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On Performance Analysis of IASEN–3 in Faulty and Non–Faulty Network Conditions

Ved Prakash Bhardwaj and Nitin, *Senior Member, IEEE**

Department of Computer Science & Engineering and Information & Communication Technology,
Jaypee University of Information Technology, Waknaghat, Solan–173234, Himachal Pradesh, INDIA
ved.juit@gmail.com and delnitin@ieee.org

Abstract

This paper presents a new fault sustainable interconnection network (IN) called as Irregular Augmented Shuffle Exchange Network–3 (IASEN–3) and its routing algorithm. The Performance of IASEN–3 has been evaluated and compared with existing IASEN–2. The experimental results shows that IASEN–3 is more efficient than IASEN–2 in terms of throughput and processor utilization. These results are analyzed in faulty and non–faulty network environments.

1. Introduction and Motivation

Presence of Multi–stage Interconnection Networks (MINs) in all parallel and distributed computing applications makes them fast and reliable. The efficiency, cost and various other factors makes it better and more robust than the other INs [1, 2]. Sometimes, MINs faces the faulty situations during data transmission process [2–5]. This situation may arise due to any link failure or any switch failure. Both conditions create disturbance in the network and degrade the performance of network [3–8]. This paper deals with the switch failure problem and presents a new IN named Irregular Augmented Shuffle Exchange Network–3 (IASEN–3). The IASEN–3 performs well in case of multiple faulty switching elements (SEs). The designed pattern of IASEN–3 is inspired by IASEN–2 [8] and therefore, performance of IASEN–2 is compared with IASEN–3 on

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* Nitin Tel.: +91-1792-239-369; fax: +91-1792-245362.
E-mail address: delnitin@juit.ac.in

the basis of various performance parameters. Data packets are transmitted through IASEN–2 [8] and IASEN–3 to a preset number of destinations. Results show that IASEN–3 has better throughput and processor utilization than the IASEN–2 [8] in faulty and non–faulty network scenario.

The rest of the paper is structured as follows: In section 2, structure of IASEN–3 is discussed. Section 3 shows the routing algorithm. In section 4, the performances factors are explained. Results are shown in section 5. At last, section 6 is followed by conclusion and references.

2. Proposed Interconnection Network

The structure of Irregular Augmented Shuffle Exchange Network–3 is based on IASEN–2 [8]. In Fig. 1, we can see that it has 16 sources and 16 destinations, hence the size of IASEN–3 is N =16. All the sources and destinations are tightly coupled with the complete network through multiplexers (Mux) and demultiplexers (Demux). This is a 3–stage MIN. In first and last stage, each source or each destination is connected with three switching elements (SEs) of that particular stage e.g. source 11 is connected with SE *f*, *a* and *d* and therefore *f*, *a* and *d* are the primary, first alternate and second alternate SEs for source 11. Similarly, we can find out the primary, first alternate and second alternate SEs for other sources and destinations. The size of each SE in first and third stage is 2×3 and 3×2 respectively. In stage 2, the size of each SE is 8×8.
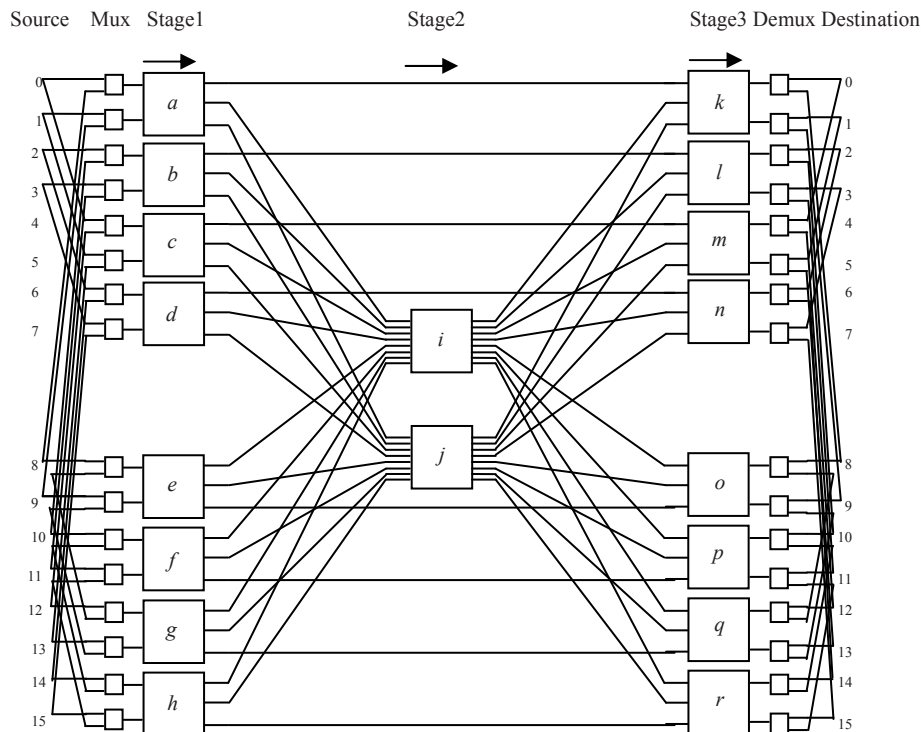

Fig. 1. irregular augmented shuffle exchange network–3

3. Routing Algorithm of IASEN–3

In the routing algorithm of IASEN–3, if request arrives at the primary SE of first stage (PSE$_1$) or primary SE of third stage (PSE$_3$), then we have to check that SE. If it is busy or faulty (FBY) then first alternate SE

(AE1) will get the request of that particular stage. If AE1 is busy or faulty then request will be arrived at second alternate SE (AE2). In case all the SEs i.e. PSE_1, AE1 and AE2 of first stage or PSE_3, AE1 and AE2 of third stage are not responding properly then request will be dropped. If request arrives at SE i of second stage and it is busy or faulty then SE j of second stage will receive the request. If it is also busy or faulty then request will be dropped. Finally, we can say that, if the required SEs of all three stages are in working condition then data will be transmitted from the given source to its given destinations otherwise data transmission process will be stopped. In third step of algorithm the term "Node" may be the SE of second stage or the given destination.

Algorithm_IASEN–3

Input: N, Source, Destinations
Output: Data Packets Reached Successfully or Drop the Request

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BEGIN
    1.   **if** $PSE_1 == FBY \,||\, PSE_3 == FBY$ *// FBY means busy or faulty*
    2.   **then** *AE1*
    3.   **else** *Send Request to Next Appropriate Node*   *// Here Node may be SE or destination*
    4.   **if** *AE1* == *FBY*
    5.   **then** *AE2*
    6.   **else** *Send Request to Next Appropriate Node*
    7.   **if** *AE2* == *FBY*
    8.   **then** *Drop the Request*
    9.   **if** $i == FBY$
    10.   **then** *j*
    11.   **else** *Send Request to Appropriate SE of Third Stage*
    12.   **if** $j == FBY$
    13.   **then** *Drop the Request*
    14.   **else** *Send Request to Appropriate SE of Third Stage*
End

Theorem: IASEN-3 is a single switch fault tolerant network in every stage.
Proof: Let the source is 2 and destinations is 9. We assumed that SEs *b*, *i*, and *o* are faulty. In this situation the rest of the paths are as follows:
Path 1: 2-6-Mux-d-j-k-Demux-1-9
Path 2: 2-10-Mux-f-j-k-Demux-1-9
Path 3: 2-6-Mux-d-j-q-Demux-13-9
Path 4: 2-10-Mux-f-j-q-Demux-13-9
These available paths prove that IASEN-3 is a single switch fault tolerant network in every stage.

4. Performance Evaluation Parameters

This section discusses the various performance factors of IASEN–2 and IASEN–3.

4.1. Bandwidth (BW)

"BW is defined as the expected number of destination receiving requests in any given cycle. It means it is the total number of requests matured [5– 7]". It is calculated as follows:

$$BW = (N_{DN} \times p_n) \tag{1}$$

Here $p_0 = p$, p_0 is the request generation probability and N_{DN} is the total number of destinations. The general probability equation can be written as:

$$\left[1 - \left(1 - \frac{p}{b}\right)^a\right] \tag{2}$$

Here a & b are the total number of inputs and output lines of a SE respectively.

Probability equation for IASEN–2

$$p_1 = \left[1 - \left(1 - \frac{p}{2}\right)^2\right] \tag{3}$$

$$p_2 = \left[1 - \left(1 - \frac{p_1}{6}\right)^{\left(\frac{N}{2}\right)+1}\right] \tag{4}$$

$$p_3 = \left[1 - \left(1 - \frac{p_2}{\left(\frac{N}{2}\right)+1}\right)^3\right] \tag{5}$$

$$p_4 = \left[1 - \left\{(1 - p_3) \times \left(1 - \frac{p_1}{2}\right)\right\}^2\right] \tag{6}$$

Here $p_n = p_4$ and therefore $BW_{IASEN-2} = (N_{DN} \times p_4)$.

Probability equation for IASEN–3

$$p_1 = \left[1 - \left(1 - \frac{p}{3}\right)^2\right] \tag{7}$$

$$p_2 = \left[1 - \left(1 - \frac{p_1}{\left(\frac{N}{2}\right)}\right)^{\left(\frac{N}{2}\right)}\right] \tag{8}$$

$$p_3 = \left[1 - \left\{(1 - p_2) \times \left(1 - \frac{p_1}{2}\right)\right\}^3\right] \tag{9}$$

Here $p_n = p_3$ and therefore $BW_{IASEN-3} = (N_{DN} \times p_3)$.

4.2. Message Transmission Time (tt)

It is the time that all generated data packets will take from a given source to a single destination. It is given by the following formula:

$$tt = [D_N \times N_{DN} \times \{t \times (T_s + 1)\}]$$ (10)

$$tt_F = [(t \times T_s) + tt]$$ (11)

D_N: Total number of data packets
T_s : Total number of stages in the network
t: Routing time between two nodes and node may be source, destination or any SE.
tt_F: Transmission time when single SE is faulty in every stage of the network

4.3. Throughput(TP)

*"TP 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 [5–7]".*TP can be calculated using the given formula:

$$TP = [BW/(N_{DN} \times tt)]$$ (12)

4.4. Processor Utilization(PU)

*"It is defined as percentage of time the processor is active doing computation without accessing the global memory [5–7]".*PU can be calculated using the given formula:

$$PU = [BW/(N_{DN} \times tt \times p)]$$ (13)

5. Performance Comparison of IASEN–2 and IASEN–3

In order to compare the performance of IASEN–2 [8] and IASEN–3, message multicasting is performed in faulty and non–faulty network condition. Let the source is 5 and it has transmitted the data packets to destinations 1, 3, 5, 9 and 11. Data is transmitted in non–faulty and single switch faulty conditions. In this paper, we assumed that routing time (t) of a data packet is 0.01 ms in non–faulty case and 0.02 ms in single switch faulty case. In this research work, both terms "Single switch faulty" and "faulty" represents that single switch is faulty in each stage during the transmission of data packets. The offered load or request generation probability is p and it is assumed to be $p = 0.1, 0.2, …, 0.9, 1$. Data packets are generated on the given probabilistic values and then sent to destinations 1, 3, 5, 9 and 11. As explained in equation (10) and (11), we will calculate the transmission time of IASEN–2 [8] and IASEN–3 in faulty and non–faulty cases. Equations of section 4 are used to calculate the throughput and processor utilization of IASEN–2 [8] and IASEN–3 in faulty and non–faulty condition. IASEN–2_F and IASEN–3_F are the IASEN–2 and IASEN–3 in faulty case as shown in Fig. 2. On the basis of the bandwidth, TP of IASEN–2 and IASEN–3 have been calculated.
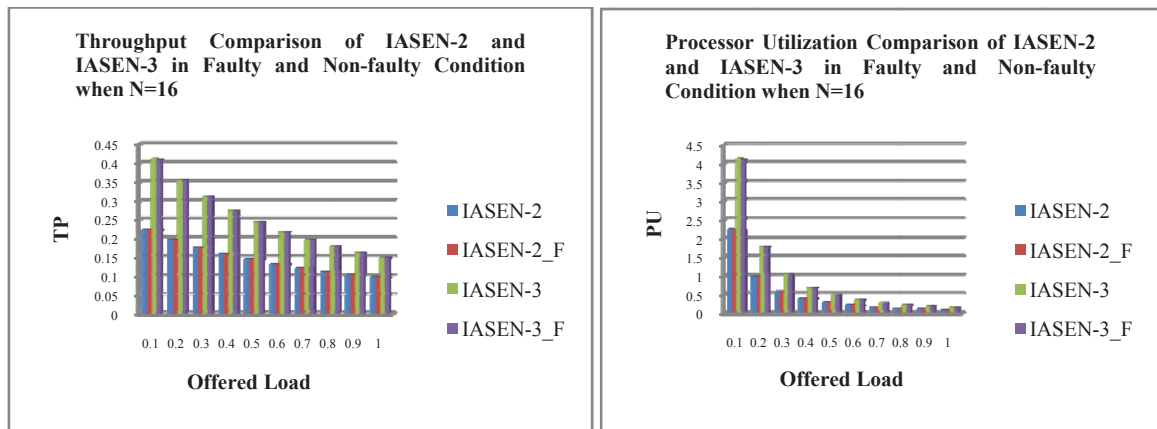
Fig. 2. throughput and processor utilization comparison

6. Conclusion

In this paper, we have examined the performance of IASEN–2 and the proposed MIN in faulty and non–faulty network conditions. Data packets have been transmitted through IASEN–2 and IASEN–3 and in both conditions it is seen that IASEN–3 produces results that are better than IASEN–2. The theorem and routing algorithm makes it reliable and more fault tolerant as compared to IASEN–2. Future work may include the following things:

- Generalization of IASEN–3,
- Comparison of performance parameter of IASEN–3 and IASEN–2 at network size 32, 64 and 128.

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