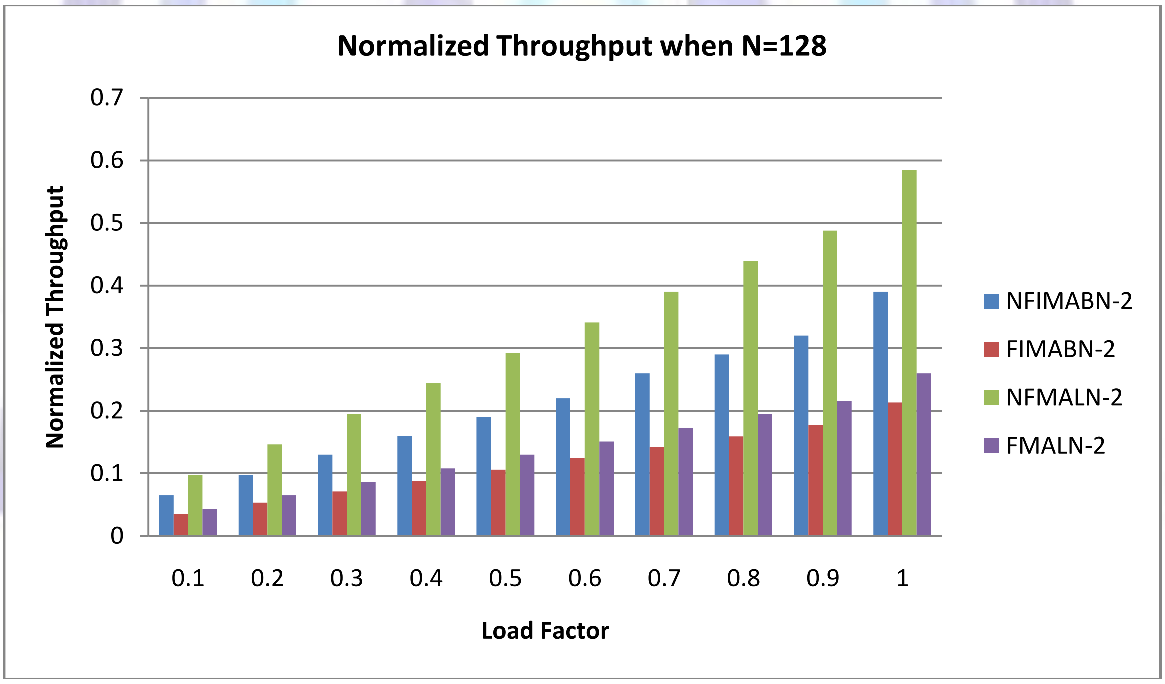

Figure 8. Performance Comparison of IMABN-2 and MALN–2 when N=128

CONCLUSION

In this paper, we have examined the performances of IMABN-2 and MALN-2 in faulty and non-faulty network conditions. Performance of MALN-2 is better than the IMABN-2. Further, cost of IMABN-2 and MALN-2 is calculated for every network size. Both INs are costly however these INs have better fault tolerability than the other INs. In future, our aim is to obtain the less costly IMABN-2 and MALN-2 INs at their same performance.

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