Guest Editorial
Next-Generation Broadband Optical Access Network Technologies

Broadband access networking is an important form of basic infrastructure that supports competitive social and economic development. Emerging broadband applications such as IPTV, real-time network gaming, backhauling of broadband wireless connection data etc., demand new technological innovations to meet their ever-increasing performance-to-cost requirements. Optical fiber has been established as a future-proof medium capable of facilitating the next-generation network applications. For instance, in Feb. 2010 Google just announced the plans to build an experimental gigabit-per-second fiber-to-the-home (FTTH) network to households in North America for testing out new concepts in technologies and applications. Worldwide, FTTH deployment had surpassed thirty million users in 2009 and is still continuing to grow at a rapid pace.

Significant R&D advancements have been made in the past several years, from basic optoelectronic component technologies to system innovations such as new medium access control (MAC) algorithms, OFDM in PON, and new system architectures. Companies and technologists are also considering marrying the capability of fiber with broadband wireless access (BWA) systems such as WiMAX/LTE to improve cost and performance while offering ubiquitous high-speed connectivity. The aim of this feature issue is to summarize and disseminate the prominent progress made in this field. Significantly, by compiling this issue, we also expect to maintain the momentum of present R&D activities and to stimulate new ideas in this field. This special issue contains a total of 17 papers on the topic. All together, they span four major categories: a standard update (one paper); PON systems and architectures (six papers); MAC design and analysis (four papers); and optical transmissions and components (six papers).

This issue begins with a paper on "Standardization Trends and Prospective Views on the Next Generation of Broadband Optical Access Systems," by Effenberger, Kani, and Maeda. Besides presenting an insightful review of the standard activities by IEEE and ITU-T on 10 Gb/s PON systems, they also discuss issues such as spectral management in fiber access systems, long reach fiber access systems, the roles of WDM in fiber access systems, and standardization directions going forward.

The second category of papers covers next-generation PON systems and architectures, and focuses particularly on emerging areas such as OFDM and fiber-wireless integration. In the first paper, "Orthogonal Frequency Division Multiple Access PON (OFDMA-PON) for Colorless Upstream Transmission Beyond 10 Gb/s," Cvijetic and her colleaegues employ a coherent frequency interleaved modulation scheme on an OLT-provided optical carrier to avoid upstream beat noise. They have achieved an upstream transmission rate of 20-Gb/s using OFDM modulation format and source-free ONU operation. In the second paper "Next Generation OFDMA-Based Passive Optical Network Architecture Supporting Radio-Over-Fiber," Lin and Tien propose a technique to overlay RF signals on a new OFDM-PON infrastructure for simultaneous WiMAX antenna signal backhaul. Experimental results show that the integrated 10 Gb/s OFDMA and RF signals are transported both downstream and upstream over a 20 km PON with high integrity. In the third paper "Studies of OFDM Signal for Broadband Optical Access Networks," Chow and his colleagues study the effect of Rayleigh backscattering on an OFDM signal which could come from an RF wireless network or be used to modulate multiple of subcarriers to increase system capacity. In the forth paper "Distributed Antenna-Based EPON-WiMAX Integration and Its Cost-Efficient Cell Planning," Min-Gon Kim et al., investigate by linking cell antennas using EPON systems, the potentially achievable cost efficiency and possible improvements in the capacity coverage area in a WiMAX system. It is worth noting that commercial TDM-PON is inherently a point-to-multipoint mulitcast architecture, whereas WDM-PON is inherently a point-to-point unicast. In the next paper "An Optical Multicast Overlay Scheme Using Optical Sub-Carriers for WDM Passive Optical Networks," Qiu and Chan then propose a WDM-PON architecture that marries both unicast and multicast capabilities on the physical layer. In the final paper of the second category, "A New Code Family Suitable for High-Rate SAC OCDMA PONs Applications," Tseng and Wu present a new code family, called partitioned partial prime (PPP) code, in an attempt to reduce interference and to increase the capacity of a spectral-amplitude-coded PON network.

The third category of papers focuses on MAC design and analysis. The first two papers are on online and offline traffic scheduling. In the first paper "Improving the Efficiency of Online Upstream Scheduling and Wavelength Assignment in Hybrid WDM/TDMA EPON Networks," Kanonakis and Tomkos address several inefficiency problems of online upstream-traffic scheduling and wavelength assignment, particularly for long-reach WDM-EPON networks. The authors propose four remedial algorithms and support the design with sound theoretical and simulation results. In the second paper,

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"Shortest Propagation Delay (SPD) First Scheduling for EPONs with Heterogeneous Propagation Delays," McGarry et al. propose an offline SPD-first scheduling policy, which requires the ONUs' upstream traffic to be transmitted in an increasing order of ONUs' propagation delays. Through probabilistic analysis and simulations, the authors demonstrate that their policy achieves higher utilization and significant reduction in packet delay. The two subsequent papers center on supporting multimedia traffic on PONs. In the third paper "A Priority-Based Processor Sharing Model for TDM Passive Optical Networks," Y. Wang et al. use a Multi-queue Processor Sharing (MPS) with Heterogeneous Traffic (MPS-HT) model to analyze the delay performance of a multi-priority dynamic bandwidth allocation system for TDM PONs supporting multimedia traffic. In the analyses, the authors derive simple closed-form approximations for the mean message delays under both fixed and prioritized service assumptions. This is followed by the fourth paper, "On Guaranteed VoD Services in Next Generation Optical Access Networks," where J. Wang et al. study the worst-case playback delay (WPD) guarantee for supporting video-on-demand (VoD) in a newly integrated WDM/TDM PON infrastructure. They propose two schemes to minimize the WPD and demonstrate via simulation results that the schemes achieve superior WPD and mean delay performance.

The final category of papers covers optical transmissions and components for next-generation optical access networks. In paper "Performance Evaluation of UWB Signal Transmission over Optical Fiber," Pan and Yao discover ways of extending the reach of ultra-wideband (UWB) signals using optical fibers. Three alternative means of generating UWB signals in fiber, as well as the temporal and spectral evolvement of the UWB signal under fiber dispersion, have been thoroughly studied in this paper. In the second paper, "Effect of Chip-Level Asynchronism on a CDMA-Based Overlay System for Optical Network Management," a low-rate CDMA based management channel is imposed on a high-rate data channel (or payload) for optical network management. Venturino et al. analyze the chip-asynchronous performance of the management CDMA channel and reveal the limitations imposed by payload interference. In the third paper "Beam Power and Angle Adaptation in Multibeam 2.5Gbit/s Spot Diffusing Mobile Optical Wireless System," which focuses on optical wireless (OW) systems, Alsaadi and his colleagues improve the bit-rate and reliability of an OW system by using adaptive power and adaptive angle multibeam diversity receivers.

The last three papers in the final category focus on physical technology innovations. In their paper, "Photonic Components for Future Fiber Access Networks," Yen and his collaborators propose quasi-reconfigurable devices that can dynamically alter power and wavelength allocation in future PON networks to achieve system optimization and smooth evolution. The authors demonstrate how the configuration of a tri-state MEMS actuated optical splitter can be maintained even after electric power is removed. In the second paper, "Return-to-Zero Transmitter for WDM-PONs Using Incoherent- Light-Injected Fabry-Perot Laser Diodes," Kim presents a cost effective method to convert an NRZ signal to an RZ signal in an incoherent-light- injection-locked FP transmitter for WDM-PON, while foregoing the use of an expensive pulse carver. Kim demonstrates via experiments that the proposed method improves the dispersion tolerance and benefits long-reach WDM-PONs that use incoherent lights. Lastly, in their paper, "High Performance Polarization Independent Reflective Semiconductor Optical Amplifiers in the S, C, and L Bands," Kelly and his colleagues demonstrate polarization independent operation of S-band RSOA over a 60-nm spectral range with a 1.25 Gb/s modulation and large path loss capability, which they combine with another similar RSOA in the C/L band to demonstrate the feasibility of continuous multi-FSR (free spectral range) upstream and downstream WDM-PON operations.

In general, we are very pleased with the quality papers published in this feature issue, and hope that they prove to be timely, informative, and stimulating for the readers of IEEE J-SAC. We would like to extend our thanks to authors who submitted their papers to the special issue in a timely manner. Unfortunately, due to space and time constraints, we regret that we could not have accepted more of the submissions. Finally, we are especially grateful to all the reviewers for carefully reviewing all the articles and for providing valuable comments. We appreciate the support and guidance of the Editor-in-Chief, Pamela Cosman, and the Executive Editor, Laurel Greenidge, throughout the process of bringing this special issue to fruition. Additionally, we thank Sue Lange, the Digital Production Manager, and all other publication staff for their patient support and help during the publication process. It is our hope that the papers included in this special issue present an insightful and comprehensive snapshot of the latest research advances in next-generation optical access networks and will provide an important reference for researchers and practitioners in the area.

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Maria C. Yuang received the B.S. degree in Applied Mathematics from the National Chiao Tung University, Taiwan, in 1978; the M.S. degree in Computer Science from the University of Maryland, College Park, Maryland, in 1981; and the Ph.D. degree in Electrical Engineering and Computer Science from the Polytechnic University, Brooklyn, New York, in 1989. From 1981 to 1990, she was with AT&T Bell Laboratories and Bell Communications Research (Bellcore), where she was a member of technical staff working on Broadband networks and protocol engineering. In 1990, she joined National Chiao Tung University (NCTU), Taiwan, where she is currently a Professor of the Department of Computer Science and Information Engineering.

Prof. Yuang served as a Guest Editor for the Special Issue of IEEE Transaction on Industrial Electronics on Multimedia and Communications in 1998. From 2001 to 2008, she has led the largest collaborative government-funded project on the research and experimentation of next-generation optical metro/access networks and systems. She has served on the technical program committee of many technical conferences including IEEE ICC and GLOBECOM, and has been invited to give invited talks at numerous technical conferences. Her main research interests include broadband optical networks, wireless networks, multimedia communications, and performance modeling and analysis. She is a senior member of IEEE, and a member of OSA. She holds 19 patents in the field of broadband networking, and has over 100 publications, including a book chapter.

Cedric F. Lam obtained his B.Eng. with First Class Honors from the University of Hong Kong, Hong Kong and Ph.D. degree from University of California, Los Angeles (UCLA), both in Electrical Engineering. He then joined AT&T Labs – Research as senior technical staff member of the Broadband Access Research Department. His researches covered fiber to the home (FTTH), hybrid fiber coax (HFC) systems, optical metropolitan/regional area networks, optical signal modulation techniques, etc. He received the AT&T Research Excellence Award for his contribution to the Metro-DWDM project in 2000. In 2002, Dr. Lam joined OpVista Inc., where he worked as Chief System Architect, responsible for the development of a ultra-dense reconfigurable WDM system for video and high speed Internet transports. Dr. Lam joined Google in 2009 as Network Architect. Besides leading the technical effort in Google's newly announced FTTH experiment, his current interests include fiber optic technologies for datacenter network applications.

Dr. Lam has served the technical program committee of many technical conferences including OFC and APOC (Asian Pacific Optical Communication Conference), and has given invited talks at many technical conferences. He was associate editor of the OSA Journal of Optical Networking from 2001 to 2007 and co-edited two feature issues on Optical Ethernet during his tenure. Dr. Lam is a senior member of IEEE, a member of OSA and a member of SCTE. He has 13 US patents in the field of optical communications and has published over 60 technical papers on international journals and conferences. He also co-authored the book "Passive Optical Networks, Principles and Technologies" published by Academic Press.

Hideo Kuwahara joined Fujitsu in 1974, and has been engaged for more than 30 years in R&D of optical communications technologies, including high-speed TDM systems, coherent optical transmission systems, EDFA, terrestrial and submarine WDM systems, and related optical components. His current responsibility is to lead photonics technology as a Fellow of Fujitsu Laboratories Ltd. in Japan. He stayed in the United States from 2000 to 2003 as a senior vice president at Fujitsu Network Communications, Inc., and Fujitsu Laboratories of America, Richardson, Texas. He is currently a member of IEEE Honorary Membership Committee. He belongs to LEOS and ComSoc. He served in 2006-2008 as a member of the Board of Governors of LEOS. He is a co-editor of the IEEE Communications Magazine Optical Communications Series. He is a member of the International Advisory Committee in European Conference on Optical Communications, and is chairing Steering Committee of CLEO Pacific Rim. He is a Fellow and a Director of the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan. He co-chaired several conferences including Optoelectronics and Communications Conference (OECC) 2007. He received an Achievement Award from IEICE of Japan in 1998 for the experimental realization of optical terabit transmission. He received the Sakurai Memorial Award from the Optoelectronic Industry and Technology Development Association (OITDA) of Japan in 1990 for research on coherent optical communication.

Alan Willner received his Ph.D. in Electrical Engineering from Columbia University. He was a Postdoctoral Member of the Technical Staff at AT&T Bell Laboratories (Crawford Hill) and a Member of Technical Staff at Bellcore. He is currently Professor of Electrical Engineering - Systems at the University of Southern California. He is the Associate Director for the USC Center for Photonics Technology, is Co-Director of the USC Communications Sciences Institute, and was an Associate Director for Student Affairs for the NSF Engineering Research Center in Multimedia. Prof. Willner has

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Prof. Willner has received the following awards: the Presidential Faculty Fellows Award from the White House, the David & Lucile Packard Foundation Fellowship in Science & Engineering, the National Science Foundation National Young Investigator Award, the Fulbright Foundation Senior Scholar Lecturing and Research Fellowship, the Institute of Electronic and Electrical Engineers (IEEE) Lasers & Electro-Optics Society (LEOS) Distinguished Lecturer Award, the IEEE LEOS Distinguished Service Award, the USC Associates Award for University-Wide Excellence in Teaching, the USC/TRW Best Engineering Teacher Award, the USC/Northrop Outstanding Junior Engineering Faculty Research Award, the 2001 Eddy Paper Award from Pennwell Publications for the Best Contributed Technical Article (across all 30 magazines in Pennwell's Advanced Technology Division) and the Armstrong Foundation Memorial Prize for the highest-ranked EE graduate student at Columbia Univ. He is a Fellow of the IEEE and the Optical Society of America (OSA), and he was a Fellow of the Semiconductor Research Corp.

Prof. Willner's professional activities have included: President of the IEEE LEOS, Co-Chair of the Science and Engineering Council of the OSA, Vice-President for Technical Affairs of the IEEE LEOS, Photonics Division Chair of the OSA, Chair of the IEEE TAB Ethics and Member Conduct Committee, General and Program Co-Chair of the Conference on Lasers and Electro-Optics (CLEO), Program Co-Chair of the OSA Annual Meeting, General and Program Chair of the IEEE LEOS Annual Meeting, General and Program Co-Chair of the OSA Slow Light Topical Meeting, General and Program Co-Chair of the OSA Optical Amplifier Topical Meeting, Elected Member of the Board of Governors for the IEEE LEOS, General Co-Chair of the IEEE LEOS Topical Meeting on Broadband Optical Networks, Steering Committee and Technical Committee Member of the Conference on Optical Fiber Communications (OFC), Technical Program Committee Member of the European Conference on Optical Communications (ECOC), and Chair of the Optical Communications and Optical Networks IEEE LEOS Technical Committees. He has chaired the IEEE LEOS Distinguished Traveling Lecturer Award Committee and has served on these other awards committees: OSA Frederic Ives Medal (J.W. Quinn), LEOS Quantum Electronics Award, and LEOS Wm. Streifer Scientific Achievement Award.

Prof. Willner's editorial positions have included: Editor-in-Chief of the IEEE/OSA Journal of Lightwave Technology (JLT), Editor-in-Chief of the IEEE Journal of Selected Topics in Quantum Electronics, Editor-in-Chief-Elect of OSA Optics Letters, Associate Editor for the IEEE Journal of Selected Areas in Communications Series on Optical Networks, Guest Editor for the Joint Special Issue of JLT and JSAC on Multiple-Wavelength Technologies and Networks, Guest Editor for the IEEE Journal of Quantum Electronics Focus Issue on Ultra-High-Bandwidth Optical Transmission Systems, and Guest Editor for the OSA Journal of Optical Networking Special Issue on OCDMA.

Prof. Willner has 670 publications, including 1 book. His research is in the area of optical communications, optical signal processing, optical networks, fiber optics, and optical device technologies.