

Advance Reservation Service for Guaranteed Communication Setup in Heterogeneous Networks

by

Abhinav Mathur

Department of Electrical Engineering

Submitted

in fulfillment of the requirements
of the degree of

Doctor of Philosophy

to the



Department of Electrical Engineering
Indian Institute of Technology
Delhi, India
December 2003

TH
621.39:681.3
MAT-A

CLASSROOM

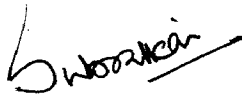
I. I. T. DELHI
LIBRARY
Acc. No. TH-3066

**A Man is a product of his thoughts,
what he thinks he becomes**
- Mohandas Karamchand Gandhi

Dedicated to my family

CERTIFICATE

This is to certify that the thesis entitled "*Advance Reservation Service for Guaranteed Communication Setup in Heterogeneous Networks*" being submitted by Mr. Abhinav Mathur for the award of the degree of Doctor of Philosophy to the Department of Electrical Engineering, Indian Institute of Technology, Delhi, is a record of bonafide work done by him under our joint supervision and guidance. The matter embodied in this thesis has not been submitted to any other institute or University for the award of any other degree or diploma.



10 Dec 2004

Dr. Subrat Kar
Associate Professor
Department of Electrical Engineering
Indian Institute of Technology
New Delhi
India



Dr. H. M. Gupta
Professor
Department of Electrical Engineering
Indian Institute of Technology
New Delhi
India

TH
621.39:681.3
MAT-A

Acknowledgment

It is the creative potential itself in human beings that is the image of God. First and foremost I would like to thank God to have held my hand and shown me the way through this arduous but pleasant journey. This thesis is the result of many years of work, and this would not have been possible without the support of many people. It is a pleasant aspect that I now have the opportunity to express my gratitude to all of them.

The first persons I would like to express my sincerest gratitude to are my supervisors Prof. H. M. Gupta and Dr Subrat Kar. They untiringly encouraged me and provided me with many valuable suggestions. I hold the lively sessions I had with them very dear to my heart. The constructive criticism and new ideas I received during these sessions have been a constant source of inspiration for me. I will always remain indebted to them for their patient guidance and constant support.

During my PhD, I have time and again got valuable inputs from the members of my Student Research Committee, which was constituted by Prof. B. Chandra, Dr. Ranjan Bose, and Dr Huzur Saran. I would like to thank them for the many hours of patient listening they have put in to understand my area and for the inputs that have helped me along.

I would like to thank Profs. G.S. Visweswaran and B. Bhaumik for allowing me to access their labs for my work. I started my thesis work under the supervision of Prof. C.P. Ravikumar and would like to thank him for the initial insights he provided pertaining to my work till the time he decided to part ways with IIT, Delhi.

There are some persons who have to be asked for help while there are others who extend it freely of their own will, without ever so generously, expecting much in return. I was very fortunate indeed to come in contact with Mr Vijay Kumar Bharaj, his wife Mrs Anajana Bharaj, and their two lovely children Ankit and Anmol. The Bharaj family has been more than an extension of my own and have been very caring

oughout.

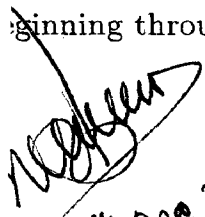
I would also like to thank the lab staff of the Electrical Engineering for their attention and time to time help.

I am grateful to my colleagues at my office who have allowed me to pursue my PhD and have taken a share of my work load at times. I would like to specifically thank Mr. Rajiv Mangla, Mr. Rajendra Gupta, Mr. Khursheed Abidin, Mr. Asif and Mr Kabiraj Sethi for helping me in my work.

I would like to thank my in-laws for having stood by me throughout and having provided constant help and encouragement whenever required. I feel a deep sense of gratitude for my parents who have allowed me to be independent and confident. My pre-occupation with this work did not allow me to spend much time with them, I now hope to compensate for all the missed time.

Last but not the least I would like to thank my wife Mona for having stood by me throughout my work and providing me constant encouragement, and my sons Nalin and Naman who had to miss the many affectionate hours that truly belonged to them during the course of this work and have been counting the days to my submission for the past fortnight.

The beginning of knowledge is the discovery of something we do not understand and then to have the urge to pursue to understand its mechanisms. I have made my beginning through this work.


10th Dec 2003

Abstract

Current trends in the evolution of communication networks is towards the improvement in the Quality of Service (QoS) offered to ongoing connections. There is an emerging class of users who use communication networks for their critical needs. These users require guaranteed connection at the future time of usage and would be willing to specify their exact requirements much in advance of their actual use and pay a premium for the guarantees offered.

Currently, available work on Resource Reservations in Advance (ReRA) is restricted to admitting a call immediately on the receipt of a request, which is referred to as Immediate Admission Decision (IAD-ReRA). The IAD-ReRA schemes usually reserve resources at the same time at which they admit the call. The possibility of buffering advance call requests and delaying the admission process, which we refer to as Deferred Admission Decision (DAD-ReRA), with an objective to meet the required network performance needs investigation. In this work, a comprehensive model for IAD-ReRA is presented and analyzed using Markov Chains. Further, the work proposes the DAD-ReRA approach as an alternative to IAD-ReRA. A detailed queueing model for DAD-ReRA is developed and analyzed. This thesis presents SIP-A as an extension to the SIP protocol to include DAD-ReRA. A Service Overlay Network for Advance Reservations (SONAR) is the architecture proposed to support DAD-ReRA. The overheads introduced by SONAR and SIP-A have been discussed. Further, the application of DAD-ReRA to Optical and Mobile networks has been studied considering the specific requirements of these networks. The behaviour of the proposed models and schemes has been studied by detailed simulation. A comparison of the IAD-ReRA and DAD-ReRA schemes indicate that there are multiple advantages of DAD-ReRA which may prove very useful to both the networks and the users that support and use ReRA for planned communication respectively.

Contents

Certificate	i
Acknowledgments	iii
Abstract	v
List of Symbols	xviii
1 Introduction	1
1.1 Need for Resource Reservations	2
1.1.1 Advance Resource Reservations	5
1.1.2 Advantages of providing ReRA	6
1.2 Issues in ReRA	7
1.3 Previous Work	9
1.3.1 Initial Work	9
1.3.2 Predictive Service	14
1.3.3 Architectures and models	17
1.3.4 Re-negotiations in Advance Reservations	26
1.3.5 Implications of ReRA on Routing	27
1.3.6 Signalling requirements for ReRA	28
1.4 Application of Resource Reservations to Optical and Mobile Networks	30
1.5 Motivation for this thesis research	31

1.6	Organization of this Thesis	33
-----	---------------------------------------	----

Modelling and analysis of Immediate Admission Decision based scheme 35

2.1	General Model	36
2.1.1	Network Model	36
2.1.2	Conventional Model for Reservations	38
2.1.3	Extended model for Advance Reservations	38
2.2	Model for Advance Reservations with Immediate Admission Decision	41
2.2.1	Description of the proposed model	42
2.3	Analysis of the IAD-ReRA Reservation model	43
2.3.1	Advance Call Reject Probability	48
2.3.2	Admitted Advance Call Drop Probability	48
2.3.3	Overflow probability	49
2.3.4	Performance Objectives	51
2.4	Resource Allocation Policies	54
2.5	Simulation Results	56
2.5.1	Variation of Advance Call Rejection Probability with the arrival rate	56
2.5.2	Variation of Advance Call Rejection Probability with bandwidth	58
2.5.3	Variation of Resource Utilization with bandwidth requested by advance calls	59
2.5.4	Study of Advance Call Rejection Probability in a network that Interrupts Current Calls	60
2.5.5	Variation of Revenue with Advance Call Arrival Rate	63
2.6	Discussion	65

Modelling and Analysis of Deferred Admission Decision based Scheme 69

3.1	Deferred Admission Decision	70
-----	---------------------------------------	----

3.2	Modelling the Deferred Admission Decision based advance reservation System	71
3.2.1	State Transition Diagram	73
3.2.2	Queuing Model for DAD-ReRA	75
3.3	Negotiations for Alternative QoS	84
3.4	Optimizing the DAD-ReRA scheme	86
3.4.1	Heuristics for Call Admission	86
3.4.2	Reallocation of the network bandwidth	87
3.4.3	Effect of re-negotiations by users	88
3.5	Simulation Results	88
3.5.1	Effect of call duration and arrival rate	89
3.5.2	Effect of Network Utilization on Advance Call Rejection Probability	90
3.5.3	Comparison of Admission Heuristics	91
3.5.4	Error in Estimation of Current Call usage	94
3.5.5	Effect of error in Estimating Abandonments or Rescheduling	96
3.6	Discussion	97
4	Overlay Architecture and Protocol for Advance Resource Reservations	101
4.1	Session Initiation Protocol Overview	102
4.1.1	Justification for choice of the SIP framework	102
4.1.2	SIP Framework Overview	103
4.1.3	Typical SIP Operation	104
4.2	Objectives of the Extended SIP Framework	105
4.3	Proposed Extensions for Advance Reservations	106
4.3.1	Proposed Extensions to the Architecture	106
4.3.2	Proposed Modifications to the Protocol	107

4.4	SONAR Architecture	107
4.4.1	Network Elements of SONAR	109
4.5	Proposed Extensions to the Session Description Protocol	113
4.6	Extensions to SIP <i>Methods</i>	114
4.7	Call Flows	118
4.7.1	Call Request	118
4.7.2	Session Progress Information to SIP Proxy-ReRA	119
4.7.3	INQUIRE and ABANDONMENT Procedures	120
4.7.4	Alternative Service	120
4.7.5	Call establishment	121
4.8	Evaluation of SIP-A	122
4.9	Discussion	126
 Applications of the Advance Resource Reservation Service to Opti- cal and Mobile Networks		129
5.1	Optical Networks	129
5.1.1	Reservation Strategies in Optical Burst Switching	131
5.2	Extending the Deferred Admission Decision model to Optical Networks	136
5.2.1	Extending SONAR to Optical Networks	138
5.3	Mobile Networks	140
5.3.1	Mobile QoS requirements	141
5.3.2	Advance Resource Reservations	142
5.4	Extending the Deferred Admission Decision model to Mobile Networks	146
5.4.1	Extending SONAR for usage in Mobile Network	146
5.5	Simulation Results	149
5.5.1	Optical Networks	149
5.5.2	Mobile Networks	155
5.6	Discussion	157

6 Conclusions	161
References	165
Publications from this Research Work	173
Brief Profile of the Author	175