PERFORMANCE ANALYSIS OF DYNAMIC SCHEDULING IN COMMUNICATION NETWORKS

SMRUTI PADHY

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
MAY 2010

PERFORMANCE ANALYSIS OF DYNAMIC SCHEDULING IN COMMUNICATION NETWORKS

by

SMRUTI PADHY

Department of Computer Science and Engineering

Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the

Indian Institute of Technology Delhi
May 2010

Certificate

This is to certify that the thesis titled **Performance Analysis of Dynamic Scheduling in Communication Networks** being submitted by **Smruti Padhy** for the award of **Doctor of Philosophy** in **Computer Science & Engg.** is a record of bona fide work carried out by her under our guidance and supervision at the **Dept. of Computer Science & Engg., Indian Institute of Technology Delhi**. The work presented in this thesis has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma.

Dr. Arzad Alam Kherani
Principal Design Engineer
Beceem Communications Inc
Bangalore
India

Prof. Huzur Saran
Dept. of Computer Science & Engg.
Indian Institute of Technology Delhi
New Delhi
India

Acknowledgments

I am greatly indebted to my supervisors Dr. Arzad Alam Kherani and Prof. Huzur Saran, for their constant, invaluable guidance and moral support. I would like to express my profound gratitude to Dr. Arzad Alam Kherani for being the the principal source of encouragement, who continued to guide my work even after he had left the Institute; without him the work would not have been possible. I am grateful for his constant support and great patience. I am also deeply indebted to Prof. Huzur Saran for his inspiring words, valuable advice and constant support to whatever I did in my doctoral studies. One of the greatest experience of my life is to learn and work with both Dr. Arzad Kherani and Prof. Huzur Saran.

I am also thankful to my Student Research Committee (SRC) members - Prof B. N. Jain, Dr S. Dharmaraja, and Dr. Amit Kumar, for their useful feedback on my work. I am also thankful to my teammate Skanda N. Muthaiah, at India Science Lab General Motors for his invaluable suggestions and technical discussions. I would also like to thank Dr. Rajeev Shorey, Debojyoti, Anita and Sheela, for their support during my internship at General Motors.

I also wish to thank the members of ERNET Lab, Mr. Rajesh, Mr. Negi, Mrinal, and Jiten, for their support. I would like to specially thank Mr. Kaushik for providing all the assistance in the Research Scholar Room. I also thank all the support staff who kept the Bharati Building a clean and secure place to work in.

I am deeply thankful to all my friends who accompanied me in this memorable journey of pursuing doctoral studies - Aryabartta, Ayesha, Murali, Vaishali, Uma, Anant, Swati, Silpa, Krishnaiah, Rudra mohan, Neeraj, Parag and all other lab colleagues, for sharing wonderful moments in the lab. I would like to specially thank Aryabartta and Ayesha for the technical discussions and providing me their inputs on the presentation of the thesis.

I wish to acknowledge my Himadri hostel friends: Priyanka, Rupali, Swati, Swapna, Aarti, Anita and others. Thank you all for a memorable time. My dear friend and ex-roommate Kamayani deserves a special mention; my IITD stay would have been

incomplete without her.

I am glad to have friends like Deepa, Prekshya, Madhusmita, Mili, Indira, Saswati, and Manaswini. I thank them from the bottom of my heart for their constant moral support all these years of studies, at Bhubaneswar, Guwahati and now at New Delhi.

This acknowledgement would be incomplete without mentioning my close friend and fiancé, Taposh. I thank him for all the help and suggestions I received from him throughout my IITD sojourn. I especially thank him for all the good times we shared in the one year of his stay at IITD.

Finally, and most importantly, I would like to thank my parents for their immense patience, constant encouragement and great moral support all these years of studies. I am really grateful to my parents for believing in me and my endeavors. I am also thankful to my elder sister, Smita, my brother Sourav, brother-in-law Himanshu and my nephew Suryansh, for their moral support all these years.

Smruti Padhy

Abstract

Scheduling plays an important role in improving the system performance in resource constrained environment. Scheduling policies used in current communication networks are dynamic in nature. For example, scheduling policies such as Least-Attained Service (LAS) and Shortest Remaining Processing Time (SRPT), assign priorities to users based on their attained service and remaining service, respectively. In this thesis, we study the performance of dynamic scheduling policies in communication networks.

We first consider two important classes of policies, Age-based and Remaining Processing Time (RPT)-based scheduling, and obtain, useful parametrization for RPT based scheduling, tail equivalence property for both the classes and results on short term fairness for Age-based scheduling. Specifically, we propose a priority function for the class of RPT-based scheduling and parameterize the class using a single parameter. Using this parametrization and a similar one already existing in the literature for Age-based scheduling, we obtain conditions on the parameters for which tail-equivalence property holds: the tail of sojourn time distribution of a customer, starting a busy period, is as heavy as the tail of service requirement distribution (to be made precise later) under heavy-tailed service requirement distribution. Tail-equivalence property implies that the large sojourn time of a customer starting a busy period is due to its own large service requirement, and thus, not affected by the presence of other jobs in the system. We observe that tail equivalence for Age-based scheduling indicates the presence of long-term fairness under specified network consideration but short term fairness may not be guaranteed. To this end, we propose a continuous time and a discrete time model to study short-term fairness under Age-based scheduling. We validate our findings for continuous time model with NS2 simulations. The discrete time model enables us to show various asymptotic properties of Age-based scheduling and is consistent with observations in continuous time model.

We next study the performance of dynamic scheduling policies in vehicular ad-hoc networks. We propose fixed point approach to analyze performance of a new security

scheme, Multiple Digital Signature Scheme (MDSS), used at the security layer in a node in Vehicle-to-Vehicle (V2V) communications, under various scheduling policies such as First Come First Served (FCFS), SRPT and Weighted Fair Queuing (WFQ). The fixed point approach proposed requires the security and MAC layer to be stable. Thus, we also provide stability conditions for the system which are necessary for the fixed point approach to be valid. We validate our results with numerical computations and simulations.

Finally, we consider dynamic node activation policies in rechargeable sensor networks and show that the threshold based policies are optimal for a useful class of utility functions.

Contents