Abstract

Experience with the design and use of parallel computers of various sorts over the past few decades indicates that the ultimate utility of a parallel computer (among other things) is largely dependent on the properties of the interconnection network that connects processors to memory or processors among themselves. Therefore, the dependability of such computing structure greatly depends on the dependability of its interconnection networks. Hence, the quantitative evaluation of dependability should be an integral part of the interconnection architecture design. Based on a system's characteristics, either reliability or availability describes its dependability. Achieving both high performance and dependability, makes the process of system design very complex. However, through modeling, a system designer can assess whether a design meets dependability requirements, identify design bottlenecks, and select an appropriate architecture.

Based on interconnections, parallel/distributed systems are broadly classified into two categories: shared memory multiprocessors and distributed memory multicomputers. A shared memory multiprocessor consists of a large number of processors connected to a large number of memory modules through a circuit switched interconnection network. Prominent candidates of this category are: Multiple Shared bus, Crossbar, Multiport Memory and Multistage Interconnection Network (MIN). In a multicomputer, however, each processor has its own private memory, and message/packet switching is used for communication between the processing modules (nodes). Hypercube and Star graphs are the two important examples of multicomputer topology.

The objective of this thesis is to study and compare the dependability of different representative parallel computing networks on a common platform, under similar assumptions. The study has required modification of a few existing techniques and development of some new ones, in a manner suitable to obtain the required results in a simpler and computationally more efficient way.

The thesis contains eight chapters. The first chapter is introductory, which contains a brief research background, motivation and objective of the present work.

Chapters II-VII are devoted to the modeling and analysis of different parallel computing networks. Brief summary of the contents of each chapter follows.

Chapter II of this thesis uses graph-theoretic concepts to evaluate the dependability of multiprocessor interconnection networks. Two methods are proposed in this chapter. The first method is based on the connection matrix approach. Various dependability measures of importance; Terminal reliability, Multiterminal reliability, Broadcast reliability, Multicast reliability, K-Network reliability and Network reliability are defined, evaluated and then compared for Generalized cube, Extra-stage cube, Baseline and Augmented baseline network. The later part of this chapter presents a new, but efficient method of computing dependability of MINs, through stage-wise decomposition of the system graph. Using the proposed method, path enumeration is accomplished without computing the higher powers of the connection matrix. This helps in saving a considerable amount of computation time. Both the approaches have been illustrated separately through simple examples. Numerical results for various multiprocessor networks are presented.

Chapter III of the thesis presents graph-theoretic methods to compute various dependability measures of interest: Connectibility, Capacity related reliability and Distance reliability of some important multicomputer networks. A method based on the spanning tree approach is proposed in the first part of Chapter III, to compute the connectibility of multicomputer networks. Utilising the proposed approach, several networks are compared with respect to their connectibility. Evaluation of the 'capacity related reliability measures' for multicomputer networks has been taken up next. In addition, Chapter III discusses on the distance reliability aspect and presents a method to evaluate it for some multicomputer networks. All the three methods of this chapter are illustrated through simple examples. Numerical results are presented.

Chapter IV, addresses the task based dependability aspect of multicomputers. The first part proposes two algorithms to generate Markov states of multicomputers and presents a task-based model for dependability analysis of these systems. Separate models are constructed and analysed for different multicomputer networks to compare the task-based measures of some multicomputer networks. The later part of this chapter implements an existing analytical method for evaluating the task-based reliability of crossed cube network. All the approaches presented in chapter IV, are illustrated through simple examples.

Chapter V of this thesis is an attempt in the direction of computing bounds on dependability for parallel computing networks. First part of this chapter proposes upper bound and lower bound measures on reliability and derives expressions for two fault-tolerant MINs upto a size of 1024×1024. The lower bound is compared with the exact solutions to ensure that it is a closer approximation. Based on the bounds other useful measures such as : cost, percentage reliability improvement, reliability-cost benefit ratio are introduced to make comparisons among the above MINs. The later part of the chapter V, develops combinatorial methods to compute lower bound on connectibility and terminal reliability of crossed cube and star-graph based multicomputer networks. The proposed methods exploit the recursive properties of the networks for computation of connectibility and the disjoint-path techniques for obtaining the lower bound on the terminal reliability.

In Chapter VI, uncertainty analysis of parallel computing networks has been carried out. The first part of the chapter proposes a fuzzy probability method for computing the dependability of MINs. Formulae for arithmetic operations on extended fuzzy numbers with continuous membership functions are derived using operations on bound-points of all α−level set intervals. Based on the proposed approach, dependability measures such as fuzzy terminal reliability, fuzzy broadcast reliability and fuzzy network reliability of MINs are computed. Further, Chapter VI presents a method to evaluate fuzzy dependability of multicomputer networks by incorporating fuzzy concepts. Here, the success and failure events are viewed as fuzzy. Fuzzy dependability of various multicomputer networks have been evaluated utilising the proposed technique.

A new, but cost-effective and dependable multicomputer network called star-cube is proposed in chapter VII. Various salient features such as node-disjoint path, fault-tolerant routing, fault-free routing, one-to-all and all-to-all broadcast have been illustrated. It is shown that the degree and diameter of the proposed network lies between the hypercube and star, and it outperforms the hypercube from the cost view point. Other important parameters based on which we compare the star-cube with its parent networks are; Cost of one-to-all, all-to-all broadcast, cost-effectiveness factor, time-cost-effectiveness factor and dependability. Comparisons establish the advantages of the proposed network over existing ones.

Finally, Chapter VIII presents a summary of the important findings and concludes the thesis. In short, the thesis is an attempt in the direction of providing a basis for dependability analysis of parallel computer interconnection networks. It is hoped that this work will serve as an useful tool for the system designers, thereby, making their tasks simpler and easier.