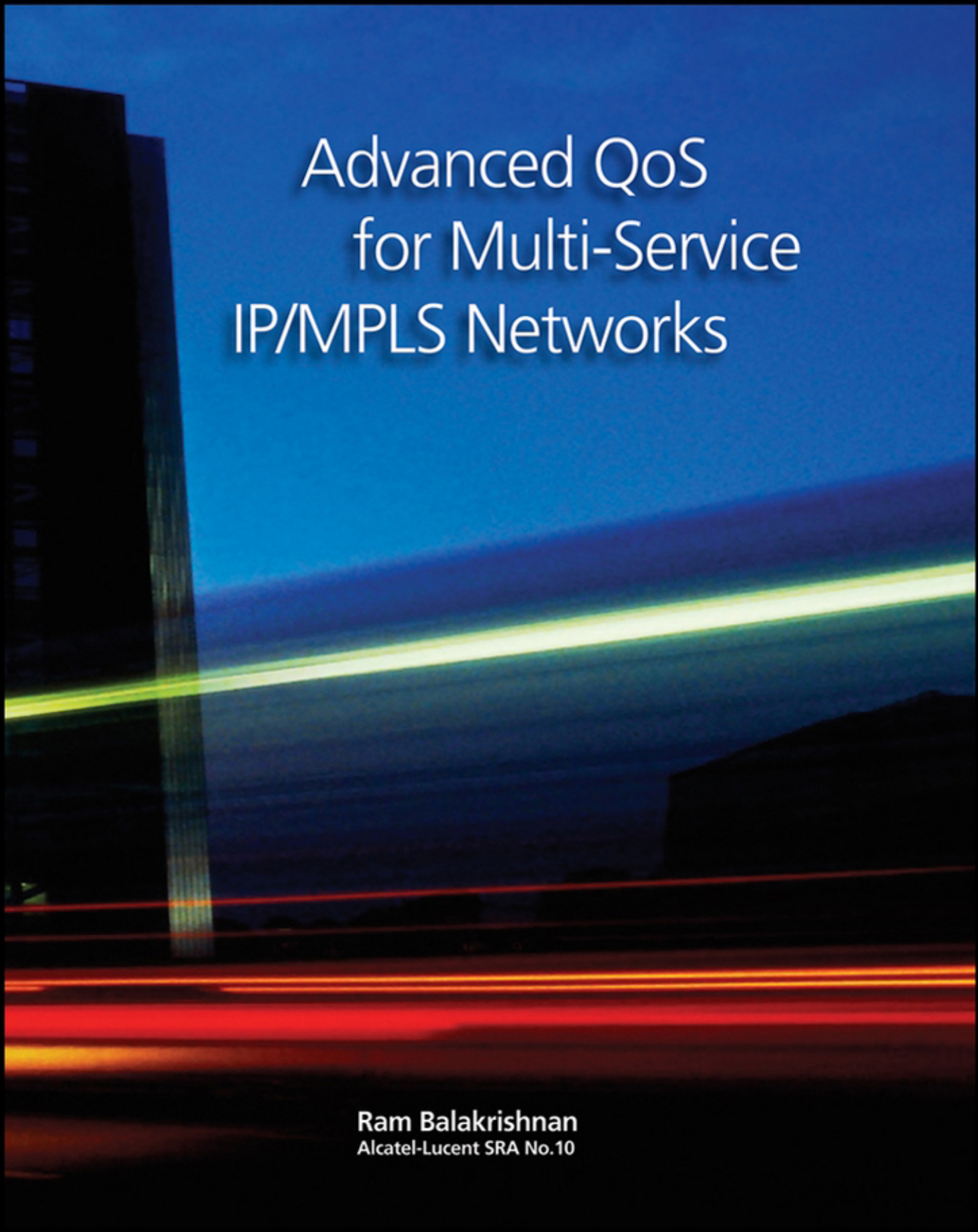
Advanced QoS
for Multi-Service
IP/MPLS Networks
Ram Balakrishnan
Alcatel-Lucent SRA No.10

"This book is much more than just Alcatel-Lucent QoS framework on the 7x50 product line as it takes the reader through a holistic QoS journey. It is useful for both the network novice and expert alike because it ties QoS concepts to the 7x50 product functionality. The knowledge acquired from this book will enable the network professional to create a solid QoS architecture/design which is mandatory to prioritize services throughout the network. The book is a reference I will return to again and again."

—BRENT CONRAD, B.Sc.(Chem), B.Sc.(CS),
Bell Canada Technology Development

"A comprehensive book that describes QoS principles and datapath traffic management capabilities of Alcatel-Lucent Service Routers. QoS is made easy with well described examples on how to design, deploy and configure services in IP/MPLS networks. A must reference for network designers or for those aspiring to become architects of modern networks."

—DR. SUDHKAR GANTI, Professor, University of Victoria

"The concept of a single IP/MPLS multiservice network provides huge economical benefits for service providers in reducing CAPEX and OPEX. With multiservice networks, the ability to assure Service Level Agreements for new service oriented application traffic has become the differentiating factor among competitors. This book educates readers on the detail operation of Quality of Service through IP/MPLS networks for converged services. I highly recommend it for network designers and test engineers."

—DEAN LEE, Senior Product Manager, IXIA

"With the dual objectives of providing cost-effective high bandwidth services and meeting stringent customer service guarantees, hierarchical service-based QoS has become invaluable for today's service providers."

—JONATHAN NEWTON, Senior Architect,
Cable & Wireless Europe, Asia & US

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To my late grandmother, Umayal,
and to my parents, Ramasamy and Alamelu:

It is your love and guidance that have made me who I am today.

—Ram Balakrishnan

About the Author

Ram Balakrishnan, a senior Network Design Architect with Alcatel-Lucent, is a renowned QoS and Triple-Play expert and educator. Leveraging his IP/MPLS knowledge in addition to his QoS expertise, Ram has led service provider and enterprise initiatives globally to design and implement converged multi-service networks. He holds patents related to intelligent routing algorithms. A frequent contributor to the *Alcatel-Lucent Telecommunications Review*, Ram has over 10 years experience in the telecommunications industry. He holds a BE degree in Electronics and Instrumentation from Annamalai University, India, and MS degrees in Engineering and Computer Science from the University of Saskatchewan, Canada. Ram is also a certified Alcatel-Lucent Service Routing Architect (Alcatel-Lucent SRA No. 10).

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Service Routing: Making IP/MPLS the Bearer of Multi-Service Traffic

The evolution of quality of service (QoS) for IP is really synonymous with the evolution of IP platforms. If you are in the service provider business, you will know the challenge of IP—especially if you were around in 2000 when the Internet really started to heat up.

Prior to the dawn of the Internet, service providers had always offered services that required service level agreements. QoS was inherent in the underlying technologies such as Frame-Relay, ATM and SONET/SDH. But the Internet was different. Its new service definition was simple: "best-effort" delivery. Despite this anomaly, service growth was explosive and made IP part of any network discussion.

Back in 2000, the question we all pondered was whether IP would form the network for all services—not just Internet services. I can recall, in the early 2000s, how often I would read about or hear a carrier calling routers "these bloody IP platforms" and bemoaning the fact that they were not carrier-class.

The challenge was clear: Could IP platforms, when blended with MPLS technology, effectively become the bearer of multi-service traffic? It was a big question. Certainly major improvements would have to occur on a number of dimensions. For example, we needed a carrier-class router design that included scalable control planes, better Operation Administration and Maintenance (OAM) features, true high availability and quality of service. So I joined up with some other like-minded veterans of switching and routing development. We pulled together a small team and conceived of and delivered to market in 2003 the world's first true "Service Router." The Alcatel-Lucent 7×50 family quickly became the leading carrier-grade routing platform of its kind, and it has since helped the world's leading service providers realize their multi-service infrastructure goals. It was designed from the ground up to support multiple services with multiple levels of QoS over IP/MPLS.

No one questions now that IP/MPLS can manage multiple services on a common infrastructure. And that is why QoS is so critically important now. This book provides essential information for today's multi-service architects. In these pages, Ram Balakrishnan will explain QoS technology and how IP/MPLS network architectures are best designed for multi-service delivery.

Enjoy the book . . . and welcome to the new era of service routing.

Basil Alwan
President, IP Division
Alcatel-Lucent

Preface

In the face of relentless competition, service providers are turning to a new wave of next generation IP-based services to retain customers, increase average revenue per user and to attract new customers. These initiatives require the highest percentage of service reliability to ensure uninterrupted subscriber sessions, to meet stringent service level agreements (SLAs) and to ensure customer satisfaction. A key means by which to ensure service reliability is through service-aware hierarchical quality of service (HQoS). HQoS ensures that the service requirements of all types of traffic flow are satisfied and controlled across the network and that each service has the reliability and the required resources to meet customer performance expectations.

Ram Balakrishnan, has created a wonderful educational resource for you. With over a decade of experience in supporting service providers globally, Ram has written a publication that provides you with a solid theoretical and practical overview of how QoS can be implemented to reach the business objectives defined for an IP/MPLS network.

From our extensive engagements delivering and supporting global customers with our Network Design and OSS Engineering services, Alcatel-Lucent has captured its vast IP service-routing knowledge and expertise in this new publication and our industry-first Service-Routing based certification (SRC) program. The future holds many new telecommunication opportunities for all of us. Have fun with this wave of IP transformation!

Enjoy the knowledge adventure you are about to begin.

Ravi Parmasad
Vice President, Customer Support
IP Division
Alcatel-Lucent

Acknowledgments

To begin, I would like to express my appreciation to Basil Alwan, Ravi Parmasad, and Mac Virdy, members of the Alcatel-Lucent IP Division senior management team for their constant support. Mac: Your enthusiasm is infectious and it made my task of writing this book much easier.

I would like to extend special thanks to Karyn Lennon and George Carroll for getting me all the additional support that I needed during the course of writing this book and helping me to focus on the content development. Karyn: Thank you for your hard work in managing the various publishing tasks of this book. George: It was your continued words of encouragement that helped me to maintain the intensity of my focus throughout this project.

I extend my gratitude to the technical reviewers: Mustapha Aissaoui, Erica Poppe, Yanick Champoux, and Olivier Le Moigne. Thank you all for your detailed comments, and for those frequent and lengthy technical conversations, even in the late evenings. Special appreciation to John Coulter, Bashar Bou-Diab, Matthew Bocci, and Jim Guillet for reviewing different sections of the book and providing valuable inputs. Thanks to Phil Cole for the cover design and for providing input on the internal layout design.

The book also benefited enormously by the inputs provided by external reviewers: Many thanks to Brent Conrad of Bell Canada; Carey Williamson, Professor in the Department of Computer Science at the University of Calgary; Sudhakar Ganti, Professor in the Department of Computer Science at the University of Victoria; Jonathan Newton of Cable&Wireless; and Dean Lee of Ixia.

Special thanks to the staff members of Wiley Publishing for their excellent support. Sara Shlaer: Your involvement in the project made a big positive change to the outcome.

An application note that I wrote on the topic became the stepping-stone for writing this book and thanks to Stephen Rowlandson for encouraging me to write it. Special appreciation to Todd Craw and Miroslav Vrana, not only for providing me with the support documentation, but also for thoroughly reviewing the application note.

My thoughts on the subject were refined because of the lengthy discussions I had with some of Alcatel-Lucent's customers. It is my good fortune that I had the opportunity to work with these people. It is not possible to list all their names here, but my heartfelt thanks to all of them.

Finally, it is the understanding and love of my wife Meena that helped me to complete this book. I spent too many nights and weekends writing this book. She not only kept feeding me, but also brought her own additional work home to keep me company. Meena: I cannot thank you enough and I love you very much.

Ram Balakrishnan

Contents at a Glance

Contents

Introduction

Internet Protocol/Multi Protocol Label Switching (IP/MPLS) quality of service (QoS) is a rapidly evolving, and with the advent of service routers, maturing technology. The legacy "best-effort" service offered by IP networks is no longer adequate. The developments in the IP/MPLS QoS is enabling IP/MPLS networks, including the world's biggest network—the Internet, to offer multiple application services. With these changes, IP is becoming the preferred networking technology for end-to-end network convergence. Therefore, QoS design is becoming a major and inevitable aspect of modern IP/MPLS network design process.

One of the fundamental goals of the Alcatel-Lucent philosophy in designing a family of service routers and offering end-to-end network solutions is to let service providers expand their service infrastructure as they grow. Service routers provide significant customization options, which enable networks to expand seamlessly. In addition, they are deployable in a wide range of network scenarios. QoS features, as core service-related features of service routers, are also fully customizable.

The growing importance of QoS considerations while designing an IP network, and the flexibility provided by service routers in configuring QoS features, increases the responsibilities of the network design and maintenance personnel in gaining a thorough understanding of the subject. The intention behind this book is to help readers to gain such a thorough knowledge of the subject.

How This Book Is Organized

Many readers may entertain the notion that QoS is a complicated topic to understand. As someone who started exploring IP/MPLS networking from a QoS perspective, I beg to differ, and I hope you will find this book provides a simple and straightforward presentation of the subject. Wherever appropriate, I have used real-life analogies to aid readers' understanding of technical concepts.

The book is divided into three parts and presents the QoS discussion in three levels of abstraction to provide a complete view of the topic. Part 1 presents a high-level end-to-end perspective and fundamental details of QoS. Part 2 explains the theoretical and practical details of the QoS features. The chapters in Part 2 also explain in detail how to configure, apply, and validate the QoS features. Wherever possible, configuration samples and example analyses are also presented. Part 3 rounds off the discussion by providing QoS design principles, a step-by-step approach to designing QoS, and case studies that illustrate using QoS design to meet business objectives.

You will find the material in the Notes and Best Practices sidebars that appear throughout the chapters to be useful as quick reference reminders while designing QoS and during the design verification process in the lab.

In topics related to networking, it is not possible to avoid TLAs (Three-Letter Acronyms) or acronyms in general. The acronyms are so heavily used in the networking industry that some of the terms are more readily recognized by their acronyms, rather than through the expanded terms. For easy reference, most of the commonly used terms and acronyms in the book are listed along with their definitions in the Glossary at the end of the book.

Conventions Used in the Book

Alcatel-Lucent provides a modular approach for configuring the individual entities of Alcatel-Lucent Service Router Portfolio (ALSRP) nodes. In the approach, most of the QoS features and Access Control Lists (ACLs) are configured as policies and applied under appropriate entities. The modular approach and QoS policies make network and QoS designs simple and elegant. This makes node configurations easier to understand and maintain.

ALSRP nodes can be provisioned and managed either directly using the command line interface (CLI) of individual nodes or through a service-aware network management system (Alcatel-Lucent 5620 SAM). Alcatel-Lucent 5620 Service Aware Manager provides different types of interfaces, including a graphical user interface (GUI), for provisioning the nodes of a network. In this book, only the command line configuration option for configuring and managing ALSRP nodes is considered.

CLI commands are entered at the command line prompt. Entering a command makes navigation possible from one command context (or level) to another. When you initially enter a CLI session, you are in the root context. At the root context, the prompt indicates the active central processor module (CPM) slot and the name of the node. For more information on CPM, see Chapter 5. Navigate to another level by entering the name of successively lower contexts. As you change through the levels, the prompt also changes to indicate the context you are in. Listing 1 shows an example CLI navigation and prompt change according to the context.

Listing 1 Navigation and prompt change

```
A:Pod2#
A:Pod2# show
A:Pod2>show#
```

The root prompt of Listing 1 indicates that the active CPM slot of the node is A and the name of the node is configured as `Pod2`. In the listing, on entering the command `show`, the prompt changes to indicate the `show` context. As you can see in this paragraph, when CLI codes are used inline along with the main text, they are indicated by the use of monofont text.

To get contextual help at a given prompt, simply enter a question mark (`?`). In a given CLI context, you can enter commands at that context level by simply entering the text. It is also possible to enter a command in a lower context as long as the command is formatted in the proper command and parameter syntax. Listings 2 and 3 show the two methods to navigate to the `show qos` context.

Listing 2 Navigation by entering context level commands

```
A:Pod2# show
A:Pod2>show# qos
A:Pod2>show>qos#
```

Listing 3 Navigation by entering lower context level commands

```
A:Pod2# show qos
A:Pod2>show>qos#
```

Listing 4 shows the command options for the `show qos sap-ingress` command. The listing is presented here to explain the syntax of CLI command options. The purpose of the command in Listing 4 is explained in Chapter 6.

Listing 4 An example of CLI command options

```
A:Pod2>show>qos# sap-ingress
  - sap-ingress [<policy-id>] [association|match-criteria|detail]

 <policy-id>          : [1.65535]
 <association>        : keyword - display associations
 <match-criteria>     : keyword - display match criteria
 <detail>             : keyword - display detailed information
```

In the command syntax, square brackets indicate optional parameters of a command; angle brackets indicate that a substitution is required for the placeholder; and a pipe (|) indicates an either/or relationship between the parameters on either side of the pipe. To shorten some of the listings, later in the book, part of the listings' outputs are stripped and replaced with … to indicate the stripping.

For further information regarding the use of the command line interface, refer to the *System Basics Guide*, which is a part of the ALSRP product manuals. This book is the first in a series of technical books to be published related to Alcatel-Lucent service routers. This book provides references to the Alcatel-Lucent manuals that come with the Alcatel-Lucent 7750 Service Router, the Alcatel-Lucent 7450 Ethernet Service Switch, or the Alcatel-Lucent 7710 Service Router platforms. If you are an Alcatel-Lucent customer and you don't have access to the Alcatel-Lucent's Service Router product manuals, contact your Alcatel-Lucent account manager. If you are not a customer of Alcatel-Lucent, visit the Contact Us area at `www.alcatel-lucent.com`.

A standard set of icons are used throughout this book. A representation of these icons and their meanings are listed under the section "Standard Icons".

Audience

This book is targeted for a wide audience, including but not limited to network architects, engineers, administrators, and operators of all types of IP/MPLS based networks. The book is also an excellent resource for students interested in gaining a practical understanding of advancements in IP QoS. If you need to design, support, or just understand IP QoS from an applied perspective, you should find this book useful.

To gain maximum benefit from this book, a basic understanding of IP and MPLS networking is required. Some familiarity with configuring the Alcatel-Lucent 7750 Service Router, the Alcatel-Lucent 7450 Ethernet Service Switch, or the Alcatel-Lucent 7710 Service Router platforms will also be useful. This book also serves as a general technical reference guide to IP/MPLS QoS.

Feedback is Welcome

It would be our pleasure to hear back from you. Please forward your comments and suggestions for improvements to the following email address:

sr.publications@alcatel-lucent.com

With that, I would like to welcome you to the exciting world of quality of service.

Ram Balakrishnan

Standard Icons

Generic ALSRP node

Generic ALSRP node

Alcatel-Lucent 5620 SAM

IP/MPLS Tunnel

Scheduler

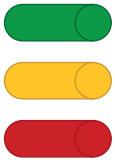
Virtual Scheduler

Traffic Policer

Rate-Limiter

Traffic Filter

Traffic Classifier



Queues

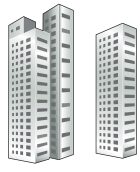
Datagrams

Scheduling loop

Network

Basic Router

Residential Customer



Business Organizational Entities

Advanced QoS for Multi-Service IP/MPLS Networks

1 Fundamentals of IP/MPLS QoS

Gaining the knowledge of the end-to-end quality of service model will give you an appreciation for roles played by the individual QoS features. The chapters in Part 1 walk you through the need for QoS, the enhancements offered by service routers from a QoS perspective, and the QoS models standardized by IETF. They describe the QoS support built into different Layer 2 and Layer 3 technologies, and the functions of fundamental QoS features.

1 The Need for Quality of Service

QoS is an integral set of features in a service router, which can help service providers exceed service level agreements for the different application traffic types carried over a multi-service network.

Chapter Objectives

- To explain the need for QoS
- To introduce the Alcatel-Lucent Service Router Portfolio
- To explain the differences between a service router and a traditional IP router
- To explain the restrictions in forwarding traffic within a network
- To discuss formalizing service commitments through service level agreements

When offering commercial airline services, there is a big difference between using an airplane designed specifically for carrying commercial passengers and using an airplane designed purely for transportation (say, a military transport plane). Although both types of aircrafts are meant for transportation, their purposes are very different. The architectural design of commercial aircraft is oriented towards satisfying the service needs of different classes of passengers, which result in increasing the profit of the airline. In contrast, military aircraft are not designed for servicing customers but are meant for transporting mainly a homogeneous class of passengers (or cargo).

Similarly, there is a big difference in using service routers and traditional IP routers to deliver carrier grade multiple application services and maximizing the profit of the service provider. In contrast to traditional IP routers, service-related capabilities were integrated into the product architecture of service routers at inception. Quality of service (QoS) is an integral set of features in a service router, essential for satisfying diverse service needs of different application traffic, while maximizing the resource utilization of the router within a multi-service network.

This book introduces you to the fundamentals of QoS for an Internet Protocol/Multi Protocol Label Switching (IP/MPLS) network. It also addresses the theoretical and practical details of advanced QoS features offered by service routers, and concludes by teaching you how to design QoS in a multi-service network.

1.1 The Changing Service Delivery Landscape

The distinction among telephone companies, cable companies, and Internet service providers (ISP) is vanishing fast. All these players are facing increasing demands to offer personalized user-centric services involving voice, video, and data application traffic. To enhance the customer network experience with media-rich application content, the service providers are embracing service convergence and delivering all killer applications over a single infrastructure. A service provider offering voice, video, and data application services using a single network infrastructure is commonly referred to as a *triple-play* service provider.

Note: In this book, the term *service provider* is used in a broad sense and includes all commercial and noncommercial broadband network operators. For noncommercial network administrators, the clients are their own enterprise or organization.

In the residential market, the High Speed Internet (HSI) infrastructures built around business models that allowed significant oversubscription and service level leniency are no longer efficient with the advent of service convergence. The new service level agreement (SLA) standards for voice and video applications have stringent quality of service (QoS) requirements. These SLAs also impose rigorous constraints on availability, system characteristics, and multicast requirements.

In the enterprise space, customers are increasingly doing business electronically, using communication technology to drive sales, improve customer relationships, train staff, simplify procurement, and collaborate between different sites. This is taking place across metro, national, and international boundaries. Enterprises want convenience and simplicity along with strict QoS and control, both in their local area networks (LANs) and across wide area networks (WANs). QoS, flexible bandwidth, and availability are critical for business networking applications such as voice, video, and data.

1.2 What Is Quality of Service?

The increasing convergence of network services leads directly to the need for a QoS approach. *Quality of service* is defined as the ability of a network to recognize different service requirements of different application traffic flowing through it and to comply with SLAs negotiated for each of the application services, while attempting to maximize the network resource utilization. QoS is absolutely essential in a multi-service network, in order to meet SLAs of different services and to maximize the network utilization.

Without QoS, datagrams are serviced in a network on a first-in, first-out (FIFO) basis, also referred to as *best-effort service*. In such scenarios, datagrams are not assigned priority, based on the type of application that they support. As a result,

differential treatment for different types of application traffic is not possible. Therefore, service level agreements for any service other than best-effort service cannot be met.

Note: Because service routers can support different media interfaces, including Ethernet, SONET, Asynchronous Transfer Mode (ATM), and Frame-Relay, the word *datagram* is used to refer to all types of traffic that can flow through a network using service routers. As such, in this book, the word *datagram* is used to collectively refer to packets, frames, and cells.

QoS allows the service provider to utilize a network infrastructure for offering multiple application services, thereby saving the capital and operating costs involved in maintaining multiple networks for each of the applications separately. Although network traffic flows are dynamic in nature, QoS allows the service provider to maximize network resource utilization, thereby increasing their profit. QoS maximizes network resource utilization and optimizes revenue generation by providing priority access to network bandwidth for high-priority traffic, and by allowing low-priority traffic to gain the bandwidth committed to high-priority traffic in the absence of high-priority traffic.

When *Don't* You Need QoS?

To play devil's advocate, you could argue that you don't need QoS if your network meets any of the following conditions:

- There will not be any congestion in your network.
- You will have only homogeneous traffic in your network.
- You are beyond the worldly pleasure of making money out of your network.

1.3 Alcatel-Lucent Service Router Portfolio

Alcatel-Lucent has unveiled the industry's first service router portfolio that provides solutions to service providers to address the challenges of the rapidly changing service delivery landscape.