ABSTRACT

Fault tolerant computing is an enabling technology for many current and future application areas and is becoming increasingly pervasive. The next generation fault tolerant systems must be designed to be dynamic, predictable and flexible in order to be able to deal with non-deterministic fault-prone environment. The hybrid redundancy, distributed and cluster systems are natural candidates for satisfying such requirements due to their potential for high performance and reliability. This demands efficient modeling techniques addressing fault tolerance issues in such computing systems.

The main objective of this thesis is to provide a complete solution to the reliability problem in hybrid redundancy, distributed and cluster systems. The attempt to reach this objective is based on hardware redundancy. For hybrid redundancy systems (HRS), two approaches are used to obtain the dependability measures. In the first approach, a semi-Markov model is developed to permit non-exponential distributions for transitions between states, as it is important to realize that in many real life situations the life times and repair times are not necessarily exponential. A comparative analysis of HRS and various N-modular redundancy (NMR) systems is given. The results show that HRS has greater advantage compared to NMR systems. An application of HRS in homogeneous distributed systems is given. The optimal degree of replication is determined such that the availability and mean time to
failure of the distributed system is maximized. Furthermore, the degree of replication for each application category is obtained.

In the second approach, a Markov model is developed and the dependability measures are obtained. It is difficult to evaluate the failure rates from past experiences, because of the dynamic environments of systems and more so in many situations where past experiences do not exist. Thus the failure rates and repair rates are represented as fuzzy numbers. The fuzzy reliability measures are obtained using fuzzy methods. Further, a comparison of fuzzy results and crisp results of HRS is obtained. It is proved that fuzzy availability and fuzzy reliability indices provide a better overview of system availability and system reliability compared to the conventional Markov method.

The distributed systems are of two kinds namely homogeneous and heterogeneous depending on whether they are made up of similar or dissimilar nodes. A Markov model of homogeneous distributed software/hardware system (HDSHS) is developed and dependability measures are obtained. The availability of HDSHS is improved by 34% in comparison with the availability obtained by Lai et al (2002). A Markov model for the heterogeneous distributed system (HDS) is also developed. The HDS has a circular consecutive $k$-out-of-$n:F$ configuration. At least $k$ out of the $n$ online hosts must fail consecutively for the HDS to fail. Each node in the HDS has access to a single repair facility. This configuration of HDS is the first of its kind which integrates fault tolerance at the system level rather than
at the application level. Dependability measures such as reliability, availability and mean time to failure are obtained.

A distributed system is a type of cluster system, which is a collection of computers in which any member of the cluster is capable of supporting the processing functions of any other member. Although active/standby cluster systems comprise of servers with different performance levels, most researchers have only analyzed them by developing the traditional binary state reliability models. In this thesis, a Markov model of the active/standby cluster system is developed and the multistate performance measures are obtained.

In conclusion, a variety of fault tolerant systems are modeled and analyzed to improve their availability and reliability measures. Furthermore, the usefulness of these systems is demonstrated. Indications to further research directions in the fault tolerant systems are also provided.