
Contents

Preface	v
Acknowledgements	vii
Acronyms	xv
1 Motivation and Basics	
<i>Torsten Braun and Thomas Staub</i>	1
1.1 Quality of Service and its Parameters	1
1.1.1 Delay and Delay Variations in End-to-End Packet Delivery	2
1.1.2 Bandwidth and Packet Loss Ratio	3
1.2 Applications' QoS Requirements	4
1.2.1 Types of Network Applications	5
1.2.2 QoS Requirements of Applications	6
1.3 Packet Scheduling in Network Elements	8
1.3.1 (Non)Work-Conserving Scheduling Disciplines	8
1.3.2 Fairness	9
1.3.3 Scheduling Disciplines	10
1.3.4 Packet Dropping	11
1.4 Quality-of-Service Architectures	12
1.4.1 Integrated Services	12
1.4.2 Differentiated Services	14
1.4.3 End-to-End QoS Mechanisms	16
1.5 Implementation and Performance of QoS-aware Applications	17
1.5.1 Prerequisites for Successful QoS Applications	17
1.5.2 Media Scaling	18
1.5.3 Applications' Performance Gain Due to QoS	19

1.5.4 Summary 20
1.6 Structure of the Book 21

2 QoS Measurements in IP-based Networks

René Serral-Gracià, Jordi Domingo-Pascual, Andrzej Bęben and Philippe Owezarski 23
2.1 Introduction 23
2.2 Measurement Metrics 24
 2.2.1 Network Level 24
 2.2.2 Call level 28
 2.2.3 User Level 29
2.3 Measurement Techniques 33
 2.3.1 Previous Considerations 33
 2.3.2 Base Techniques 36
 2.3.3 Active Measurements 39
 2.3.4 Passive Measurements 44
2.4 Conclusions 48

3 Traffic Engineering

Luciano Lenzini, Enzo Mingozzi and Giovanni Stea 49
3.1 Introduction 49
3.2 A Motivating Example 50
3.3 Multi-Protocol Label Switching Architecture 52
 3.3.1 The Forwarding Component 53
 3.3.2 The Control Component 54
 3.3.3 MPLS Optimisation 56
3.4 MPLS-Based Traffic Engineering 58
 3.4.1 Constraint-Based Routing 58
 3.4.2 Explicit Route Signalling 61
 3.4.3 Traffic Engineering Practices 64
3.5 Traffic Engineering and Quality of Service 66
 3.5.1 QoS Support over MPLS 67
 3.5.2 Traffic Engineering Extensions for DiffServ 70
3.6 Conclusions 73

4 Signalling

Ilaria Marchetti, Antonio Pietrabissa, Massimiliano Rossi, Fernando Boavida, Luís Cordeiro, Edmundo Monteiro and Marilia Curado 75
4.1 Introduction 75
4.2 Session Initiation Protocol (SIP) 76
 4.2.1 SIP and Its Value Propositions 76
 4.2.2 Protocol Components 77
 4.2.3 SIP Messages 80
 4.2.4 Session Description 82
 4.2.5 Establishment of an SIP Session 83

4.2.6 SIP's Extension 86

4.3 The Next Steps In Signalling (NSIS) 86

 4.3.1 Background and Main Characteristics 86

 4.3.2 Overview of Signalling Scenarios and Protocol Structure 89

 4.3.3 The NSIS Layer Transport Protocol 91

4.4 Common Open Policy Service (COPS) 98

 4.4.1 COPS Overview 98

 4.4.2 Basic Model 99

 4.4.3 COPS Protocol 100

 4.4.4 COPS Messages 102

 4.4.5 Common Operation 106

 4.4.6 Using Examples: COPS for RSVP 107

4.5 Conclusions 109

5 Enhanced Transport Protocols

Nicolas Wambeke, Ernesto Exposito, Guillaume Jourjon and

Emmanuel Lochin 111

5.1 Introduction 111

5.2 State of the Art of Transport Protocols 112

 5.2.1 TCP and UDP 113

 5.2.2 TCP Evolution 113

 5.2.3 SCTP 116

 5.2.4 DCCP 117

 5.2.5 Discussion 117

5.3 Transport Mechanisms 118

 5.3.1 Overview 118

 5.3.2 Congestion-Control Mechanisms 119

 5.3.3 Reliability Mechanisms 120

 5.3.4 Discussion 122

5.4 Enhanced Transport Protocol Mechanisms 122

 5.4.1 TFRC and gTFRC, a QoS-Aware Congestion Control 122

 5.4.2 Application-Aware Transport Mechanisms 123

5.5 Conclusions 129

6 The EuQoS System

Michel Diaz, José Enríquez-Gabeiras, Laurent Baresse, Andrzej Beben, Wojciech Burakowski, María Ángeles Callejo-Rodríguez, Jorge Carapinha, Olivier Dugeon, Ernesto Exposito, Mathieu Gineste, Enzo Mingozzi, Edmundo Monteiro, Antonio Pietrabissa, Florin Racaru, Jarosław Śliwiński, Giovanni Stea, Halina Tarasiuk, Nicolas Wambeke and Markus Wulff 131

6.1 Introduction 132

6.2 Architecture 133

 6.2.1 Goals and Requirements 133

 6.2.2 Functional Blocks and their Main Functions 134

 6.2.3 Control Plane Elements: RM and RA 137

- 6.3 Provisioning, Invocation, and Operation, Administration and Management 139
 - 6.3.1 Provisioning Process 140
 - 6.3.2 Invocation Process 145
 - 6.3.3 Operation, Administration and Management 149
- 6.4 End-to-End Classes of Service in Heterogeneous Networks 149
 - 6.4.1 End-to-end Classes of Service in EuQoS 150
 - 6.4.2 QoS Mechanisms and Algorithms for Specification of e2e Classes
of Service 153
 - 6.4.3 Implementation of e2e Classes of Service in Underlying
Technologies..... 155
- 6.5 EuQoS Enhanced Transport Protocol 161
 - 6.5.1 Introduction 161
 - 6.5.2 Enhanced Transport Protocol Services for EuQoS 161
 - 6.5.3 Services for Streaming/Nonstreaming Applications 162
- 6.6 Multicast 163
 - 6.6.1 Application Layer Multicast 165
 - 6.6.2 Application Layer Multicast in the EuQoS System 166
 - 6.6.3 Multicast Middleware 168
 - 6.6.4 Introducing QoS to Multicast Middleware 170
- 6.7 Telemedicine Application 172
 - 6.7.1 Telemedicine—the Case for Application-Driven QoS 172
 - 6.7.2 Overview of Medigraf 173
 - 6.7.3 Medigraf Adaptation to EuQoS 174
- 6.8 Conclusions 176

7 Summary and Outlook

- Torsten Braun and Thomas Staub* 179

Appendix A: Implementing Protocols on Network Simulators ..

- Thomas Staub, Jana Krähenbühl and Torsten Braun* 181
- A.1 Main Simulation Terms and Concepts 181
 - A.1.1 Simulation Process 182
 - A.1.2 Simulation Types 182
- A.2 Network Simulation 183
 - A.2.1 Parallel/Distributed versus Serial Execution of Simulations 183
 - A.2.2 Packet-Level, Fluid-Based and Hybrid Model Simulation 184
 - A.2.3 Simulation Speedup 185
 - A.2.4 Network Simulation in Research 185
 - A.2.5 Simulation for Education Purposes 186
- A.3 Network Simulators 187
 - A.3.1 GloMoSim and Qualnet 187
 - A.3.2 JiST/SWANS 187
 - A.3.3 Scalable Simulation Framework (SSF) and SSFNet 188
 - A.3.4 OMNeT++ and OMNEST 188

A.4 The Network Simulator ns-2 188

 A.4.1 The Language Concept 189

 A.4.2 Hierarchical Structure 189

 A.4.3 First Steps—Simulation Script Template 190

 A.4.4 Nodes, Links and Traffic 191

 A.4.5 Wireless Networks 193

 A.4.6 Implementing Protocols with ns-2 196

 A.4.7 Advice for Running ns-2 Simulations 214

 A.4.8 Analysing Methods 215

Appendix B: Network Emulation Focusing on QoS-Oriented Satellite Communication

Laurent Dairaine, Mathieu Gineste and Hervé Thalmensy 217

B.1 Network Emulation Basics 217

 B.1.1 Introduction to Network Emulation 217

 B.1.2 What is Network Emulation? 219

 B.1.3 Why Use Network Emulation? 222

 B.1.4 Requirements for Emulation Systems 223

 B.1.5 Network Emulation System Approaches 226

B.2 Case Study: Emulation of QoS-oriented Satellite Communication 236

 B.2.1 Introduction 236

 B.2.2 DVB Satellite Communications 236

 B.2.3 QoS Support for Satellite Network Systems 238

 B.2.4 Emulation of a DVB-S, DVB-RCS Satellite System 239

B.3 Conclusions 247

References 249

Index 261