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QUALITY OF SERVICE IN OPTICAL PACKET SWITCHED NETWORKS

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To my parents
and my family

CONTENTS IN BRIEF

CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

Welcome to the era of unlimited communications, video-centric applications, and Internet! Internet applications require both bandwidth and Quality of Service (QoS) because of a huge number of Internet users and growing number of real-time applications (such as 3D TV, ultrahigh-definition TV, video-on demand, Internet Protocol TeleVision (IPTV), video-conferencing, Internet gaming, voice over IP, etc.) that need different levels of QoS. IP networks consist of core networks and access networks. By increasing IP traffic, access networks can grow in both size and count [1]. For example, traffic of broadband access networks such as ADSL and Fiber To The Home (FTTH) is continually increasing every year. To transport the huge traffic offered by IP networks, the core networks capabilities must be increased to avoid them from becoming bottleneck for IP traffic. This could be a problem when the network bandwidth is limited, the network supports only the best effort traffic, and the Internet traffic does not have a uniform characteristic.

The need for more and more bandwidth forces us to think of more granularity. The best promising solution is to use Wavelength Division Multiplexing (WDM) all-optical networks in core networks. Note that an optical network that uses optical transmission and keeps optical data paths through the nodes from source to destination is called all-optical network. Due to the fact that all-optical networks use photonic technology for the implementation of both switching and transmission functions, signals in these networks can be maintained in optical form without any conversion to the electronic domain resulting in much high transmission rates. All-optical networking with deployment of Dense Wavelength Division Multiplexing (DWDM) appears to be the sole approach to transport the huge network traffic in future backbone networks. The DWDM technology provides the multiplexing of many wavelength channels in a single optical fiber, resulting in several Tbits/s bandwidth capacity.

Similar to the electronic domain in which packet switching is the most granular method of switching, the most promising technique for optical core networks could be Optical Packet Switching (OPS) due to its high throughput and very good granularity and scalability. In an OPS edge node, a header is attached to each client packet received from a legacy network, where the header includes the information about source edge node, destination edge node, and content of packet payload such as its length. The packet is then transmitted in the optical domain, called an optical packet, toward the OPS network. In OPS, an optical packet stays in the optical domain inside the core network and switched optically. The optical packet can only be converted to the electronic domain in its destination edge node. Packet switching provides connectionless transmission of packets. Thus, there is no need to establish a path (i.e., a circuit) between source–destination nodes like in circuit switching. However, contention of optical packets in the core network is the major problem in OPS networks.

Since different applications need different levels of QoS, service differentiation must be considered in optical networks as well. Under the best-effort service in which no guarantees are given to any packet regarding loss rate, delay, and delay jitter, all traffic in the network is equally treated. This will, in turn, degrade the QoS requirements for real-time traffic. Thus, having a QoS-capable optical backbone network will be a requirement in which low latency, low jitter, low loss, and bandwidth guarantees must be provided for real-time traffic.

For providing QoS in OBS networks, [2] details (a) the basic mechanisms developed for improving end-to-end QoS and (b) relative and absolute QoS differentiation among multiple service classes. On the other hand, for OCS networks, the work in [3] focuses on the methods developed for service-differentiated and constraint-based wavelength routing and allocation in multi-service WDM networks. However, there is no comprehensive work on QoS in OPS networks.

In future, OPS networks must be setup for worldwide communications in order to transport the huge traffic generated by Internet users and applications. In addition, research and development on optical communication networking have been matured significantly during the last decade to the extent that some of these principles have moved from the optical research laboratories to formal graduate courses. Moreover, there are a large number of experts working on designing optical devices and physical-layer of optics that are interested in learning more about OPS network architectures, protocols, and the corresponding engineering problems in order to design new state-of-the-art OPS networking products. Finally, there are many books written for device level of optical communications, and there are even devices suitable for OPS. However, there is almost no work dedicated solely for system level of OPS (say architectures and protocols), improving quality of service, and the operation of OPS networks.

In general, there are some books published for covering optical networking such as [4–10]. However, the number of published books dedicated to the system level of OPS is limited to OPS in access networks [11], design of optical buffers for OPS [12], edge node design for contention avoidance in slotted OPS [13], scheduling in star-based OPS networks [14], and OPS for ring networks [15].

This book provides a comprehensive study on OPS networks, its architectures, and developed techniques for improving its quality of switching and managing quality of service. This book is organized in six chapters, each covering a unique topic in detail:

- Chapter 1 provides an introduction to OPS networks, its architectures, and QoS in OPS. Since many optical networking books have stated optical systems in much detail, this chapter does not include them. In addition to OPS networks, GMPLS-supported optical networks and optical networks based on Orthogonal Frequency Division Multiplexing (OOFDM) are studied in this chapter.

- Chapter 2 describes contention avoidance schemes proposed for OPS networks in which edge switches send optical packets to the OPS network in a way to reduce their collisions. Broadly, these schemes are classified as either hardware-based or software-based.

- Chapter 3 details contention resolution schemes proposed for OPS networks in which OPS switches resolve the collision of contenting optical packets. In general, contention resolution schemes are classified as either hardware-based or software-based.

- Chapter 4 studies the hybrid contention resolution schemes that use a number of contention resolution schemes in the same architecture in order to reduce optical packet loss rate. In addition, hybrid contention resolution and contention avoidance schemes are reviewed that can efficiently reduce optical packet loss rate in a cost-effective manner.

- Chapter 5 describes hybrid optical switching schemes in which OPS networking is combined with another optical switching technique (say optical circuit switching) in order to improve the performance of traffic transmission in the optical domain.

- Chapter 6 states different OPS architectures designed for metro area. These networks are mainly based on ring and star topologies with active optical switches.

This book is a useful resource for students, engineers, and researchers to learn more about optical packet switched networking from system level points of view. It is intended as a textbook for graduate level and senior undergraduate level courses in electrical engineering and computer science on (advanced) optical networking. Knowledge about computer networks is a prerequisite for understanding this book. For advanced optical networks course relevant to OPS, the book can be entirely used.

Reasonable care has been taken in eliminating any types of errors. However, readers are encouraged to send their comments and suggestions to the author via e-mail. I personally hope that this book will give the reader enough information in OPS networks and motivate his/her interests to develop efficient, QoS-capable, and cost-effective OPS networks suitable for future core optical networks.

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