NETWORK MANAGEMENT IN WIRED AND WIRELESS NETWORKS

Tejinder S. Randhawa
Stephen Hardy

KLUWER ACADEMIC PUBLISHERS

NETWORK MANAGEMENT IN WIRED AND WIRELESS NETWORKS

THE KLUWER INTERNATIONAL SERIES
IN ENGINEERING AND COMPUTER SCIENCE

NETWORK MANAGEMENT IN WIRED AND WIRELESS NETWORKS

by

Tejinder S. Randhawa
Acterna, Canada

Stephen Hardy
Simon Fraser University, Canada

KLUWER ACADEMIC PUBLISHERS
Boston / Dordrecht / London

Distributors for North, Central and South America:
Kluwer Academic Publishers
101 Philip Drive
Assinippi Park
Norwell, Massachusetts 02061 USA
Telephone (781) 871-6600
Fax (781) 681-9045
E-Mail < kluwer@wkap.com>

Distributors for all other countries:
Kluwer Academic Publishers Group
Distribution Centre
Post Office Box 322
3300 AH Dordrecht, THE NETHERLANDS
Telephone 31 78 6392 392
Fax 31 78 6546 474
E-Mail < services@wkap.nl>

Electronic Services < http://www.wkap.nl>

Library of Congress Cataloging-in-Publication Data

A C.I.P. Catalogue record for this book is available
from the Library of Congress.

Copyright © 2002 by Kluwer Academic Publishers

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, mechanical, photo-copying, recording, or otherwise, without the prior written permission of the publisher, Kluwer Academic Publishers, 101 Philip Drive, Assinippi Park, Norwell, Massachusetts 02061

Printed on acid-free paper.

Printed in the United States of America

Table of Contents

List of Figures ix

List of Tables xii

Preface xiii

1. Introduction 1

1.1 Motivation for Performance Control 3

1.2 Related Work 8

1.2.1 Packet Level Control 8

1.2.2 Call Level Control 11

1.2.3 Network Level Control 15

1.2.4 The Proposed Framework 15

2. Performance Management in Broadband Networks 18

2.1 Performance Monitoring 19

2.1.1 Performance Monitoring Functions 20

2.1.2 Role of Performance Monitoring 20

2.1.3 Performance Monitoring Requirements 21

2.2 Performance Control 22

2.3 Performance Monitoring in T-Carrier Systems 23

2.3.1 T-Carrier System: an Overview 24

2.3.1.1 T1 Fundamentals 24

2.3.2 T3 Fundamentals 27

2.3.2.1 M13 Frame 28

2.3.3 Performance Monitoring 29

2.3.3.1 Performance Monitoring Data 29

2.4 Performance Monitoring in SDH/SONET based Networks ... 30

2.4.1 SDH/SONET: an Overview 31

2.4.1.1 Layered Overhead Structure 32

2.4.2 Performance Monitoring 34

2.4.2.1 Performance Monitoring Locations 34

2.4.2.2 Performance Monitoring Data 35

2.4.2.3 SDH/SONET Performance Primitives 35

2.4.2.4 SDH/SONET Performance Parameters 37

2.4.2.5 SONET Maintenance Signals....38

2.5 Performance Monitoring in ATM Networks....38

2.5.1 ATM: an Overview....39

2.5.2 Operations, Administrations, and Maintenance (OAM) Flows....41

2.5.3 Performance Monitoring....42

2.5.3.1 Monitoring Locations....43

2.5.3.2 Performance Monitoring at TC sublayer....43

2.5.3.3 Performance Monitoring at ATM layer....44

2.6 Performance Monitoring in Frame Relay Networks....47

2.6.1 Frame Relay Protocol and Protocol Architecture....48

2.6.1.1 Frame Relay Protocol Architecture....48

2.6.1.2 Frame Relay Protocol....49

2.6.2 Performance Monitoring....52

2.6.2.1 Performance Monitoring Locations....52

2.6.2.2 Performance Monitoring Data....53

2.7 Transmission Quality Assurance....53

2.7.1 Nature of Impairments....54

2.7.2 Determination of QoS and Facility Performance....56

2.7.3 Proactive Maintenance....57

2.7.3.1 Thresholding....58

2.7.3.2 Trending....58

2.7.3.3 Pattern matching....59

2.8 Traffic Management....59

2.8.1 Network Status and Monitoring....61

2.8.1.1 Circuit Groups....61

2.8.1.2 Switching nodes....62

2.8.1.3 Network Performance Monitoring/Control Requirements....62

2.9 Summary....64

3. Performance Management in Cellular Networks....65

3.1 Cellular Networks: an Overview....66

3.1.1 RF Channels....67

3.1.2 Terrestrial Channels....69

3.1.3 Signaling Channels....69

3.2 Performance Monitoring in GSM/GPRS Networks....71

3.2.1 Network Architectures and Signaling Protocol Stacks....72

3.2.2 The Proposed Framework....75

3.2.3 GSM Performance Estimation 77
3.2.3.1 Resource Utilization 79
3.2.3.2 Error performance 82
3.2.4 GPRS Performance Estimation 85
3.2.4.1 Resource Utilization 86
3.2.4.2 Radio Resource Error Performance 89
3.3 Summary 91
4. Estimation & Prediction of Multiplexed VBR Traffic .. 93
4.1 The System Model 95
4.2 Video-Conferencing or Video-Phone Sources 96
4.2.1 Estimating Current Traffic State 99
4.2.1.1 Deterministic Arrival 100
4.2.1.2 Poisson Arrival 101
4.2.2 Predicting Future Traffic States 102
4.3 MPEG Sources 103
4.3.1 Time-Sequenced Adaptive Filters 104
4.4 Predicting Time of Congestion 105
4.5 Results 107
4.6 Summary 116
5. Channel Access Control 118
5.1 Call Model 119
5.2 CS (Complete Sharing) 119
5.3 CP (Complete Partitioning) 122
5.4 PS (Partial Sharing) 122
5.5 CD (PS with Call Dropping) 123
5.5.1 DQ (Dropped Calls Queued) 126
5.5.2 LQ (Low Priority Calls Queued) 130
5.6 DA (PS with Discouraged Arrivals) 131
5.7 Numerical Results 132
5.8 Summary 140

6. Bandwidth Optimization in Broadband Networks 142
6.1 The Network Model 143
6.2 Bandwidth Optimization Procedure 144
6.3 Summary 150

7. Capacity Optimization in Cellular Networks 152
7.1 Network Model 153
7.2 Capacity Optimization Procedure 157
7.3 Soft Capacity of CDMA Cells 160
7.3.1 Cell Capacity Estimation 162
7.3.1.1 Channel Utilization Models 163
7.3.1.2 Statistical Multiplexing Gain 167
7.3.2 Cell Level QoS Evaluation 168
7.3.2.1 Complete Sharing 169
7.3.2.2 Complete Partitioning 172
7.3.2.3 Partial Sharing 172
7.4 Results 173
7.5 Summary 184

A. Transient State Analysis of an (S+1) State Birth-Death Markov Process 185

B. Properties of Exponential Random Variables 189
B.1 Transition Rates in CD Policy 190
B.2 Handover Probability 192
B.3 Non-Exponential Call Durations 192

C. Capacity Optimization Procedure 195

D. List of Abbreviations and Symbols 200

References 213

Subject Index 221

List of Figures

Figure. 1-1. A Multi-Service Multi-Resource Broadband Network. 4

Figure. 1-2. The Proposed Framework. 17

Figure. 2-1. STS-1 frame format and overhead layers 33

Figure. 2-2. Section, Line, and Path overheads with network elements 34

Figure. 2-3. B-ISDN Protocol Reference Model, and ATM Cell Headers 46

Figure. 2-4. Frame and Address Field Format....51

Figure. 2-5. Transmission Performance Impairments 55

Figure. 3-1. Logical Architecture of a GSM/GPRS Network ...73

Figure. 3-2. Logical Architecture of an SS7 Signaling Network 75

Figure. 3-3. Functional Framework of the Proposed System....76

Figure. 3-4. GSM Signaling Plane....78

Figure. 3-5. GPRS Signaling Plane 86

Figure. 4-1. Model of the Proposed Scheme. 96

Figure. 4-2. Input Traffic and Time Sequenced Adaptive Predictor Structure. 105

Figure. 4-3. Estimation Performance of Least Mean-Square Filter (a) Deterministic Arrival (b) Poisson Arrival. 109

Figure. 4-4. (a) A Sample Function of x(j) (b) Prediction over 1 Frame Interval (c) Prediction over 2 Frame Intervals (d) Prediction over 5 Frame Intervals. ..110

Figure. 4-5. Traffic Prediction (a) Single Source (Terminator Trace) (b) Three Sources Multiplexed with Random Starting Times (c) Five Sources Multiplexed with Random Starting Time. 112

Figure. 4-6. Transient Behavior in Response to Sources Turning Off and On (a) using LMS (b) using RLS. 115

Figure. 4-7. Probability Distribution to Overload. 116

Figure. 5-1. Two Dimensional Markov chain for (a) Complete Sharing (b) Complete Partitioning (c) Partial Sharing. 121

Figure. 5-2. Priority Based Policies (a) PS with Call Dropping (b) PS with Discouraged Arrivals. 124

Figure. 5-3. PS with Call Dropping with (a) Dropped Calls Queued (b) Low Priority Calls Queued. 129

Figure. 5-4. (a) Blocking Probability of Service 1 for CS (Complete Sharing), CP (Complete Partitioning), PS (Partial Sharing), and CD (Call Dropping). (b) Blocking Probability of Service 2 for CS, CP, PS, CD, and DA (Discouraged Arrivals). 134

Figure. 5-5. Call Blocking Probability of s_1 under CD, DQ and LQ policies. 136

Figure. 5-6. (a) Call Dropping Probability of s_1 calls under PS with Call Dropping scheme (b) Average System Time of dropped calls under Dropped-Calls-Queued scheme (c) Average System Time of low priority calls under Low-Priority-Calls-Queued scheme with K=60. 137

Figure. 5-7. Performance evaluation of CD when traffic characteristics of s_1 and s_2 are similar. 138

Figure. 5-8. Performance evaluation of CD (a) Call Blocking Probability of s_1 (b) Call Blocking Probability of s_2 (c) Call Dropping Probability of s_1. 139

Figure. 6-1. The Network Model 143

Figure. 6-2. Network revenue as a function of (C_1,C_2,C_s) for a two service single link case with specified traffic load 149

Figure. 7-1. Channel Activity Models (a) VBR Video Source (b) Voice Source. 166

Figure. 7-2. Acceptable states for $\varepsilon = 0$ and 170

Figure. 7-3. Two Dimensional Markov chain when $\varepsilon = 0$ for (a) Complete Sharing (b) Complete Partitioning (c) Partial Sharing 171

Figure. 7-4. Blocking Probability when $\varepsilon = 0$ for (a) Service 1 (b) Service 2. 178
Figure. 7-5. Dropping Probability when $\varepsilon = 0$ for (a) Service 1 (b) Service 2. 179
Figure. 7-6. Blocking Probability when $\varepsilon = 10^{-5}$ for (a) Service 1 (b) Service 2. 180
Figure. 7-7. Dropping Probability when $\varepsilon = 10^{-5}$ for (a) Service 1 (b) Service 2. 181
Figure. 7-8. Call Dropping Probability vs. size of Guard Band. 182
Figure. 7-9. Effect of reserving Channels for s_1 and s_2 on Network Revenue. 183
Figure. C-1. The Main Functional Blocks. 197
Figure. C-2. Iterations of Step 1. 198
Figure. C-3. Iterations of Step 2. 199

List of Tables

TABLE 4-1. Relative Performance of NLMS and RLS. The metric used is SNR-1. [x,y] means the range. ... 113

TABLE 7-1. Channel Utilization Model Parameters for VBR Video Sources. ... 174