CHAPTER-VI

CONCLUDING OBSERVATIONS
CHAPTER VI

CONCLUDING OBSERVATIONS

In this chapter we have critically reviewed in brief the work presented in the earlier chapters of the thesis and drawn certain conclusions. In this thesis, we have primarily studied the reliability and availability of software systems based on the architectures of the systems. The possible directions, along which further research work on the topics that can be carried out, are also discussed in brief. The industrial significance and limitations of the present work are also mentioned.

6.1 REVIEW OF THE PRESENT WORK AND RESULTS

We have primarily discussed the architecture based reliability and availability of some software systems using Markovian approach. In Second chapter, analysis of reliability and availability for web-based software system with three tier architecture is carried out. The mathematical formulation of Chapman-Kolomogrov differential equation, determining the reliability and availability of the web-based software system, is then developed. As the Chapman-Kolomogrov differential equation is mathematically complex system of linear differential equation and is not solvable using any analytical method. Hence in this thesis, we have used numerical methods earlier used by Gupta et al. (2005) to compute reliability of some process industries. The behavior analysis of the
system is then carried out for various combinations of repair and failure rates of the sub-
systems assuming failure and repair rates as constant. Following the approach of Gupta et
al. (2005), the system of differential equations together with initial condition has been
solved numerically using Runge Kutta fourth order method, assuming step size $h=0.005$
as one hour. The reliability of the web-based system for various combination of failure
and repair rates of the subsystems has finally been computed. In steady state, the system
of linear equation together with the normalized condition, have been solved numerically
using Gauss elimination method. The availability of the system has been calculated for
various combinations of failure and repair rates of the subsystems and finally, sensitivity
analysis of availability of system to software failure rates of application server, database
server and router software are carried out. The results reveal that the maximum affect on
the MTBF, reliability and availability of the system is due to variation in software failure
and repair rates of application server as compare to database server and router. Thus in
order to maximize the reliability and availability of the web-based software system, the
failure rates of application servers should be minimized by and the repair rates should be
maximized. To achieve this, level of redundancy should be increased in case of
application servers.

There are some parameters like software failure and repair rates, which are either
cannot be accurately measured in limited time frames through testing, or may vary on
different customer sites. Therefore, an attempt has been made in chapters three, four and
five to carry out fuzzy reliability and availability analysis of Sun Java System
Application Server, router software system and clustered architecture system to
incorporate such uncertain parameters. A mathematical model of systems has been
formulated and Chapman-Kolomogrov differential equation thus formed, have been solved in transient and steady state for determining the reliability and availability of the system. The uncertain parameters are modeled as fuzzy numbers using triangular membership function. The fuzzy reliability and availability has been calculated for various combinations of failure and repair rates for different $\alpha$-cut levels. The sensitivity analysis has finally been carried out in both transient and steady state by studying the effect of failure and repair rates of various components on the reliability and availability of the system.

The comparative study of effect of variation in software failure and repair rates of various components on the reliability and availability of Sun Java System Application Server, the inference can be made that the variation in the failure and repair rates of application server instance affects the reliability and availability of the system to more extent as compare to the other components. Thus the number of application server instances should be increased and their repair rates should be maximized in order to maximize the reliability and availability of the system.

Results presented in chapter four reveals that the variation in the software failure rates of router software affects the reliability and availability of the system to maximum extent as compare to the variation in the software repair rates. So the software failure rates should be minimized in order to maximize the reliability and availability of the router software system. The interpretation can be made from the analysis of results presented in chapter five that the reliability and availability of the clustered architectures can be considerably increased by increasing the fault detection coverage rate. So in order
to maximize the reliability and availability of the clustered architecture system the value of fault detection coverage rate should be kept as high as possible.

The results obtained from the present study completely agree with the earlier results obtained by Sun Microsystem (2003) for Sun Java System Application server, Meng and Shao, (2005) for router software and Mendiratta (2007) for clustered architectures. The uncertain parameter in our analysis has also been incorporated in reliability and availability estimation through fuzzy logic, which was not discussed in earlier studies. We have also carried out the analysis of lower and upper bounds of availability for various possible values of software failure and repair rates. The lower and upper bounds have also been computed for various $\alpha$-cuts keeping other parameters constant.

6.2 LIMITATIONS AND SCOPE OF FUTURE STUDY

In the present thesis, we have mathematically formulated and analyzed the transition diagrams of Web-based system with three tier architecture, Application server software system, Router software system and Clustered architecture system. In the transient state the system of differential equations with initial conditions has been solved using Runge-Kutta fourth order method. The reliability of the systems has been calculated up to 500 hrs by taking step size, $h=0.005$ as one hour. The Runge-Kutta method has the limitation that it gives erroneous results if step size, $h$ is large. We have verified the results presented in various chapters by using other numerical methods also and the results are in good agreement that justifies the correctness of the Runge-Kutta fourth order method and the results obtained by applying this method. In the steady state the system of differential equations has been solved numerically using Gauss elimination
method as well as recursively and the results are in good agreement that justifies the correctness and validity of results. Other analytical methods can also be applied for such type of system of equations.

In the present analysis, while investigating the problems of reliability and availability of software system, it has been assumed that failure and repair rates of the sub-systems are constant as long as the systems are functioning. This assumption may not be realistic in all types of software systems. Thus the study of software systems under variable failure and repair rates of the sub-systems can be carried out in future.

The reliability and availability analysis of software systems is a very complex problem as it is not possible to provide general results as the operational profile of the software vary from one implementation to another. Another problem is the availability of realistic data as the values of various parameters vary even for the same system when deployed in different operational environment. We plan to apply the approach used in this thesis on various other types of software systems including embedded systems, wireless and mobile networks and virtual networks. We also plan to model various systems using Unified Modeling Language.

6.3 INDUSTRIAL SIGNIFICANCE OF THE RESULTS

In the present thesis analysis of reliability and availability of Web-based system with three tier architecture, Application server software system, Router software system and Clustered architecture system has been presented. These software systems are a part of almost all the software products developed and used in software companies. Due to the uncertainties associated with parameters like software failure and repair rates, which either cannot be accurately measured in limited time frames through testing, or may vary
on different customer sites, reliability and availability analysis must be able to accommodate the uncertainties and produce meaningful results. The approach described in the thesis carries out fuzzy reliability and availability analysis to incorporate such uncertain parameters and the reliability and availability estimation can be easily done even if the values of the parameters are not exactly known. On the basis of the results presented in the thesis, one can analyze whether the software system has achieved the desired levels of reliability and availability or not. Testing should be done until the desired level of reliability is not achieved. Thus reliability measures can be used for evaluating the project schedules.

For software projects in which reliability and availability goals are very critical, the results can help in determining the testing intensity or manpower according to the difference in achieved and required levels of reliability and availability.

The software reliability and availability measures can also be used to evaluate software engineering technology quantitatively and can be useful in comparison of the new process or technology with the older one and can be helpful in taking decision about whether the new technology should be implemented or not. The new features are added to software systems from time to time as per requirements of the user. Software reliability and availability measures can be used to monitor the operational performance of software, when changes are made to the software.

Moreover, by studying the effect of failure and repair rates of various components on the reliability and availability, one can also identify the most sensitive component of the software system. The failure rates of such sensitive components should be minimized and the repair rates should be maximized in order to maximize the reliability and
availability of the system. Thus, in present scenario, the analysis of these software systems for their reliability and availability is of great significance to system analysts and software developers.