

Preface

Motivation

Data transmission and networking technologies have witnessed tremendous growth over the past decade. However, much of this development and growth has been primarily in the core networks where high-capacity routers and ultra-high-capacity optical links have created a truly broadband infrastructure. The so-called first mile—the access network connecting end-users to backhaul infrastructure—remains a bottleneck in terms of the bandwidth and quality of service it affords to the end-users.

Until recently, the lack of broadband Internet access has been an inconvenience, but today this type of Internet access is truly essential for further development of many aspects of life. High-speed Internet expands our ability to communicate, learn, and entertain. Nowadays, Internet access is commonly associated with entertainment and information browsing, where most end-users use Internet connection for exchanging information, online gaming and applications such as Facebook and Twitter. On the other side, the number of business users has dramatically increased as network infrastructure is becoming the necessity for successful business operations. Service providers are mainly focused on the development and implementation of applications such as video on demand (VoD), high definition TV (HDTV), and online gaming which further increases the need for higher access speeds.

Moreover, broadband infrastructure is able to improve the quality of life in addition to supporting and improving business operations. Broadband online learning, video conferencing, online education for people with disabilities, national health network, and electronic health records are only a few examples that demonstrate the importance of the further development of broadband infrastructure.

In last decade, Ethernet passive optical networks (EPONs) were considered as a potential optimized architecture for the access network. An EPON is a point-to-multipoint fiber optical network designed to carry Ethernet frames at standard Ethernet rates. Propelled by rapid price declines of fiber optic and Ethernet

components, these access networks combine the latest in optical and electronic technology and become the dominant players for delivering gigabit broadband connectivity to homes over a unified single platform. A major feature for this architecture is the use of a shared transmission media between all users; hence, medium access control arbitration mechanism is essential for the successful implementation of EPON. This mechanism ensures a contention-free transmission and provides end-users with an equal access to the shared media. Moreover, with the development of different multimedia-based applications such as HDTV, internet protocol TV (IPTV), and many others, the related quality of service (QoS) issues are also becoming a key concern. Namely, together with an increasing number of users in the access network, the number of bandwidth-hungry applications is increasing as well.

Until today, different models for incremental migration from TDM (Time Division Multiplexing) to TDM/WDM (Wavelength Division Multiplexing) EPON networks have been proposed, but most attention has been given to those solutions that support QoS implementation. Moreover, with the rapid development of different bandwidth applications, QoS support is becoming a key concern in WDM EPON network as it was the case with EPON networks.

Organization

Throughout the chapters of this book, we address many of the specified issues and present models and algorithms that we believe could resolve these issues. Moreover, we are convinced that the hardware implementation of the presented models and algorithms would operate in a foreseen manner and would not involve any additional implementation complexity. In the first place, we present a theory of differentiated services that essentially represents a basis for the QoS implementation in Ethernet-based networks since the QoS support has become a crucial requirement for a converged broadband access network with heterogeneous traffic. Furthermore, we present a detailed analysis and discuss the most important aspects of QoS support and implementation in networks that are based on optical transmission, particularly EPONs and WDM EPONs.

Following the outline of the theory of differentiated services, we present the overview of the EPON technology and introduce the readers with the challenges and unresolved issues in currently deployed EPON networks. We propose to use the multipoint control protocol (MPCP) defined within the IEEE (Institute of Electrical and Electronics Engineers) 802.3ah Task Force to arbitrate the transmission of different users, and we discuss the implementation of different dynamic bandwidth allocation (DBA) algorithms to effectively and fairly allocate bandwidths between end-users. In our first main contribution, we propose a novel dynamic intra-ONU (Optical Network Unit) scheduling algorithm for single-channel EPON systems, termed hybrid granting protocol (HGP), with full QoS support in accordance with the theory of differentiated services. For the presented

model, we analyze how new scheduling algorithm can be combined with existing dynamic bandwidth allocation schemes in order to minimize packet delay and jitter. Specifically, the presented dynamic scheduling algorithm minimizes packet delay and jitter for delay and delay-variation sensitive traffic (e.g., voice transmissions) by allocating bandwidth in a GRANT-before-REPORT (GBR) fashion. This considerably improves their performance without degrading QoS guarantees for other service types. Detailed simulation experiments are presented for studying the performance and validating the effectiveness of the presented solutions.

However, given the steadily increasing number of users and bandwidth-hungry applications, although standardized, the current single-channel systems will not be able to satisfy the growing traffic demands in the future. Accordingly, we further suggest the implementation of wavelength division multiplexing technology in Ethernet passive optical networks in order to overcome problems that exist in the classical single-channel systems. Implementation of WDM technology would allow access network operators to respond to user requests for service upgrades and network evolution. Moreover, the deployment of WDM technology adds a new dimension to current TDM EPONs whereby the benefits of the new wavelength dimension are manifold. Among others, it may be exploited to increase network capacity, improve network scalability by accommodating more end-users, and separate services and service providers.

As previously discussed, the development of various multimedia applications requires QoS implementation in WDM EPONs just as it was the case with EPONs. In our next main contribution, we further present and analyze two models for wavelength and bandwidth allocation in the hybrid TDM/WDM EPON system with full QoS support, namely the fixed wavelength priority bandwidth allocation (FWPBA) model, and the dynamic wavelength priority bandwidth allocation (DWPBA) model. In order to implement QoS support, we present a new approach for QoS analysis and implementation in WDM EPON in which wavelength assignment takes place per service class and not per ONU, as suggested by the common approach in literature. In this way, the need for implementation of additional complex algorithms in order to support QoS, which increases system cost and increases the overall system efficiency, is avoided. Additionally, we propose a method for providing an upgrade to WDM in EPONs that includes an extension of the MPCP. In this way, the presented architecture and models will allow an incremental upgrade from TDM EPON to TDM/WDM EPONs. For each of the proposed models, wavelength and bandwidth allocation algorithms with full QoS support have been presented in order to fulfill all the requirements of new applications and services in a converged triple-play network. The presented models and algorithms are then compared in terms of average and maximum packet delay, packet variation delay (jitter), queue occupancy, packet loss rate, throughput, and overall system performance. Once again, detailed simulation experiments are presented for studying the performance and validating the effectiveness of the presented solutions.

In addition to FWPBA and DWPBA models, we present the future development of the proposed model that includes further segregation of medium priority traffic

class according to the IEEE 802.1d standard and add another wavelength to be used for transmission of medium priority traffic, i.e., multimedia applications.

In the last chapter of the book, we conclude our work and present guidelines for future developments within this field.

Instruction for Readers

This book is intended to resolve misunderstood facts, equations, algorithms, and routines connected with EPONs, especially those directly connected to QoS and overall quality of traffic transmission in access networks. It may be very useful for students studying communication sciences, telecom operators, professionals in fields of optical networks and, of course, academic educators and scientists.

The first part of the book, namely Chapters I to IV, are intended to introduce readers to the field of EPON and describe and explain the most important facts about EPONs and the extension to WDM EPONs. These chapters recapitulate EPONs and QoS support in EPON and are more appropriate for students and readers that study EPONs for the first time. The second part of book, Chapters V to VII, are more advanced and introduce a novel concept of WDM EPON (wavelength assignment per service class) which may be designated as new generation EPON; a name which may seem more appropriate than “next generation EPON” which has been commonly used for WDM EPON and 10G EPON within the classical approach (wavelength assignment per ONU). These chapters are intended for readers with knowledge of basic architecture of PONs and EPONs, professionals in the field as well as for university educators at advanced levels of postgraduate studies (Master and Ph.D. courses).

We hope that the following text will be very useful for all readers and that it will open new frontiers for the future development of optical access networks.

Verba volant, scripta manent.

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