Chapter 6: Conclusion & Summary

Conclusion

This chapter will summarize the progress made in this dissertation in developing a performance monitoring modelling approach for complex systems using Petri nets. It is defined in terms of various modelling architecture approaches and techniques that help build models for performance monitoring of complex systems. It helps to improve efficiency and suggest effective ways to handle the various challenges that arise during modeling thereby developing successful models.

The focus of the work is Modeling of the interdependencies in complex systems (Example used is Information Technology (IT) infrastructure components) and representing cause effect relationship between the components, conditional branching, hierarchical representations. During this research work, we also found that Petri net could be effectively used as a What-if analysis tool to study the model behavior if the model parameters/environment is modified / omitted.

At first a model was built using Petri nets to monitor the various key performance parameters of a server. Hierarchical representation of Petri nets was used to make the model more comprehensible without compromising the properties and integrity of the model. Modeling of the underlying IT infrastructure was done by developing a graphical portrayal of the monitoring model using Petri net. Then analysis of the performance was
carried out by simulating and studying the behavior during different scenarios. Whenever performance issues were identified alerts were raised to notify the anomaly. This work showed how performance monitoring of complex systems like IT infrastructures can be carried out and how the model can be used to carry out dynamic simulations and analyzed.

In this extension to the earlier work, further complexity was introduced into the model and it was extended to include time delays and priorities to specific activities. This was needed for the model to be more realistic in terms of modeling real world monitoring scenarios. This model architecture also included ways to represent cause effect relationship by prohibiting execution of some selected parts of the monitoring model if the set base criteria’s monitoring failed. This work enhanced the understanding of how cause effect relationships can be modeled and used effectively in performance monitoring and management of complex systems like IT infrastructures. This also proposed how role based monitoring approach can be implemented successfully and used effectively in IT infrastructures to optimize resource utilization. Avoiding performance monitoring overheads and improved resource utilization in real time complex systems has been shown via this model architecture.

Furthering the earlier works, mapping the monitoring problem onto timed Petri nets as a set of resources and tasks used for monitoring has been carried out. A Petri net model based on the mappings was developed. Assessment of properties was done by analyzing the reachability tree and reachability graph. P-invariants and T-invariants which are powerful analysis tools of Petri nets were used to validate the structural properties. Also, other analysis
and validation properties of Petri nets like Liveness, Boundedness and Reversibility were studied.

To portray a realistic complex system like an IT infrastructure monitoring scenario, multiple parameters of the web server were included. This included the monitoring of response time a critical parameter in web environments. Then mapping of monitoring onto timed Petri nets was carried out and model was built and analyzed. The analysis results of the simulation showed that the built model net was like and there are no deadlocks in the system and the net was error free. Resolution of conflicts was done by conditions that allow flow of control based on the underlying values of the preceding places. The minimum cycle time method is used to estimate the required time to monitor the web server health status for a single iteration. Analysis of realistic large detailed models of complex systems like IT infrastructure involves in-depth calculations. Such situations lead to usage of automated modeling tools for modeling and analysis. A modeling tool Platform Independent Petri net Editor (PIPE) was used for building, dynamic simulation and analysis of the models built for this study.

Since modeling and simulation applicability come in various size, shapes and applications, we moved to model another complex system, a tsunami warning system and analyze it. This was developed based on the Deep-Ocean Assessment and Reporting on Tsunamis (DART) II buoys. This was taken up to demonstrate that the architecture and techniques developed earlier and was used for performance monitoring could be used/adapted to any complex system. This analysis justifies that the approach has broader appeal to various areas of application and not just for IT infrastructures. This work showed that alert based modeling have wider applicability in complex
systems like tsunamis which are in life threatening and destructive, and not just bound to IT infrastructures.

The functioning of DART II buoy was done in two parts. In the first part, the communication from the buoy to the station at periodic intervals was done. In the second part, the warning station requests for data from the tsunameter via a satellite. Metrics to evaluate the effectiveness of a modeled system are important. The mean response time is a critical metric to evaluate the effectiveness of the model. This has been computed for the tsunami warning system.

Alerting has been the backbone of performance monitoring in complex systems be it IT infrastructure monitoring or Tsunami warning systems. More often than not, too many alerts some/many of them redundant may be flagged for want of fine tuning or variations in the monitored environment. Redundant alerts may be tiring to deal with and can cause fatigue in monitoring staff and can result in complacency at work having costly/disastrous consequences.

To avoid such situations, Effective alert management is one the key challenges faced in organizations by operational managers in critical applications, large industries and also in large IT infrastructures where hundreds of servers are managed daily. Hence, critical alert management system was modeled from a monitoring point of view using an example of monitoring an industrial boiler. A study was done on how redundant alerts from an industrial boiler can be managed effectively. An alert management
algorithm was developed and the same was demonstrated in the industrial boiler monitoring scenario by modeling using timed Petri nets.

The effectiveness of this approach was validated by verifying the different structural properties of the model developed based on the algorithm. This was done by using both the qualitative and quantitative analysis techniques of the model. The qualitative techniques use to validate the developed model/architecture include checking if the model is valid, live, bounded and deadlock free etc. The quantitative techniques used to validate the developed model/architecture include temporal behavior like cycle time, mean response time etc.