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Mean Time to Failure Analysis in Shuffle Exchange Systems

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Abstract: Multistage Interconnection Network (MIN) has been researched for the interconnection implementation of switches and multiprocessors. The topology of the interconnection, the number of stage and the switching element used in the network distinguish between each MIN's tolerance of failure.This paper introduces a topology called Replicated Shuffle Exchange Network and Replicated Augmented Shuffle Exchange Network. A replicated technique is described for making the network more reliable. The replicated technique results in reduced the Mean Time to Failure in the network. Performance measurement shows that replicated network achieve a significant improvement over a basic network have been measured.

Keywords: Multistage Interconnection Network, Shuffle Exchange Network, Reliability, Mean Time to Failure, Replicated Network.

I.INTRODUCTION

Multistage Interconnection Network (MIN) offers an attractive way to implement an efficient packet switches distribution in communication networks. MINs provide a simplified routing control through a unique route characteristic from any input to the output port.Due to the unique path property the failure of any single switch or link in the MIN can disconnect several inputs from several outputs and leads to a lack of fault tolerance (Kumar & Reddy, 1987). With a rapid progress in the field of multiprocessing, a demanding focus requires to be placed on multipath networks. When the amount of stages and system complexity increases the efficiency of reliability becomes a major issue. (Bistouni & Jahanshahi, 2014a).Hence, the efficiency of reliability has become a problem for in MINs communication. Mostly the basic networks provide a lower reliability performance as compared to modification networks. Replicating is a technique to generate a redundant route by replicating the network into *L*layer with the benefits of an additional links(Bistouni & Jahanshahi, 2015). Compared to the basic network, the increasing number of layers in replicated MINs possibly will improve the reliability performance(Yunuset al, 2018).

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In this paper we present a replicating method to create an alternate path between each source and destination to reduce the failure rate in the network. The measurement performance used in this paper is based on the mean time to failure in the network communication.

II.RELATED WORKS

A number of reliability and fault tolerance techniques have been suggested to increase the reliability and fault tolerance. The basic fault tolerance initiative is to provide various routes for a source and destination pair(Gunawan & Fard, 2012). The switching network is made up of a with a large amount of switching nodes, therefore the velocity of the switching control over the entire network relies on how it is distributed (Yunus et al., 2016). MINs is capable to ensureat least one substitute path available to use when there is a collision or fault in order to maintainthe reliability of the load (Nitin et al., 2011). The evaluation of the reliability of a large range network might be very tedious, since there could be many substitute routes involving in two specific switching elements.Previously, the replicating approach has been applied to create a multipath MINs (Newman, 1988). The multipath MINs between each input and output in a network are provided by connecting the switching elements in the same stage (Hafizur Rahman et al., 2013). While several number of multipath MINs have been built that provide fault tolerance, the challenge in accepting new fault tolerant MINs to improve efficiency and reliability become an important issues(Varma & Raghavendra, 1989). In multipath MINs systems, it is clear that the existence of extra paths, between each processor and memory increase the performability of the system (Adam III et al., 1987).Shuffle Exchange Network (SENs) connecting the input and output devices through the combination of switching stages. It can be simply referred as a 2 × 2 topological. Switching element could be transmitting between input and output neither straight nor exchange connection(Yunus et al., 2018). Basically, SENs consist of N =2^nnamely as sources and destinations. SEN was built up with $log_2 N$ stages with N/2 switching element for each stage. In this network, the address shifts one bit to the left circularly in the connection. Each source and destination provided with a unique path properties. The Augmented Shuffle Exchange Network (ASEN) is a self-routing network.ASEN have $log_2 N - 1$ stages and N/2 switching element. Implementation of thethe loops as modules makes it simpler for ASEN to preserve and repair any failure within the network. ASEN is not restricted to a single switch fault, but expands to faults that affect all switches in a particular loop.

It is possible to remove the loop containing the defective switch from the network and insert a substitute loop without interrupting the network operation(Bistouni & Jahanshahi, 2014b).

III.REPLICATING METHOD

In this section, by replicating the network on topology of SENs, we suggested a new configuration called the Replicated Shuffle Exchange Network and Replicated Augmented Shuffle Exchange Network. Compared to the regular MINs, the replicated MINs lead to the out of order packet sequence due to the availability of multipath for each source and destination pair. Increasing the number of layers in replicated network will lead to reliability improvements in the network for reliability purposes. The system can be described as a parallel system since the system consists of two series processes in parallel network.

Replicated Shuffle Exchange Network

Replicated SEN extends the regular SEN by replicating the network into L time. As shown in Figure 1 the respective input and output were linked synchronously. Packets received by the inputs of the network and distributed throughout the layers. Each series system is comprises$\log_2 N$ of SE. The rationale to sending packets belongs to the same source is to avoid packet order destruction (Soni et al., 2014). The multiplexer will chooses which packet to select for data transmission according to its scheduling algorithm.

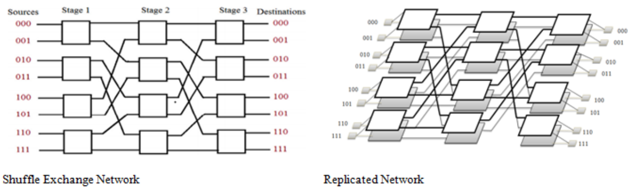

Fig. 1 Replicated Shuffle Exchange Network

Replicated Augmented Shuffle Exchange Network

Replicated ASEN adopted the ASEN topology to create the multipath MINs, however there is some modification, this network applied the replicating method by replicate the network into $L = 2$ layer to create the redundant path and increase the reliability performance. Each source has primary multiplexer and secondary multiplexer. If either of the main components is faulty, the request is sent to secondary multiplexer. This strategy essentially enables a network to detect failure and re-route the request whenever possible. Figure 2 show the three dimensional view of the Replicated ASEN with two layers of replication.

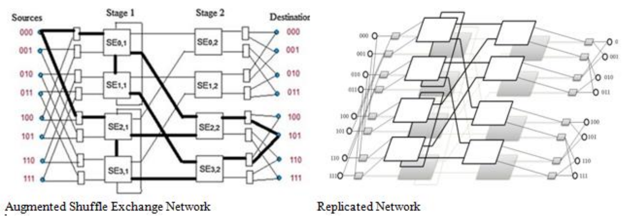

Fig. 2 Replicated Augmented Shuffle Exchange Network

IV.PERFORMANCE ANALYSIS

An interconnection networks reliability is used to assess a systems capability to transmit the data from input to output (Saini et al., 2013). Reliability is described as the probability of a device performing its necessary function for a particular period of time under specified circumstances. The reliability block diagram is a method used to analyze systems and assess their reliability. The blocks represent the groups of components or the smallest entities of the system, which are not further divided. If the individual components of a system are connected in series, the failure of any component causes the system to fail. If the individual components of a system are linked in parallel, any component defects cause the system to fail(Čepin, 2011).

If E_i is the event that component C_i is operating at time t, then the reliability of the system may be written as:

$$R = P[E_1 * E_2, \dots, E_i, \dots, E_n] \; [1]$$

If all the events are independent of each other, then the reliability may be expressed as:

$$R = \prod_{i=1}^{n} P[E_i] [2]$$

If E_i is the event that component C_i is operating at time t, then the reliability of the system may be written as:

$$R = P[E_1 + E_2 + \dots + E_i + \dots + E_n] [3]$$

If all the events are independent, then the reliability may be written as:

$$R = 1 - \prod_{i=1}^{n} P[\overline{E_i}] [4]$$

Therefore, the equation used to calculate the terminal reliability performance for each topology can be derived as follows:

$$SEN = r^{\log_2 N} \; [5]$$

$$ASEN = 1 - [1 - (r^{(\log_2 N)-1}[1 - (1 - r^2)(1 - r^3)])]^2 [6]$$

$$R.\ SEN = 1 - (1 - (r^{\log_2 N}))^2 [7]$$

$$R.ASEN = 1 - (1 - (1 - [1 - (r^{(\log_2 N)-1} [1 - (1 - r^2)\,(1 - r^3)])]^2)^2 [8]$$

The Mean Time To Failure (MTTF) can be described as the time anticipated to pass before disconnecting some source from any destination(Yunus et. al, 2019). The MTTF can be obtains for the MINs by incorporating their time with the reliability features from 0 to infinity. We assume that switch failures occur independently in a network with a failure rate of λ for 2×2 crossbar switches so that their reliability is $R(t) = \exp(-\lambda t)$. Let $\lambda = 10^{-6}$/hour, and $R(t)$ = terminal reliability for each network. The network size measurement ranges from 8 to 1024. The MTTF of the MINs is estimated by taking the average of the time to failure for the overall simulations run.

$$MTTF = \frac{time}{reliability} = \frac{\lambda}{R(t)} [9]$$

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V.RESULTS AND DISCUSSION

The improvement in the performance of mean time to failure is discussed in this section. The results of the performance improvement of replicated network over regular network are shown in Figures 3-5. For overall performance, The Replicated ASEN achieve the lowest mean time to failure for each comparison have been performed. The replicated network provide more paths between each source and destination pair as compared to regular network. As a result, the Replicated SEN and Replicated ASEN attain better fault tolerance characteristics.

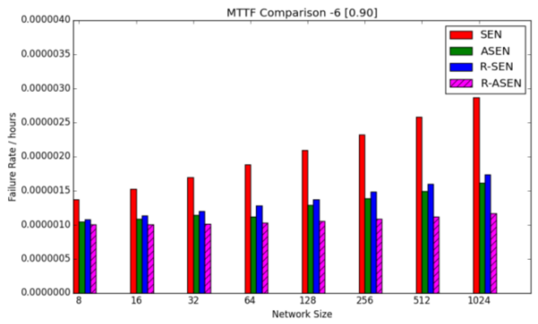

Fig. 3 MTTF Comparison for 0.90

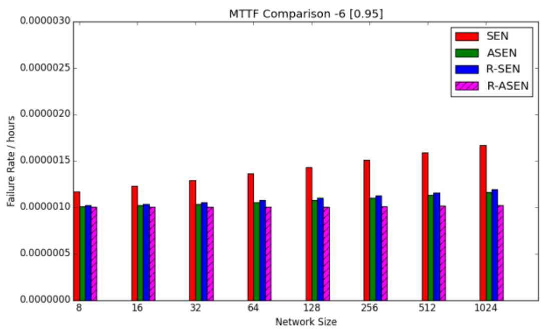

Fig. 4 MTTF Comparison for 0.95

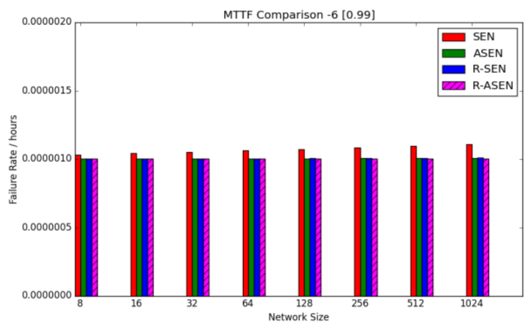

Fig. 5 MTTF Comparison for 0.99

For overall MTTF comparison it is shown that in Figure3 SEN has the highest failure rate in the network as compared to other networks. In contrast with SEN, the Replicated ASEN has the lowest failure rate in the network due to the availability of an additional auxiliary links to route the message from source to destination in the network.The existing of lesser path in the SEN topology provides an inefficient communication in the network. Since the failure of any path in the network will lead to the failure of entire systems.For replicated topology, the results indicate MTTF for Replicated ASEN is superior compared to Replicated SEN as shown in Figure 4. The advantages of redundant paths in the Replicated ASEN decrease the failure rate in the network. The result shows the failure rate of the Replicated ASEN and Replicated SEN is lowest to ASEN and SEN topology due to the network offers redundant paths to prevent the network from failure.In general, when the size of the network increase it will increase the failure rate in the network. However, it is shown in Figure 5 the multipath network provide less failure rate as compared to single path network. It can be conclude that for each sizes comparison the multipath ASEN, Replicated SEN and Replicated ASEN has a lowest failure rate as compared to single path SEN. It can be seen the failure rate for ASEN is equal to both replicated network. Despite the equal failure rate in the network the replicated network for both network lead to highest reliability performance for ASEN and SEN topology. The advantages of an auxiliary link and redundant path providing from the replicated network help to decrease the failure rate in the network.

VI.CONCLUSION

In this paper we analyzed the replicating method in shuffle exchange network and augmented shuffle exchange network. The result shown in this paper concludes that the replicating methodsachieveda significant fault tolerance as compared to regular network. The analysis showed that the Replicated ASEN provides a better performance in general and more reliable compared to others network. Therefore, for the conclusion we can summarize that the failure rate of replicated network is the lowest as compared to the regular network have been measured in this paper.

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