Stochastic modeling approach for performance and dependability analysis of communication networks

By

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Certificate

This is to certify that the thesis entitled *"Stochastic modeling approach for performance and dependability analysis of communication networks"* submitted by *Ms. Vandana Gupta* 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.

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Abstract

Computer and communications networks are key infrastructures of the information society, and have become an ever-increasing part of our daily lives. Future generation network technologies, architectures and protocols are hence required to overcome the limitations of the legacy networks and add new capabilities and services. The future communication networks should be ubiquitous, resilient and secure for which it is crucial to analyze its performance and dependability attributes.

The efficiency of communication networks depend critically on its performance and dependability attributes (e.g. availability, reliability, safety, integrity and maintainability). Performance analysis of communication networks involves the characterization of network traffic and derives the QoS measures such as delay, throughput, utilization, etc. Dependability analysis of communication network involves the study of at least two of its attributes. The research work in this thesis focuses on applying the stochastic modeling approaches such as Markov modeling, stochastic reward net (SRN) modeling, semi-Markov processes, and fluid queues for computing various performance metrics and dependability attributes in terms of availability, reliability and safety.

We begin with a brief description of communication networks and its various aspects. Thereafter, a short account of mathematical modeling paradigms

used/suitable for performance and dependability analysis of communication networks, like Markov modeling, stochastic reward nets, semi-Markov processes (SMP) and fluid queues is presented. We, next deal with the performance analysis of the IEEE 802.11 MAC protocol. A fluid queue approach to model the flow of information from one node to another (via any intermediate node) in a network based on the IEEE 802.11 protocol is presented. Using the fluid queue model, the steady-state distribution of the buffer content at any intermediate node is obtained. Certain performance measures relevant to a communication network such as average throughput, server utilization, expected buffer content and mean delay are also obtained at the fluid queue level. Further, an SRN formalism for the IEEE 802.11 bidirectional multi channel MAC protocol is presented to study the performance advantages of its two features, namely bidirectional channel reservation for TCP traffic, and multi channel operation, over the classic IEEE 802.11 protocol.

Next, we deal with the performance analysis of the TCP. An SRN model for the TCP flow mechanism in WLANs is presented. The model captures various aspects of the protocol algorithm such as congestion window evolution, slow start and congestion avoidance phases, TCP packet transmissions, management of packet losses due to time-out and due to triple duplicate ACKs. The performance metrics such as throughput and delay of the TCP traffic are obtained. We are also able to show an interesting unfairness problem in WLAN existing between the upload users and the download users using SRN modeling.

We then move on to the performance and dependability analysis of a VoIP network. An analytical framework of dependability model for VoIP is proposed which models the dependability attributes of availability, reliability and confidentiality in the presence of resource degradation and security breaches. The dependability model is developed using a stochastic process based on SMP because of the non-Markovian nature of the various events involved in the model. Next, we present a hierarchical analytical model which combines the reliability and performance of a server based

VoIP system operating on a wireless network. At the top level of the hierarchy, there is a pure reliability model with component redundancies and software rejuvenation, and it also incorporates failure of multiple components at the same time. And at the lower level, there is a pure performance model from which the performance metrics of the VoIP system at each state of the top level reliability model is obtained.

Finally, we discuss the end-to-end connection delay in a VoIP network in detail. And based on the various delay components, we present two different queueing models to analyze the end-to-end VoIP connection delay in two different queueing scenarios.

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