STOCHASTIC MODELING FOR PERFORMANCE AND DEPENDABILITY ANALYSIS OF COMMUNICATION SYSTEMS

by

RESHAM VINAYAK

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Certificate

This is to certify that the thesis entitled *"Stochastic Modeling for Performance and Dependability Analysis of Communication Systems"* submitted by *Ms. Resham Vinayak* to the Indian Institute of Technology Delhi, for the award of the Degree of Doctor of Philosophy, is a record of the original bona fide research work carried out by her under my supervision and guidance. The thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted in part or full to any other university or institute for the award of any degree or diploma.

New Delhi | **Prof. S. Dharmaraja**

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Abstract

Stochastic process is a collection of random variables used to represent the evolution of a random value or system, over time, probabilistically. Stochastic processes find wide application in the field of communication systems. Communication systems provide a set of services that facilitate transfer of information. Complexity, dynamism, unpredictability and randomness are its predominant features. Stochastic techniques provide effective means of representing this nature and are helpful in evaluating the performance and dependability of the systems. In this thesis we model a few core aspects of communication systems. The content is organized as follows:

The thesis begins with a brief description of stochastic processes in **Chapter 1** and their utility in analyzing the performance and dependability of communication systems. A short account of the stochastic modeling paradigms used for modeling and analysis, such as Markov modeling, generalized stochastic Petri net (GSPN) and semi-Markov processes (SMP), is provided in this chapter. In the chapters that follow, few functional aspects of the communication systems are dealt with, one at a time, and their performance is analyzed using stochastic techniques.

The Transmission Control Protocol (TCP) is one of the core protocols used for transmission over the wired as well as wireless networks. In **Chapter 2**, we examine the NewReno variant of the TCP. The flow mechanism is modeled using GSPN. The model captures various aspects of the protocol such as congestion window evolution, slow start phase, congestion avoidance phase and the modified fast retransmit and recovery phase. The performance is accessed in terms of throughput, delay and task completion time. The performance of TCP NewReno is compared with that of TCP Reno. The results are also verified using network simulator (version 2) (NS-2) simulation.

Traffic flow is modeled in **Chapter 3**. It is generally seen that the customers arriving into a communication system require a random amount of resources for transmission. Also, at times, priority needs to be given to a certain class of customers that arrive to the system, while not losing the lower priority customers. Hence, in this chapter, we model the scenario in which customers require simultaneous service from a random number of servers, using the queuing model approach. The performance of the model is examined along with the queuing disciplines of preemptive priority and retrial.

Resource depletion is a direct consequence of traffic load arriving to the communication system, which leads to degradation in performance. Hence, in **Chapter 4**, a maintenance scheme, to analyze and optimize the performance of the system during resource degradation, is investigated. The performance of the proposed scheme is analyzed with respect to the traffic load arriving to the system. Closed-form solution for the dependability of the system in terms of availability, reliability and maintainability are obtained. The performance and dependability of the proposed methodology is also compared with an existing maintenance policy.

The evolution of communication systems in the recent years has brought forth a host of new applications and services, one of them being vehicular ad hoc networks (VANET). In **Chapter 5**, the VANET system architecture is analyzed for its reliability and survivability using reliability block diagrams (RBDs), Markov chains and Markov reward model approach. The analysis is performed for two types of communication methodologies, namely, vehicle-to-vehicle and vehicle-to-roadside.

With the enormous development in communication systems, the fourth generation (4G) of communication systems are expected to be launched soon. 4G and beyond (4G+) communication systems aims at integrating the wired and wireless network. The 4G+ systems are characterized by high speed, integration amongst heterogenous networks and devices, seamless roaming and mobility. With increase in system complexity, growing connectivity, inter-operability and dynamism, in both human and network activity, the evolving network yields massive pressure on a dependable and high performance oriented network. In this view, the features, requirements, strategies and protocols proposed for 4G+ systems are highlighted and their incompatibility and inflexibility to the existing 3G devices and network is explored in **Chapter 6**.

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