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The existing challenges in the backhaul of the 4G networks and the Optical Transport Networks (OTN) affect the performance, the flexibility, and the cost of building the next generation of the communication network in Egypt. At the same time, the solutions to these challenges will lead to the evolution of the 5G mobile networks, which are characterized by an increasing number of wireless devices, service complexity, and the high demands to access more mobile services. The thesis discusses the impact of the implementations of the new technologies such software-defined network and machine learning in the core optical network on the flexible functionality of the access networks and how the centralized controller in the heterogeneous networks could improve the capacity and the resilience of the 4G services. There are many challenges of the LTE network in the backhaul section and the core OTN, such as the integration between the different heterogamous optical networks, synchronization of the network, the security of the customer data over the core optical network, and the available capacity of the backhaul LTE network. One of these changes is the security of the mobile customers over the backbone optical network such as OTN. The proposed security model in this thesis is implemented on the basis of protecting the vital client signals only over the optical layers by passing these signals into extra layer called security layer, this done by adding a new card in the Network Element (NE) to perform this job and by using the concept of the software-defined network (SDN) of the centralized controller with the help of the machine learning technology to perform the automatic detection of any intrusions over the optical layers. Another challenge in building the 4G network in Egypt is the high cost of the leased lines over the core optical network, which is used to connect the 4G sites between the different regions in the country. In this thesis, for the first time an Intelligent Universal Platform (IUF) is proposed to manage and optimize the operational tasks in the optical network. Use cases in two situations As-Is and To-Be are studied, the cases are about the energy consumptions, the fault locations, the circuit creations and finally the variation in the signal to noise ratio. The results show that by using the machine learning (ML) in our platform the time of the fault location, the efforts to create one circuit, the number of the complaints, and the response time to the customer complaints are enhanced by significant percentages, this indicates that the machine learning techniques will play a significant role in monitoring, detecting, localizing the faults, and finally optimizing the resources of optical core network, all without human interventions in the near future. There are many other difficulties in the OTN, such the expensive cost of the multilayer services planning, the quality of the services, and the quality of the resilience, all of these difficulties must be recovered first to cope with the changes in the new generations of the access communication networks. The needs to overcome many of these difficulties become vital nowadays, and depend on many factors in the OTN, such the status of the optical cables, the flexibility, the responsive, and the availability of OTN assets to direct customer control. In this thesis for a new proposed model is introduced by reorganizing the OTN resources to fit the needs of the new generations of the communications market, the model consolidates two promising technologies with each other which are the Software-Defined Network (SDN) and the Machine Learning (ML) to overcome the previous challenges and to reconstruct the control of the traditional OTN to be more smart, virtualized and automated. For the first time, the optical cloud concepts are introduced in the OTN by slicing and virtualizing the various domains with its vendors in the heterogeneous optical network. Transport networks evolved from DCS (Digital Cross-connect Systems)-based mesh architectures, to SONET/SDH (Synchronous Optical Networking/Synchronous Digital Hierarchy) ring architectures in the 1990’s. In the past few years, technological advancements in optical transport switches have allowed service providers to support the same fast recovery in mesh networks previously available in ring networks while achieving better capacity efficiency and resulting in lower capital cost. Optical transport networks today not only provide trunking capacity to higher-layer networks, such as inter-router connectivity in an IP-centric infrastructure, but also support efficient routing and fast failure recovery of high-bandwidth services. This is possible due to the emergence of optical network elements that have the intelligence required to efficiently control the network. Optical mesh networks will enable a variety of dynamic services such as bandwidth-on-demand, Just-In-Time bandwidth, bandwidth scheduling, bandwidth brokering, and optical virtual private networks that open up new opportunities for service providers and their customers alike. Path Routing in Mesh Optical Networks combines both theoretical as well as practical aspects of routing and dimensioning for mesh optical networks. All authors have worked as technical leaders for the equipment vendor Tellium who implemented such capabilities in its product, and whose product was deployed in service provider networks. Path Routing in Mesh Optical Networks Presents an in-depth treatment of a specific class of optical networks, i.e. path-oriented mesh optical networks. Focuses on routing and recovery, dimensioning, performance analysis and availability in mesh optical networks. Explains and analyses routing specifically associated with Dedicated Backup Path Protection (DBPP) and Shared Backup Path Protection (SBPP) recovery architectures. As most of the core backbone networks evolve to mesh topologies utilizing intelligent network elements for provisioning and recovery of services, Path Routing in Mesh Optical Networks will be an invaluable tool for both researchers and engineers in the industry who are responsible for designing, developing, deploying and maintaining mesh optical networks. It will also be a useful reference book for graduate students and university professors who are interested in optical networks or telecommunications networking. With a foreword by Professor Wayne D. Grover, author of the book Mesh-Based Survivable Networks. Includes recently approved adopted and implemented standards for versatile switches, routers and multi-service provisioning platforms. Numerous illustrative examples showing actual situations or cases implemented. Covers the activities of all the major optical networking standards bodies and forums (ITU-T, IETF, MEF, and OIF). This book presents advances in the field of optical networks - specifically on research and applications in elastic optical networks (EON). The material reflects the authors’ extensive research and industrial activities and includes contributions from preeminent researchers and practitioners in optical networking. The authors discuss the new research and applications that address the issue of increased bandwidth demand due to disruptive, high bandwidth applications, e.g., video and cloud applications. The book also discusses issues with traffic not only increasing but becoming much more dynamic, both in time and direction, and posits immediate, medium, and long-term solutions throughout the text. The book is intended to provide a reference for network architecture and planning, communication systems, and control and management approaches that are expected to steer the evolution of EONs. Passive optical network (PON) technologies have become an important broadband access technology as a result of the growing demand for bandwidth-hungry video-on-demand applications. Written by the leading researchers and industry experts in the field, Passive Optical Networks provides coherent coverage of networking technologies, fiber optic transmission technologies, as well as the electronics involved in PON system development. Features: An in-depth overview of PON technologies and the potential applications that they enable Comprehensive review of all major PON standards and architecture evolutions, as well as their pros and cons Balanced coverage of recent research findings with economic and engineering considerations Presents system issues of protocols, performance, management and protection Extensive references to standards and research materials for further studies This book provides an authoritative overview of PON technologies and system requirements and is ideal for engineers and managers in industry, university researchers, and graduate students. Balances treatment of the optical technologies with systems issues such as protocols, performance, management and protection Covers latest developments in WDM-PONS, protection switching, dynamic bandwidth allocation Practical coverage with a chapter on PON applications and deployment Case studies on implementing PONs H/SONET Explained in Functional Models represents a fresh approach to the modeling of transport network technologies. This practical guide and reference text uncovers the description of SDH (Synchronous Digital Hierarchy), SONET (Synchronous Optical Network) and OTN (Optical Transport Network) transport networks and equipment using functional/atomic modeling techniques. It clearly explains the use of models in the ITU-T and ETSI standards, the transport networks and the transport equipment in the definition, implementation and deployment phase. Pays particular attention to the SDH and OTN standards using functional/atomic modeling, as used and defined in the ITU-T (International Telecommunication Union) recommendations G.805 and G.809 and the ETSI (European Telecommunications Standards Institute) standards EN 300 417, as opposed to the formal language used in the ANSI (American National Standards Institute) standard T1.105. Topics of discussion range from functional modeling high level transport networks to the most detailed device functions, aided by a variety of figures and tables. Shows that functional modeling is not restricted to SDH/SONET but that is can be used to describe any transport network, connection-oriented and connectionless, e.g. Ethernet and MPLS networks. Written by a leading authority in the area, this is the first book dedicated to the novel approach of using functional modeling to describe SDH/SONET/OTN networks. This volume will appeal to manufacturers, engineers and all those involved in developing and deploying SDH, SONET, OTN, Ethernet, MPLS technology. It will be an invaluable resource for postgraduate students on network communications courses and advanced users using functional modeling. This book investigates survivability schemes for optical networks that rely only on a single layer, as well as for those that have more than one layer survivability functions and uses different approaches to solve QoS survivability related problems. We have simulated the restoration process of single transport layer: IP; ATM; SONET and OTN, which have been analyzed by similar studies. Also, we have simulated the process of the multi-layer restoration schemes for previously analyzed IP/SONET, IP/OTN and IP-MPLS/OTN by using the hold- off timer concept. We have extended their restoration concept and applied it for IP/OTN and ATM/SONET restoration schemes. Further more, we have introduced IP Restoration/OTN Protection combined multi-layer survivability, IP Restoration/SONET Protection combined multi-layer survivability and IP- MPLS Protection and Restoration/OTN Protection combined multi-layer survivability. In this book, we have combined the analyses with simulations to form a comprehensive study. We focused on four of the most commonly used IP over OTN architectur possibilities: IP/POS/OTN; IP/GbE/OTN; IP- MPLS/OTN, and IP/ATM/SONET/OTN. This book provides up-to-date coverage in the area of optical network architectures from an academia and industry perspective Optical Transport Networks: A Cross-Layer Approach focuses on the recent developments and innovative research in the area of optical transport networks, proposing the design of cross-layer architecture. In addition, the authors address the current the need to redesign the existing optical transport network (OTN) using an efficient control plane design and programmable optical layer. Operations, Administration, and Management (OAM) issues for enabling such clean-slate network architectures are also discussed. The book explores these cross-layer approaches, encompassing both theoretical and experimental perspectives from close collaboration with experts and researchers in industry (Alcatel-Lucent/Bell Labs, and AT&T) and academia, and summarizes the recent research findings, work, results, and developments in this area. Offers an overview on new, emerging, and innovative area of cross-layer optical networks Covers developments in the field from experts in both industry (Alcatel-Lucent, IBM, AT&T, IBM) and academia Demonstrates experimental findings and theoretical analyses Discusses the existing state-of-the-art networks and provides a comparison with futuristic cross-layer architectures and approaches Presents architectures for enabling optical packet switched networks The increasingly important role of Internet-based, “cloud” service delivery is motivating the evolution of the Internet to a flatter hierarchy of more densely interconnecting networks that shall cost-effectively scale to Zettabytes of bandwidth with improved operational efficiency, under increased traffic variability, and forecast unpredictability. This chapter reviews the implications of this evolution in its underlying metro regional and core transport network architectures, and evaluates the most important innovations in photonics, optical transport, routing, and traffic engineering technologies enabling it. Most notably, 1) a new generation of coherent DWDM systems with more than 2 b/s/Hz spectral efficiency is scaling the existing fiber infrastructure, albeit at a significantly higher proportion, typically more than 50%, of the total transport network cost, while 2) the convergence of IP/MPLS with flexible DWDM promises the most cost-efficient transport evolution, in open architectures that combine advancements in photonics, routing, multi-layer control-plane and management coordination, with interoperability, to improve operation, automate provisioning and restoration, and may optimize network utilization. Fiber-optic networks are continually evolving to accommodate ever-increasing data transport rates demanded by modern applications, devices, and services. Network operators are now beginning to deploy systems with 100 Gb/s per-wavelength data rates while maintaining the 50 GHz dense wavelength division multiplexing grid that is (generally) standard for 10 Gb/s systems. Advanced modulation formats incorporating both amplitude- and phase-based data symbols are necessary to meet the spectral efficiency requirements of fiber-optic data transport. These modulation formats require coherent detection, enabling future networks to take advantage of advances in silicon CMOS via digital signal processing algorithms and techniques. The primary challenge for future networks is the fiber nonlinear response; changes in the intensity of the propagating optical signal induce changes in the optical fiber refractive index. Limiting the allowed propagation intensity will reduce these nonlinear effects and correspondingly limit the total available signal-to-noise ratio (SNR) within the channel. Predicting the nonlinear SNR limits of fiber-optic transport for data rates 100 Gb/s and beyond is a primary purpose of this research. This dissertation expressly matches several novel expressions for nonlinear interference accumulation to experimental data and demonstrates robust theoretical prediction of nonlinear transmission penalties. The experiments were performed to isolate the

transmission performance of the fiber medium in the highly dispersive regime -- no dispersion compensation or Raman amplification was employed and all other hardware was kept static. These results are the first experimental validation of the nonlinear interference expressions on a fiber-type basis. Second, this dissertation moves to data transport beyond per-wavelength rates of 100 Gb/s by employing 16QAM at baud rates as high as 32 GHz. It examines signal processing strategies for 16QAM transport and extends the nonlinear interference prediction techniques to 16QAM. The results reveal that the SNR requirements of 16QAM as limited by nonlinear interference will likely limit deployments to high-density regional and metro networks. A guide to light-based networks. Advantages of optical nets include greater bandwidth and speed. Covers architecture, design, and monitoring/management issues. Rapidly increasing network demand based on unpredictable services has driven research into methods to provide intelligent provisioning, efficient restoration and recovery from failures, and effective management schemes that reduce the amount of “hands-on” activity to plan and run the network. Integrating the service-oriented IP layer together with the efficient transport capabilities of the optical layer is a cornerstone of this research. Converged IP-optical networks are being demonstrated in large multi-carrier and multi-vendor venues. Research is continuing on making this convergence more efficient, flexible, and scalable. In this chapter, we review the current key technologies that contribute to the convergence of IP and optical networks, describing control and management plane technologies, techniques and standards in some detail. We also illustrate current research challenges, and discuss future directions for research. Written by a leading expert in the field, this book provides a comprehensive introduction to the fundamental concepts of transport and data networks. This resource examines backbone network architectures and functions. The evolution, key components, and techniques of telecommunication networks are presented, including voice and data transmission, fiber optic communication and optical link design. This book explores the photonic network architecture and includes chapters on transport networks, synchronous optical networks, optical transport networks, and dense wavelength division multiplexing. Professionals are brought up-to-speed with the applications and architecture of next generation photonic networks, and are provided with references for all applicable standards. This book offers insight into reality technologies, including virtual reality, augmented reality, mixed relativity, and telecommunication infrastructure challenges. Details on the photonic circuit switched network architecture and photonic packet switched core network are presented. The book concludes with a full treatment of the virtualization and software defined networking ecosystem as well as a discussion on future developments. The new information services provided worldwide through the Internet are fostering the upgrade of existing access and transmission plants, and the de ployment of new ones. The bandwidth bottlenecks of existing electronic plants are being gradually removed by the massive use of optics at all levels. The latest technological developments in optical system components have finally made the huge bandwidth of optical fibers available both for increas ing the amount of transmitted information and for reducing the transmission cost per information bit. Wavelength Division Multiplexing (WDM) is now a commercial reality, widely employed in the upgrade of existing point-to point optical communications links, and in most upcoming newly installed fiber links. High speed Optical Time Division Multiplexing (OTDM) offers a complementary approach to WDM to tap even more into the fiber bandwidth. OTDM is however still in competition with Electronic TDM (ETDM), and as technology in integrated electronics progresses (along with the optical tech nology), the boundary where OTDM becomes more convenient than ETDM is still blurred and is a time-dependent variable. While the main design guidelines for point-to point optical links are now well established, much research work remains to be done in the area of optical networking, where the resources of many interconnected point-to point optical links are time shared. Work is to be done in the transmission field, as well as in the protocol, control and management field. This book takes a pragmatic approach to deploying state-of-the-art optical networking equipment in metro-core and backbone networks. The book is oriented towards practical implementation of optical network design. Algorithms and methodologies related to routing, regeneration, wavelength assignment, sub rate-traffic grooming and protection are presented, with an emphasis on optical-bypass-enabled (or all-optical) networks. The author has emphasized the economics of optical networking, with a full chapter of economic studies that offer guidelines as to when and how optical-bypass technology should be deployed. This new edition contains: new chapter on dynamic optical networking and a new chapter on flexible/elastic optical networks. Expanded coverage of new physical-layer technology (e.g., coherent detection) and its impact on network design and enhanced coverage of ROADM architectures and properties, including colorless, directionless, contentionless and gridless. Covers ‘hot’ topics, such as Software Defined Networking and energy efficiency, algorithmic advancements and techniques, especially in the area of impairment-aware routing and wavelength assignment. Provides more illustrative examples of concepts are provided, using three reference networks (the topology files for the networks are provided on a web site, for further studies by the reader). Also exercises have been added at the end of the chapters to enhance the book’s utility as a course textbook. A comprehensive guide to SDH, SONET, and OTN The ComSoc Guide to Next Generation Optical Transport provides a unique overview of SDH and OTN for engineers who are new to the field, as well as manufacturers, network operators, and graduate students who need a basic understanding of the topics. Fully up-to-date with the latest research and written by one of the foremost experts in the field, it covers: Network architectures Frames and structures Network modeling Packet transport network modeling Frequency justification Protection mechanisms Mapping methodologies Concatenation SDH and SONET overhead processing The book is complemented with 200 illustrations that explain key concepts in an easy-to-understand format, while references point readers to the appropriate standards documents for further reading. Whether you're new to the field or just need a basic understanding of SDH, this is a must-have guide. All-optical networking is generally believed to be the only solution for coping with the ever-increasing demands in bandwidth, such as the World Wide Web application. Optical backbone networks efficiently achieve a high level of traffic aggregation by multiplexing numerous users on circuit-switched wavelength paths - the so-called wavelength routing approach. In contrast, the reduced level of traffic aggregation in access and metro networks makes wavelength routing solutions not adequate. In these network areas, packet-interleaved optical time-division multiplexing with its finer and more dynamic bandwidth allocation is advocated. The book presents such an approach, known as photonic slot routing. It illustrates how this approach may provide a cost-effective solution to deploying all-optical transport networks, using today's optical device technology. To that end, the author combines DWDM-technology with fixed slot optical switching, and gives a comprehensive description of this approach in which slots are aligned across the wavelengths to form groups of data-flows that propagate as a whole inside the network. Operating algorithms are developed, and network performance is analyzed, both by means of theoretical analysis and many simulations of sample networks. This work will be of particular interest to researchers and professionals who are active in photonic networking. Covering past, present and future transport networks using three layered planes written by experts in the field. Targeted at both practitioners and academics as a single source to get an understanding of how transport networks are built and operated Explains technologies enabling the next generation transport networks