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Irregular Modified Shuffle Multistage Interconnection Network

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Abstract:
Interconnection networks play vital role in parallel computing environment. They define how several processors and memory modules are interlinked. The pattern used for interconnecting these functional units (processors, memory modules, switching elements) determines the performance of the system. Interconnection networks use links and switches for connecting various functional units. Multistage Interconnection Networks use various switches arranged in stages for interconnecting processors and memory modules. In this paper, a new fault tolerant multistage interconnection network named Irregular Modified Shuffle Network (IMSN) is proposed and analyzed. Fault Tolerance and Permutation Passibility behavior of IMSN is discussed in this paper.

Key Words: Multistage interconnection network (MIN), Fault Tolerance, Irregular Modified Shuffle Network (IMSN), Permutation Passibility.

INTRODUCTION

Multistage Interconnection Networks (MINs) connects processors and memory modules using multiple stages of Switching Elements (SE). Switching Elements map a fixed number of inputs to outputs. The size and the number of switching elements changes according to the design of the network. MINs are widely used for data transmission in multiprocessor systems. They provide efficient communication between functional units in parallel processing environment. A new irregular fault tolerant multistage interconnection network named Irregular Modified Shuffle Network (IMSN) is proposed and analyzed in this paper in terms of permutation passibility. Irregular network implies that the number of switching elements is not same at every stage. The latency or delay is also reduced in irregular networks. The Fault Tolerance of IMSN is also discussed.

The rest of the paper is organized as follows: Section 1 discusses various MINs proposed in literature. Section 2 discusses the construction procedure of IMSN. Section 3 outlines fault tolerance of IMSN. Section 4 entails permutation passable analysis of IMSN. It is followed by conclusion in Section 5 and references in Section 6.

1. RELATED WORK

Various Irregular Multistage Interconnection Networks have been proposed in literature. Some of MINs are described here which includes Improved Four Tree Network (IFTN) [13], New Irregular Augmented Shuffle Network (NIASN) [11] and Modified Alpha Network (MALN) [14].

A. IMPROVED FOUR TREE NETWORK (IFTN)

An Improved Four Tree Network (IFTN) [13] of size 16x16 contains total (2n+2 -8) switches, where n= log2N. There are 2n-1 switches of size 2x2 and rest of size 3x3. The two groups are formed based on the most significant bit (MSB) of the source destination terminals. Every 3 x 3 SE (switching element) in a stage forms a loop with the corresponding numbered 3 x 3 SE of other sub-network in the same stage. An IFTN network being an irregular network supports multiple paths of different path lengths.

B. NEW IRREGULAR AUGMENTED SHUFFLE NETWORK (NIASN)

New Irregular Augmented Shuffle Network (NIASN) [11] is a NxN (2n x 2n) network (where N is the number of sources and destinations, n = log2 N) which consists of m stages (where m = log2 N/2). The first and the last stage of the network consist of equal number of switching elements (SEs) that is 2n -1 each whereas the intermediate stages consist of less number of switching elements equal to (2n-2+2) each. The switches in the last stage are of size 2x2 and the rest switches from stage 1 to

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(m-1) are of size 3x3. There are 2n multiplexers of size 2 x 1 and 2n demultiplexers of size 1 x 2.

C. MODIFIED ALPHA NETWORK (MALN)

Modified Alpha Network (MALN) [14] of size N*N has N sources and N destinations. MALN consists of n stages (n=log2 N). 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. Use of these links makes the network fault tolerant. The modified Alpha network of size 2n * 2n consists of (2m- 2) stages where m=log2(N/2).This network has 2n no. of switches of size 3*3 and 2n-1 no. of switches of size 2*2.

2. PROPOSED MULTISTAGE INTERCONNECTION NETWORK (IMSN)

The structure of Irregular Modified Shuffle Network (IMSN) is shown in Figure 1. IMSN is an irregular multistage interconnection network of size NxN (2^n x 2^n) where N=16 as it has 16 sources and 16 destinations (and $n=\log_2 N$). IMSN consists of $\log_2 N$ stages and as N=16, it has 4 stages. This network consists of 2^n multiplexers and 2^n demultiplexers of size 2x1 and 1x2 respectively. The first and last stage of the network consists of 2^{n-1} switching elements (SEs) and intermediate stages consist of less number of switching elements. The second stage of the network consists of 2^{n-3} switching elements and third stage contains 2^{n-2} switching elements. The first stage of the network has N/2 switches of size 3x3, the second stage of the network contains N/8 switches of size 5x5, the third stage of the network contains N/4 switches of size 2x8 and the last stage of the network has N/2 switches of size 5x2.

The SEs of first stage are linked to SEs of second and last stage, the SEs of second stage are connected to SEs of third stage, the SEs of third stage are connected to SEs of fourth stage as shown in Figure 1. Each source is connected to SEs of first stage using multiplexers and each destination is linked to SEs of last stage using demultiplexers. The SEs at first and second stage form auxiliary links to avail more paths to each source-destination pair. They can endure faults by following any alternate path available using auxiliary links. In this network, each source is connected to 3 SEs like source 4 is connected to switching elements C, G, H. Thus each source has 1 Primary SE like C to which it is directly connected and 2 alternate SEs like G and H to which it is connected indirectly. Source, Destination, Mux, Demux and various stages are shown in Figure 1.

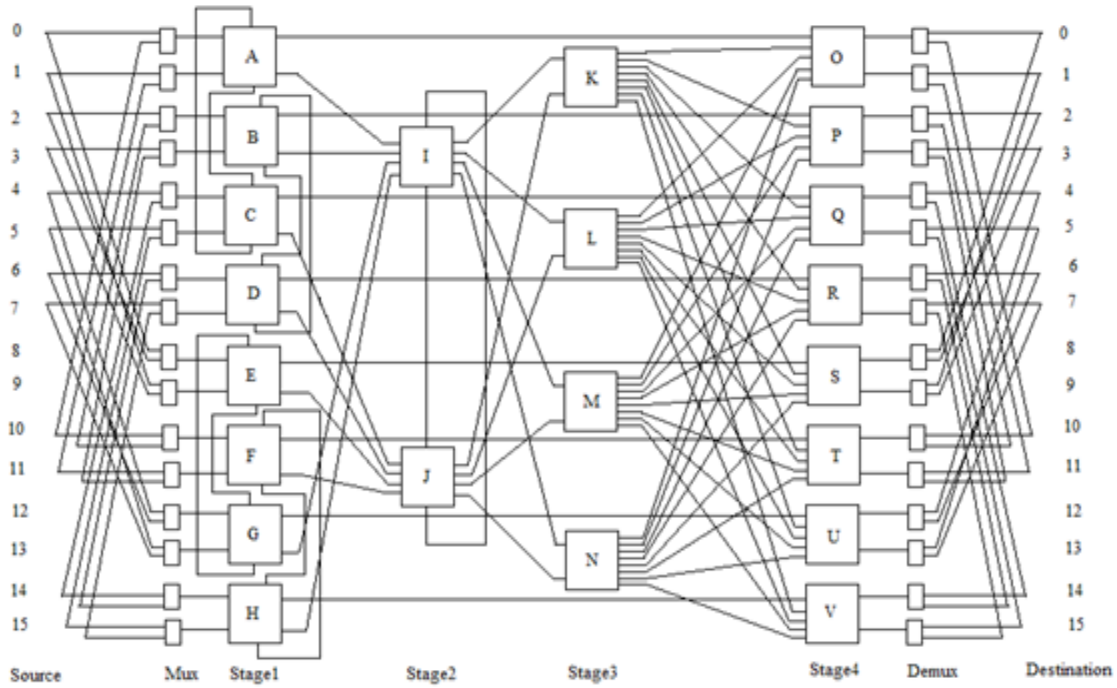

Figure 1: Irregular Modified Shuffle Network (IMSN)

3. FAULT TOLERANCE

Fault Tolerance or Endurance is the capability of the network to operate smoothly despite of presence of some faults. Faults may be like Switch fault or Link fault. Therefore, the network which operates gracefully even in presence of faults although at degraded performance is often desirable [6].

Fault tolerance is a criteria that must be met for the network to operate successfully. A network is a single fault tolerant if it can function as specified by its fault-tolerance criteria despite any single fault or fault in single switching element [14]. In general, if any set of I faults can be tolerated by a network, then network is I-fault tolerant. The proposed network IMSN fulfills the criteria of fault tolerance as it can work despite of presence of certain faults. In this network if primary path is found to be faulty, the data can be rerouted to first alternate path available. If first alternate path is also faulty, data can be rerouted again to second alternate path available. Hence it can tolerate multiple faults. Therefore, IMSN has sixteen alternative paths available. The presence of auxiliary links helps in availing more paths to source-destination pairs during data transmission so that in case the path is found to be faulty the data can be rerouted to other alternate paths available.

4. PERMUTATION PASSABLE ANALYSIS OF IMSN

Permutation Passibility defines how many of input requests are simultaneously able to pass through given MIN & reach successfully at the intended destination as they occur in different permutations. The request always prefers to pass through the most suitable path available. If the path is found to be faulty or busy then request is rerouted to alternate paths available. If no such alternate path is available then request has to be dropped or clash occurs [10]. This paper evaluates permutation as:

A. IDENTITY PERMUTATION

A one-to-one correspondence between same source and destination number is called Identity Permutation [8] [9] [10] [11] [12]. In terms of source and destination this can be expressed by:

(S0 -> D0), (S1 -> D1) ……. (Sn-1 -> Dn-1)

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)

It can be represented as shown in Figure 2:

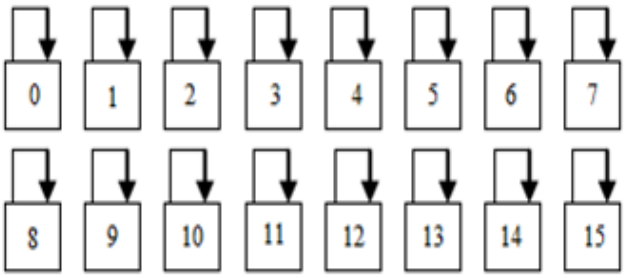

Figure 2: Identity Permutation

B. INCREMENTAL PERMUTATION

A source is connected in a circular chain to the destination in incremental permutation [8] [9] [10] [11] [12] as shown:

(S0 -> D3), (S1 -> D4) ……. (S15 -> D2)

For Example:

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

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

It can be represented as shown in Figure 3:

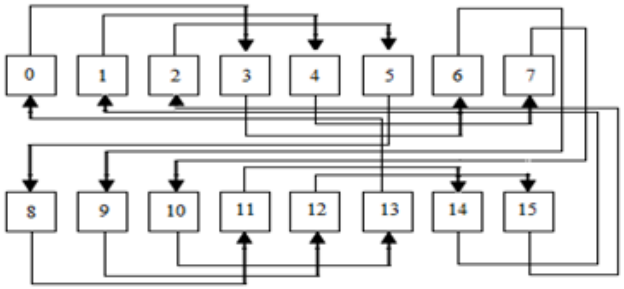

Figure 3: Incremental Permutation

In this paper, two cases are considered to find out permutation. These are:

(i) Non Critical Case: If a fault is present in a single switch.

(ii) Critical Case: If the switches are faulty in a loop.

The results of identity and incremental permutation of proposed network named IMSN are shown in tables given below. Table 1 shows the results of identity permutation of IMSN and Table 2 shows results of incremental permutation of IMSN.

Table 1: Identity Permutation of IMSN

Fault	Total Path Length	Total number of request passes	Average Path Length	(%) passable
Without	48	16	3.00	100
Mux	46	15	3.06	93
S1 A	41	14	2.92	87
S1 B	34	12	2.83	75
S2 A	32	12	2.66	75
S3 A	40	14	2.85	87
S4 A	41	14	2.92	87
Demux	46	15	3.06	93

Table 2: Incremental Permutation Of IMSN

Fault	Total Path Length	Total number of request passes	Average Path Length	(%) passable
Without	56	16	3.5	100
Mux	52	15	3.46	93
S1 A	49	14	3.5	87
S1 B	42	12	3.5	75
S2 A	40	12	3.33	75
S3 A	48	14	3.42	87
S4 A	49	14	3.5	87
Demux	53	15	3.53	93

5. CONCLUSION

In this paper, new network named Irregular Modified Shuffle Network (IMSN) is proposed and analyzed in terms of permutation passibility and fault tolerance. It is found that it has more fault tolerance than existing networks like Improved Four Tree Network (IFTN) [13], New Irregular Augmented Shuffle Network (NIASN) [11], Modified Alpha Network (MALN) [14] and permutation passibility of IMSN is found to be comparable with networks like (IFTN) [13], (NIASN) [11], (MALN) [14].

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