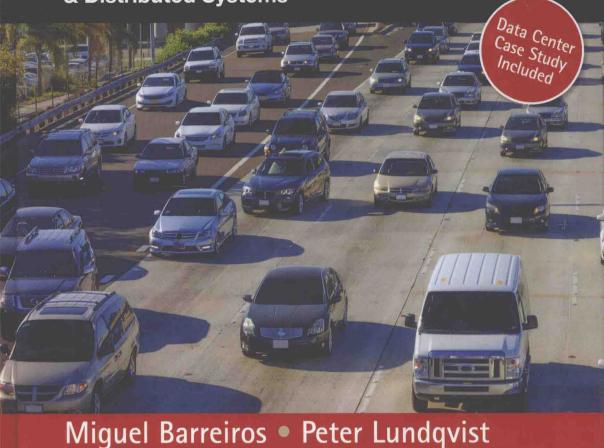
Wiley Series in Communications Networking & Distributed Systems



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SECOND EDITION

QOS-ENABLED NETWORKS

Tools and Foundations

with a Foreword by Jeff Doyle

WILEY

QOS-ENABLED NETWORKS TOOLS AND FOUNDATIONS

SECOND EDITION

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Foreword

Network consolidation has been with us since the 1990s, driven by the simple requirement to reduce the costs of business communication. For IT, it is a matter of controlling CapEx and OpEx. For service providers, it is a matter of offering multiservice solutions at a competitive cost. (Remember when "triple play" was the buzzword of the day?) Consolidation has been so successful that you seldom encounter an organization these days that runs separate data and telephony networks. Voice and video over IP is proven, reliable, and cheap. And modern service providers—whether they got their start as a telephony, cable, long distance, or Internet provider—now run all of their services over an IP core.

Treating all communications as data, and sending it all over a shared IP infrastructure—or series of IP infrastructures—has also revolutionized our modern lives from smart phones to shopping to entertainment to travel. For myself, one of the most interesting impacts of technology has been how different my teenagers' social lives are from my own when I was a teenager. Their activities are more spontaneous, their social groups are larger, and always-available communications make their activities safer.

And consolidation is still evolving. These days the excitement is around virtualization, improving the utilization of our existing communications resources.

From the beginning, one of the biggest challenges of consolidating all communications onto an IP infrastructure stems from the fact that not all data is equal. As users we expect a certain Quality of Experience (QOE) related to the service we're using. So QOE for voice is different than QOE for videoconferencing, both of which are different from high-definition entertainment. Each kind of data stream requires different treatment within the network to meet users' QOE expectations, and that's where Quality of Service (QOS) comes in.

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QOS has been around as long as IP has. The IP packet header has a Type of Service (TOS) field for differentiating services, and over the years that field has evolved into the more sophisticated Differentiated Services Code Point (DSCP) field to better fit modern QOS classification strategies. And from the beginning it was understood that although IP provides connectionless best-effort delivery, some applications need reliable, sequenced, connection-oriented delivery. Hence TCP, which "fakes" the behavior of a wired-up point-to-point connection over IP.

QOS is really all about managing limited network resources. You don't get extra bandwidth or faster delivery; you just get to decide what data gets first dibs at the available resources. High-Def video requires very prompt delivery. A web page can wait a bit longer, and e-mail can wait much longer still. Over the years, QOS technologies and strategies have become more and more sophisticated to deal with the diversity of applications using the network. Routers and switches have better and better queues and queuing algorithms, better ingress control mechanisms, and better queue servicing mechanisms. And the advent of Software-Defined Networking (SDN) introduces some new and interesting ways of improving QOE.

All of this growing sophistication brings with it growing complexity for network architects and engineers. There are a lot of choices and a lot of knobs, and if you don't have the understanding to make the right choices and set the right knobs, you can do some serious damage to the overall quality of the network. Or at the least, you can fail to utilize your network's capabilities as well as you should.

That's where this book comes in. My longtime friends Miguel Barreiros and Peter Lundqvist have deep experience designing modern QOS strategies, and they share that experience in this book, from modern QOS building blocks to applied case studies. They'll equip you well for designing the best QOS approach for your own network.

Jeff Doyle

Preface

Five years have elapsed between the original publishing of this book and this second edition, and it is unquestionably interesting to analyze what has changed. The original baseline was that Quality of Service, or QOS, was in the spotlight. Five years have elapsed and QOS prominence has just kept on growing. It has entered in new realms like the Data Center and also spread into new devices. It is no longer just switches and routers—now even servers have at their disposal a complete QOS toolkit to deal, for example, with supporting multiple virtual machines.

This book's focus remains in the roots and foundations of the QOS realm. Knowledge of the foundations of QOS is the key to understanding what benefits it offers and what can be built on top of it. This knowledge will help the reader engage in both the conceptual and actual tasks of designing or implementing QOS systems, thinking in terms of the concepts, rather than thinking of QOS simply as a series of commands that should be pasted into the configuration of the devices. It will also help the reader to troubleshoot a QOS network, to decide whether the undesired results being seen are a result of misconfigured tools that require some fine-tuning or the wrong tools. As Galileo Galilei once said, "Doubt is the father of all invention."

A particular attention is also dedicated to special traffic types and networks, and three case studies are provided where the authors share their experience in terms of practical deployments of QOS.

Although the authors work for two specific vendors, this book is completely vendor agnostic, and we have shied away from showing any CLI output or discussing hardware-specific implementations.

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History of This Project

The idea behind this book started to take shape in 2007, when Miguel engaged with British Telecom (BT) in several workshops about QOS. Several other workshops and training initiatives followed, and the material presented matured and stabilized over time. In July 2009, Miguel and Peter, who had also developed various QOS workshop and training guides, joined together to work on this project which led to the creation of the first edition.

In December 2014, both authors agreed that the book needed a revamp to cover the new challenges posed in the Data Center realm, which originated this second edition.

Who Should Read This Book?

The target audience for this book are network professionals from both the enterprise and the service provider space who deal with networks in which QOS is present or in which a QOS deployment is planned. Very little knowledge of other areas of networking is necessary to benefit from this book, because as the reader will soon realize, QOS is indeed a world of its own.

Structure of the Book

This book is split into three different parts following the Julius Caesar approach ("Gallia est omnis divisa in partes tres"):

Part One provides a high-level overview of the QOS tools. It also discusses the challenges within the QOS realm and certain types of special traffic and networks.

Part Two dives more deeply into the internal mechanisms of the important QOS tools. It is here that we analyze the stars of the QOS realm.

Part Three glues back together all the earlier material in the book. We present three case studies consisting of end-to-end deployments: the first focused on VPLS, the second focused on Data Center, and the third one focused on the mobile space.

Have fun.

Miguel Barreiros, Sintra, Portugal Peter Lundqvist, Tyresö, Sweden April 30, 2015

Acknowledgments

Several colleagues of ours have helped us during this project. However, three were absolutely key to the creation of this book:

Patrick Ames led this project in all its nontechnical aspects, allowing Miguel and Peter to focus on writing.

Aviva Garrett played the key role of the editorial review of the entire book and also guided Miguel and Peter in how to improve the book's organization and contents.

Steven Wong (Juniper JTAC) provided technical reviews for much of the book while sharing his immense knowledge of QOS.

The authors would also like to gratefully thank the following people: Antoine Sibout, Bobby Vandalore, Guy Davies, Jeff Doyle, John Peach, Jos Bazelmans, Kannan Kothandaraman, Margarida Correia, and Pedro Marques.

Finally, the authors would like to express their personal thanks:

Miguel: I would like to dedicate this book to Maria Eugénia Barreiros and to my grandparents José Silva and Dores Vilela.

Peter: My work on this book was possible only with the understanding and patience of the most dear ones in my life, my wife Lena and my great kids Ida and Oskar.

Abbreviations

2G Second Generation

3GPP Third-Generation Partnership Project

ACK Acknowledgment
AF Assured-forwarding
APN Access Point Name
AUC Authentication Center
BA behavior aggregate

BE best-effort

BHT Busy Hour Traffic Bps bits per second

BSC Base Station Controller BSR Broadband Service Router BTS Base Transceiver Station

BU business

CDMA Code Division Multiple Access
CEIR Central Equipment Identity Register

CIR Committed Information Rate
CLI Command Line Interface

CNTR control traffic CoS Class of Service

CT class type

CWND congestion window

DA data

DF Don't Fragment

DHCP Dynamic Host Configuration Protocol

DiffServ Differentiated Services

Abbreviations xvii

DNS Domain Name System
DRR Deficit Round Robin

DSCP Differentiated Services Code Point

DSL Digital Subscriber Line

DSLAM Digital Subscriber Line Access Multiplexer

DWRR Deficit Weighted Round Robin
EBGP External Border Gateway Protocol

EF Expedited-forwarding

EIR Equipment Identity Register

EPC Evolved Packet Core ERO Explicit Routing Object

eUTRAN evolved UMTS Terrestrial Radio Access Network

FIFO First in, first out FQ Fair queuing

GBR Guaranteed Bit Rate

GGSN Gateway GPRS Support Node GPRS General Packet Radio Service GPS Generic Processor Sharing

GSM Global System for Mobile Communications

GTP GPRS Tunneling Protocol HLR Home Location Register

ICMP Internet Control Message Protocol

IMEI International Mobile Equipment Identity

IMS IP Multimedia System

IMSI International Mobile Subscriber Identity

IntServ Integrated Services

L2 Layer 2 L3 Layer 3

LBE lower than that for best-effort

LFI Link Fragmentation and Interleaving

LSP label-switched path
LTE Long-Term Evolution

MAD dynamic memory allocation

ME Mobile Equipment MED multi-exit discriminator

MF Multifield

MME Mobility Management Entity
MPLS Multiprotocol Label Switching

MPLS-TE MPLS network with traffic engineering

MS Mobile System ms milliseconds

MSC Mobile Switching Center
MSS Maximum Segment Size
MTU Maximum Transmission Unit

NAS Non-Access Stratum
NC Network-control
P2P point-to-point

PB-DWRR Priority-based deficit weighted round robin

PCR Program Clock Reference

PCRF Policy and Charging Rules Function

PDN Packet Data Networks

PDN-GW Packet Data Network Gateway

PDP Packet Data Protocol

PE provider edge PHB per-hop behavior

PID Packet ID

PIR peak information rate

PLMN Public LAN Mobile Network

PMTU Path MTU

pps packets per second PQ priority queuing

PSTN Public Switched Telephone Network

Q0 queue zero Q1 queue one Q2 queue two

QCI QOS Class Identifier
QOS Quality of Service
RAN Radio Access Networks
RED Random Early Discard

RNC Radio Network Controller
RSVP Resource Reservation Protocol

RT real time

RTCP RTP Control Protocol RTT Round Trip Time

SACK selective acknowledgment SAE System Architecture Evolution

SCP Secure Shell Copy

SCTP Stream Control Transmission Protocol

Abbreviations xix

SDP	Session Description Protocol
SGSN	Serving GPRS Support Node
S-GW	Serving Gateway
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SLA	service-level agreement
SSRC	Synchronization Source Identifier
STP	Spanning Tree Protocols
TCP	Transmission Control Protocol
TE	Traffic Engineering
TOS	Type of Service
TS	Transport Stream
UDP	USER Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTP	Unshielded Twisted Pair
VLAN	Virtual LAN
VLR	Visitor Location Register
VoD	Video on Demand
VoIP	Voice over IP
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
WFQ	Weighted Fair Queuing

WRED Weighted RED

WRR

Weighted Round Robin

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