

**August 28, 2014 (Thu.)**

[TA1] Software Defined Optical Network

[TB1] Optical Data-Center Networking

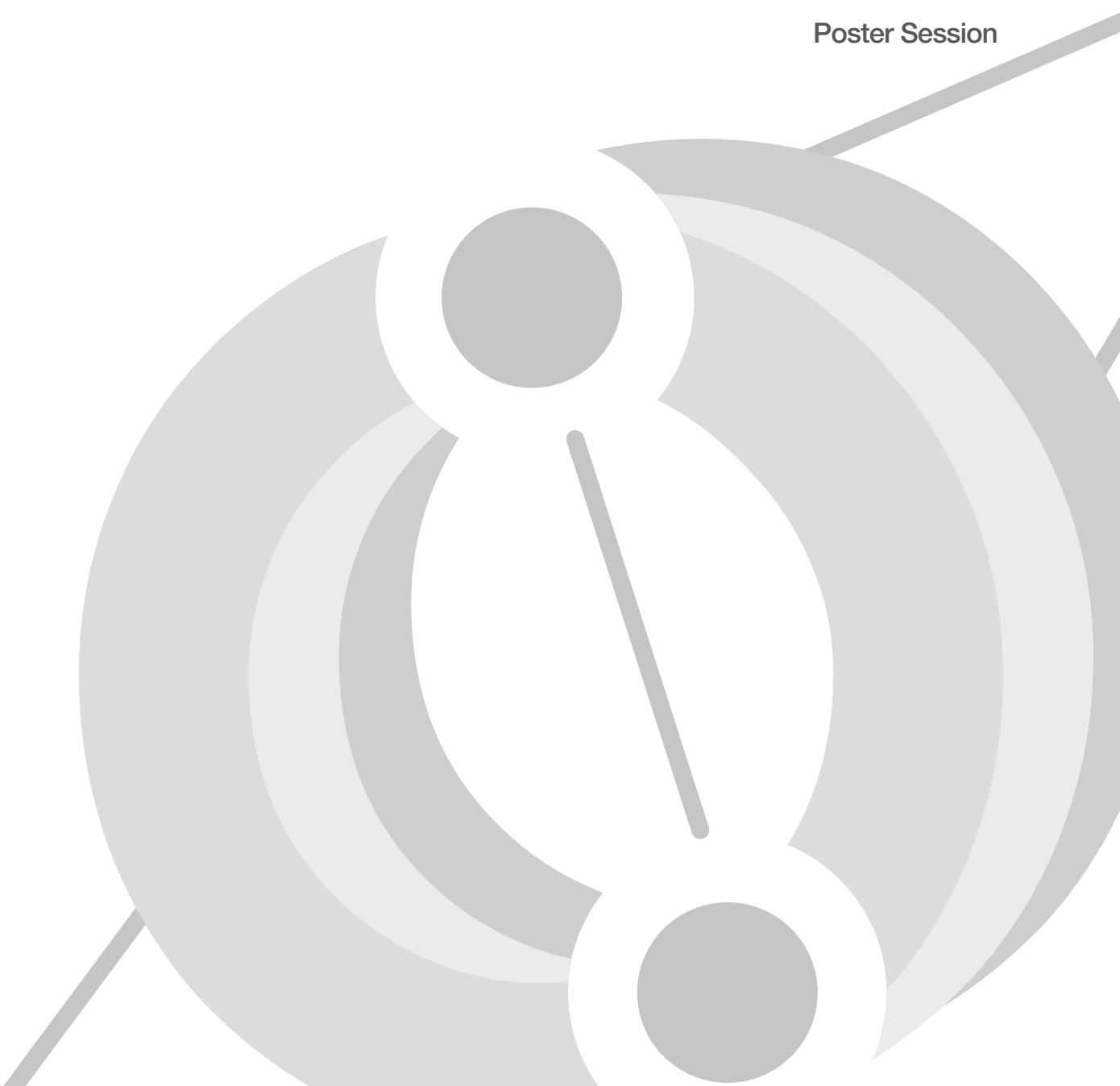
[TC1] Photonic Device Technology

[TA2] Next Generation Access Architecture & Trial

[TB2] SDM

[TC2] Mobile Optical Networks

Poster Session





Session Title	<b>[TA1] Software Defined Optical Network</b>
Date	August 28, 2014 (Thu.)
Time	13:30-15:00
Room	Room A
Session Chair	Takafumi Tanaka (NTT, Japan)

TA1-1

13:30-14:00

**[Invited] Preparing the End-to-end Virtualized Networking over Software-Defined Infrastructure**

Jongwon Kim (GIST, Korea)

With SDN-supported virtualized networking and DevOps(Development & Operation)-based cooperation, the provisioning of hyper-convergent compute/networking/storage resources could be appropriately streamlined with the lifecycle of service realization and thus the agile and economic realizations of diverse services could become a reality in very near future. In this paper, by focusing on the end-to-end virtualized networking, we discuss how to prepare and play with futuristic SDI (Software-Defined Infrastructure).

TA1-2

14:00-14:15

**Using SDN in Centralized Data Centers in Power Communication Networks for Disaster Recovery**

Yang Wang (China Electric Power Research Inst., China), Yiming Yu, Yongli Zhao, and Jie Zhang (Beijing Univ. of Posts and Telecommunications, China)

We proposed a SDN-based networking framework for disaster recovery center in electric power communication networks. Typical tasks such as rapid data migration and fast disaster recovery have been proved efficient and reliable under this framework.

TA1-3

14:15-14:30

**A Reliable Mapping Algorithm for Multiple Virtual Network Requests with Location Constraints**

Dan Liao, Gang Sun, Ke Cheng, and Hongfang Yu (Univ. of Electronic Science and Technology of China, China)

One of the challenge issues in network virtualization is the efficient mapping of a virtual network (VN) onto a shared substrate network. VN mapping problems include static VN mapping problem and dynamic VN mapping problem. The VN requests arrive and leave dynamically in a certain period in dynamic VN mapping, while in static VN mapping there can be one or more spontaneously VNs requiring to be mapped onto the physical network at the same time with no dynamic arrival or leaving. In this paper, we research on the VN mapping problem of guaranteeing the survivability of the VN when there can be several VN requests needing to be mapped onto the physical network while each VN node with geographic constraint. We propose Geographic-Guided Survivable Multiple VN Mapping (GG-SMVNM), which considering resource sharing while mapping VN nodes and links. Our simulation results show that our approach outperforms existing solution.

TA1-4

14:30-15:00

**[Invited] HADES: A Compatible SDN based Network Virtualization Architecture**

Xuan Luo, Sai Ma, and Yaohui Jin (Shanghai Jiao Tong Univ., China)

Network virtualization has been regarded as a candidate solution for providing cloud network services. VLAN has been the most common approach for providing isolated logical network but with a well-known scalability issue. Both the Industry and the Academia carried out promising network virtualization solutions to address the problem. However, upgrading the virtualization technology makes data center operator suffer from a series of risks, such as the waste of early investment and the interruption of running application. To overcome this barrier we presented a novel software defined network (SDN) based network virtualization architecture HADES. In HADES, virtual machines within the same virtual network could communicate with each other normally regardless of the underlying network virtualization technology. We describe and implement a prototype of HADES architecture and demonstrate the scalability and the efficiency of the solution.

Session Title	<b>[TB1] Optical Data-Center Networking</b>
Date	August 28, 2014 (Thu.)
Time	13:30-15:00
Room	Room B
Session Chair	Shu Namiki (AIST, Japan)

TB1-1

13:30-14:00

**[Invited] Hybrid Cloud Rendering-oriented Virtual Network Embedding in Optical and Data Center Networks**

Weigang Hou and Lei Guo (Northeastern Univ., China)

Cloud rendering consolidates heterogeneous server resources into a renderfarm. A high-speed optical interconnection is also required between user and renderfarm. So we need a cloud convergence of Optical and Data Center Network (ODCN). Considering cloud rendering features, we build a mapping-costaware renderfarm by heuristics.

TB1-2

14:00-14:15

**A Novel Future-proof Software Defined Networking Architecture**

Nam-Seok Ko, Hwanjo Heo, Jong-Dae Park (ETRI, Korea), and Hong-shik Park (KAIST, Korea)

This paper proposes a novel future-proof software defined networking architecture that has multiple programmable function modules that interact with flow tables. The proposed architecture can easily adapt to new protocols with variable-length header, provides new network functions locally, and let the switch serves offloaded network functions from the cloud with minimized network latency.

TB1-3

14:15-14:45

**[Invited] Application-centric, Energy-efficient Network Architecture, ACTION, based on Flexible Optical Network**

Naoaki Yamanaka, Satoru Okamoto (Keio Univ., Japan), Eiji Oki (The Univ. of Electro-Communications, Japan), Andrea Fumagalli (The Univ. of Texas at Dallas, USA), and Malathi Veeraraghavan (Univ. of Virginia, USA)

The Compound Annual Growth Rate (CAGR) of Internet traffic volume lies in the 30-70% [1] range. For several good reasons (to handle unexpected traffic spurts, link failures and traffic growth), network resources are significantly over-provisioned in today's networks, and it is quite common to see link utilization in the 30%-40% range [2]. While new optical fibers can be laid, the costs of such deployment should be weighed against the costs of solutions that enable network operation at higher utilization levels.

For example, new developments in optical technologies, such as flexible elastic optical networks, enable the provisioning of variable-bandwidth, variable-QoS (Quality of service) transmission pipes. In addition, current and future multi-media services have widely divergent bandwidth and QoE (Quality of Experience) requirements. ACTION (Applications Coordinated with Transport, IP and Optical Networks) is a multi-QoE, application-centric, highly energy-efficient network architecture that leverages flexible elastic optical network technologies. This project is supported by both the NSF, USA, and NICT, Japan, under the JUNO (joint collaboration between Japan and US) program. This paper provides a brief overview of the project.

TB1-4

14:45-15:00

### **Flexible Data Center Backup in WDM Networks Based on Virtual Machine Migration and Elastic Bandwidth Allocation**

Cunqian Yu, Lei Guo, Weigang Hou, and Yue Zong (Northeastern Univ., China)

Since data center carries plentiful applications, its failure results in huge data loss. In order to mitigate service's paralysis caused by data center failure, we propose a flexible data center backup framework through highly efficient virtual machine migration and grading along with elastic bandwidth allocation.

Session Title	<b>[TC1] Photonic Device Technology</b>
Date	August 28, 2014 (Thu.)
Time	13:30-15:00
Room	Room C
Session Chair	Joel Carpenter (Univ. of Sydney, Australia)

TC1-1

13:30-14:00

**[Invited] Silicon Photonics Optical DeMUX Technology for WDM Applications**

Seok-Hwan Jeong, Yu Tanaka, and Ken Morito (PETRA, Japan)

We report recent progress of high-performance Si-wire-based WDM devices based on higher-order microring resonators and multi-stage delayed interferometers fabricated by 300-mm wafer-scale 193-nm ArF-immersion CMOS process.

TC1-2

14:00-14:30

**[Invited] Mach-Zehnder Modulators with Active Y-branch Structure for Precise Lightwave Control**

Hirochika Nakajima, Yuya Yamaguchi (Waseda Univ., Japan), Tetsuya Kawanishi (NICT, Japan), and Masayuki Izutsu (Waseda Univ., Japan)

High extinction ratio optical modulation using Mach-Zehnder interferometer with active Y-branch is proposed. The measured extinction ratio was over 60 dB, and we successfully operated optical two-tone signal generation over a long period of time with automatic bias control technique.

TC1-3

14:30-14:45

**Stable Wavelength Switching within 50 ns using Tunable Distributed Amplification (TDA-) DFB Lasers**

H. Onji, S. Takeuchi, Y. Tatsumoto, K. Kato (Kyushu Univ., Japan), N. Nunoya, M. Shimokozono, and H. Ishii (NTT Corp., Japan)

Aiming fast wavelength switching for the tunable distributed amplification (TDA-) DFB lasers, the transfer function is deduced from the transient response and then the feedforward controller is designed. Experimental results show that the wavelength can be accurately stabilized within 35 ns and 30 ns when the optical frequency changes from 192.8 THz to 193 THz and vice versa, respectively.

TC1-4

14:45-15:00

**Effect of Wavelength Detuning on Hysteresis Width of Single Mode Fabry-Perot Laser Diode and Its Impact on the Realization of Optical SR Latch**

**Bikash Nakarmi and Y. H. Won (KAIST, Korea)**

In this paper, we have experimentally analyzed the effect of hysteresis width on optical bistability present in single mode Fabry-Perot laser diode (SMFP-LD). Hysteresis width on optical bistability plays an important role on the latching operation. Input injected power and wavelength detuning are two parameters that can effect on the hysteresis width and hence the optical bistability. With this analysis we demonstrated simultaneous inverted and non-inverted output of optical SR latch with input set and reset data rate of 8.5 Gbps.



Session Title	<b>[TA2] Next Generation Access Architecture &amp; Trial</b>
Date	August 28, 2014 (Thu.)
Time	15:15-17:15
Room	Room A
Session Chair	Jie Hyun Lee (ETRI, Korea)

TA2-1

15:15-15:45

**[Invited] Towards Green NG-PON2 Systems**

Rui Wang, Partha Bhaumik (Univ. of California, USA), Han Hyub Lee, Sang Soo Lee (ETRI, Korea), and Biswanath Mukherjee (Univ. of California, USA)

We study real-time energy saving in NG-PON2 systems, i.e., TWDM-PON, and analyze impacts on quality of service and reconfiguration overhead. Our proposed methods are compatible with existing EPON/GPON protocols.

TA2-2

15:45-16:00

**A Novel TWDM-PON Architecture with Control Channel**

Chengjun Li, Wei Guo, Wei Wang, and Weisheng Hu (Shanghai Jiao Tong Univ., China)

In this paper, we present a novel TWDM-PON architecture. A 1G control channel is added to control all ONUs. Then, we establish a flexible management framework, including bandwidth assignment mechanism, auto-discovery process and ONU migration mechanism. Numerical simulation is conducted to show the flexibility and effectiveness of the proposed framework.

TA2-3

16:00-16:15

**Real World Single Fiber Single Wavelength Transceivers with Integral Micro-OTDR and Reflection Immune Operation**

Meir Bartur (Optical Zonu Corp., USA), Ken Rhie (Post Info Systems, Korea), Josef Berger, and Michael J. Hartmann (Optical Zonu Corp., USA)

Network operators and users may enjoy the benefits of SFSW operation, without any of the drawbacks associated with legacy systems, along with the additional functionality of Micro-OTDR. Reflection Immune Operation - *RIO*<sup>®</sup> resolves self-reflection from an open connector and/or other reflectors. Only remote data is transferred into the host equipment.

TA2-4

16:15-16:30

**Investigation of ONU Power Leveling Method for Mitigating Inter-Channel Crosstalk in TWDM-PONs**

Han Hyub Lee, Jong Hyun Lee, Sang Soo Lee (ETRI, Korea), Hee Yeal Rhy (Ericsson-LG, Korea), Hark Yoo (ETRI, Korea), and Yoonkoo Kwon (Lightron, Korea)

We investigate ONU power leveling methods for mitigating Inter-channel crosstalk of upstream signals in TWDM-PON. 6-dB power dynamic range was archived with maximum 1.4-dB power penalty by adjusting operation current of Tx. The proposed method is thought to be a simple, low-cost solution in comparison with that with a VOA or SOA. Further study is needed for trade-off between crosstalk and eye distortion penalty and how to specify.

TA2-5

16:30-16:45

**ONU Transmit Power Levelling for TWDM-PONs**

Hark Yoo, Young Sun Kim, Dong Soo Lee, and Han Hyub Lee (ETRI, Korea)

In this paper, we investigate the required range of ONU transmit power levelling for TWDM-PONs based on the worst case inter-channel crosstalk analysis. To overcome the crosstalk impairment, an OLT-shared architecture of the ONU transmit power levelling and its operation rule is also proposed.

TA2-6

16:45-17:15

**[Invited] Future Prospects on the Evolution of Giga Internet Access Network**

Hyungjin Park (KT, Korea)

Fiber based broadband access network is deployed nationwide, locating Korea as one of the highest fiber penetrated country in the world. Along with the increase of the fiber penetration, the transmission capacity has also evolved. 10G-PON solution is one of the latest access technology deployed as the next generation access technology. We analyze on the driving factors of the evolution in the access network in the perspective of service, technology, policy environment. Also analysis on the deployment strategy of Giga internet is mentioned in regards of network simplification and TCO optimization.

Session Title	<b>[TB2] SDM</b>
Date	August 28, 2014 (Thu.)
Time	15:15-17:15
Room	Room B
Session Chair	Sun Hyok Chang (ETRI, Korea)

**TB2-1****15:15-15:45****[Invited] MIMO-Based Mode-Division Multiplexed Transmission over Multimode Fibers****Roland Ryf and Nicolas K. Fontaine (Alcatel Lucent, USA)**

We present results of combined mode- and wavelength multiplexed transmission over conventional graded-index multimode fibers. We selectively couple and receive up to 6 spatial modes of multimode-mode fibers with 3 and 6 and 45 spatial modes using photonic-lanterns based mode-couplers. The transmitted signals are recovered using MIMO digital signal processing.

**TB2-2****15:45-16:15****[Invited] 3D Waveguide and All-Fiber “Photonic Lantern” Spatial Multiplexers****Nicolas K. Fontaine (Alcatel Lucent, USA)**

Space-division multiplexing requires spatial multiplexers that support over 10 modes with low insertion loss and low mode-dependent loss. Photonic lantern spatial multiplexers provide a lossless interface between N single-mode fibers and the N modes of a multi-mode fiber. Devices fabricated using all-fiber technology and 3D waveguide technology have enabled transmission in multi-mode fibers supporting 12 spatial and polarization modes.

**TB2-3****16:15-16:45****[Invited] Multicore EDFA to Realize Simultaneous Excitation with Cladding-pumped Technology****Y. Tsuchida, K. Maeda, M. Tadakuma (Furukawa Electric Co., Ltd., Japan), K. Doi, H. Matsuura (Tohoku Gakuin Univ., Japan), and R. Sugizaki (Furukawa Electric Co., Ltd., Japan)**

We report some recent research activities of multicore EDFAs with cladding-pumped technology. We successfully developed cladding-pumped MC-EDFAs with Cband L-band application, respectively. Cladding-pumped L-band MC-EDFA realized output power of 19 dBm for each core between 1576-1603 nm with 33 % reduced power consumption.

TB2-4

16:45-17:15

**[Invited] Multi-core Fiber Technology for Optical-access and Short-range Links**

**Yong Lee, Kenichi Tanaka, Etsuko Nomoto, Hideo Arimoto, and Toshiki Sugawara (Hitachi, Ltd., Japan)**

To provide high-capacity/high-reliability optical-access and short-range links, a novel failurerecovery system utilizing protection optical switch units and multi-core fibers was developed. Configuring the proposed failure-recovery system, the developed multicore fiber (MCF) connection technology (i.e., fan-in/-out modules and MCF connectors) and a protection opticalswitch unit experimentally demonstrated automatic impairment-aware optical-switching.

Session Title	<b>[TC2] Mobile Optical Networks</b>
Date	August 28, 2014 (Thu.)
Time	15:15-17:15
Room	Room C
Session Chair	Sung-Man Kim (Kyungsoong Univ., Korea)

TC2-1

15:15-15:45

**[Invited] Wireless Signals Transport in Fiber-Wireless Links: Digitized versus Analog**

Christina Lim, Yizhuo Yang, and Ampalavanapillai Nirmalathas (The Univ. of Melbourne, Australia)

This paper reviews some of the work we have carried out in the transport of wireless signals in fiber-wireless links.

TC2-2

15:45-16:15

**[Invited] Mobile Optical Network for Future Radio Access**

Tomohiro Taniguchi, Takayuki Kobayashi, Shigeru Kuwano, Jun-ichi Kani, Jun Terada, and Hideaki Kimura (NTT Corp., Japan)

As a future step of LTE-Advanced, future radio access based on large numbers of small cells of various types has been studied. Possible architectures and requirements of a mobile optical network that forms mobile fronthaul and mobile backhaul of the small cells, as well as some passive optical network (PON)-based technologies are provided.

TC2-3

16:15-16:30

**Investigations of EVM Performance Degradations caused by Nonlinearity in Mobile Fronthaul Architecture based on IFoF Technology**

Seung-Hyun Cho, Hwan Seok Chung, Chan Gyo Han, Sangsoo Lee, and Jong Hyun Lee (ETRI, Korea)

We investigated analog optical transmission performance degradation caused by nonlinear distortion by varying several operating conditions including the number of IF carrier, IF channel spacing, modulation index and transmission distance for future-proof cost-effective next generation mobile fronthaul architectures based on intermediate frequency over fiber (IFoF) technique.

TC2-4

16:30-16:45

**Downlink Transmission Timing Shift in Mobile Fronthaul for TDD Radio Access Network**

Takahiro Kubo, Takahiro Asai, and Yukihiro Okumura (NTT DOCOMO, INC., Japan)

We propose a downlink transmission timing shift in the fronthaul that advances the downlink transmission timing in order to improve the frame efficiency for time-division duplex radio access network in the centralized radio access network architecture. Numerical results show that the proposed technique provides high frame efficiency regardless of the optical transmission length in the fronthaul.

TC2-5

16:45-17:00

**Design of an FPGA based Visible Light Communication System**

Yinjie Jia, Minglun Zhang, Yongqing Huang, and Yangan Zhang (Beijing Univ. of Posts and Telecommunications, China)

Visible light communication (VLC) has won much attention in recent years. In this work a visible light communication system based on IEEE 802.3 standard Media Access Control (MAC) layer is presented. The digital signal processing module of the physical (PHY) layer is implemented in FPGA (Field Programmable Gate Array). The PHY layer is connected to the MAC layer via a Media Independent Interface (MII) which has been specified in IEEE 802.3 standard. The digital part of the system is tested by a Streaming Media Server system. Maximum data rate of 30 Mb/s is achieved.

TC2-6

17:00-17:15

**SRS Induced Power Depletions of WDM Signals by a High Power OTDR Signal in Mobile Fronthauls**

Eon-Sang Kim, Han Hyub Lee, Jyung Chan Lee, and Sang Soo Lee (ETRI, Korea)

We analyze power depletions of DWDM signals caused by a high power OTDR signal in a mobile fronthaul including four optical add/drop nodes in 20 km SMF. We suggest a 1625-nm wavelength or a 1665-nm wavelength as an OTDR signal wavelength to mitigate the stimulated Raman scattering (SRS) induced power depletion of C-band WDM signals.

Session Title	<b>[TP] Poster Session</b>
Date	August 28, 2014 (Thu.)
Time	17:15-18:30
Room	Terrace B & Lobby

TP-01

17:15–18:30

### **Inline Conversion Filter Capable of Selecting Reflection and Transmission Spectra of Different Bragg Gratings Using Polarization-Diversity Loop**

Jihoon Kim and Yong Wook Lee (Pukyong Nat'l Univ., Korea)

In this paper, we have demonstrated an inline conversion of transmission or reflection spectra of two fiber Bragg gratings (FBGs) having a different Bragg wavelength by incorporating a polarization-diversity loop without reconfiguring the filter structure. The proposed apparatus consists of a fiberpigtailed polarization beam splitter, two FBGs, and three quarter-wave plates (QWPs). Without requiring reconnect of input/output ports or additional optical switches, the spectral selecting operation of the FBGs were carried out through proper adjustment of the QWPs contained in the proposed filter.

TP-02

17:15–18:30

### **SOI-Based Plasmonic Nanogap Resonator Based Wavelength Filter**

Geum-yoon Oh, Junhee Park, Jeong-ho Ha, Tai-young Kang, Han-young Lee (KETI, Korea), and Young-wan Choi (Chung-Ang Univ., Korea)

We report the nanogap resonator with the straight waveguide without the ring shape resonator, which is replaced with a straight waveguide, metallic layer, and nanogap. We use the numerical method to investigate the resonant properties of the structure. The results reveal that the proposed structure has the band stop characteristic.

TP-03

17:15–18:30

### **Time Delay Characteristics of All-Pass Filter with Three Coupled Rings**

H. Moon, H. Kim, Y. Ko, J. Kim, and Y. Chung (Kwangwoon Univ., Korea)

The pulse delay characteristics through all-pass filters with three coupled rings are measured and analyzed. The all-pass filters are fabricated in polymer material with large refractive index contrast between core and cladding. The measured delay time is 238ps and 330ps when two and three rings are in resonance, respectively. The experimental result agrees very well with the split-step time-domain simulation results.

TP-04

17:15-18:30

#### **Reduced Light Induced Degradation of a-Si:H Thin Film Transparent Solar Cells**

Jung Wook Lim (ETRI, Korea) and Chang-Bong Kim (Kongju Nat'l Univ., Korea)

We fabricated a-Si:H transparent solar cells with thin absorbers. The light induced degradation of 17 % to 22 % was obtained when 130, 150 and 200 nm thick absorbers were used in the fabrication of a-Si:H transparent solar cells. However, the cells with 108 and 120 nm thick absorber showed improved light induced degradation. In particular, the cell with 108 nm thick absorber showed highly improved degradation of 7.3 %. In this case, the p-layer thickness is crucial to determine the degradation rate.

TP-05

17:15-18:30

#### **Fabrication and Characterization of Angled Ribbon Fibers using a CO<sub>2</sub> Laser**

Hun-kook Choi, Duk-Jung, Ik-bu Sohn, Young-Chul Noh, Yong-Tak Lee (GIST, Korea), Man-Seop Lee (Phoco Co.,Ltd, Korea), Jin-Kyoung Oh (P-CUBE Co., Ltd, Korea), and Hyung-Jong Lee (Chonnam Nat'l Univ., Korea)

We have produced angle at the end face of optical fibers. Repetitive experiment result illustrates its reliable and stable production of the 8 degree angle. Comparing the beam profile of regular and angled optical fibers, we confirm the focusing of beam attributed to curvature of the angled optical fiber.

TP-06

17:15-18:30

#### **InP-Based Vertical Dual-Waveguide Fiber-Coupling Structure**

Duk-jun Kim, Won Seok Han, Dong-Young Kim, Joong-Seon Choe, Chun Ju Yun, Jong-Hoi Kim, and Yong-Hwan Kwon (ETRI, Korea)

An InP-based fiber-coupling structure in which additional waveguide is overlaid on deep-ridge main waveguide is proposed with design and fabrication results. It is a feature of the structure that both the overlying and main waveguides participate in the fiber coupling.

TP-07

17:15-18:30

#### **Compact Polarization Beam Splitter based on a Bridged Silicon Nanowaveguide Coupler**

Dong Wook Kim, Yudeuk Kim, Heung-sun Jeong, Moon Hyeok Lee, Kyong Hon Kim (Inha Univ., Korea), Sang Chul Jeon, Dong Eun Yoo, and Ki Nam Kim (Nat'l Nanofab Center, Korea)

We propose a polarization beam splitter (PBS) based on a bridged silicon nanowaveguide directional coupler. The device is designed via 3D-FDTD simulation, and demonstrated experimentally. The measured polarization extinction ratio and the insertion loss of the PBS with 7.5- $\mu$ m long coupling length and 550 nm-wide bridged waveguides width are about 22 dB and 2 dB, respectively, for a TE-mode optical beam input.



TP-08

17:15-18:30

**Bismuth Oxide-based Erbium-doped Fiber Amplifiers for DWDM-TDM Passive Optical Networks**

Minwan Jung (Univ. of Seoul, Korea), Sangbae Lee (KIST, Korea), and Ju Han Lee (Univ. of Seoul, Korea)

We propose a long-reach hybrid DWDM-TDM PON architecture in which the proposed amplifier can be effectively used. The feasibility of using the proposed amplifier for long-reach hybrid DWDM-TDM PONs is experimentally investigated by performing a series of signal transmission experiments with an exemplary PON configuration having a total reach of 75 km and 8 split users.

TP-09

17:15-18:30

**Design and Analysis of High Speed Uni-traveling-carrier Photodiodes**

Ge Zang, Yongqing Huang, Yang Luo, Xiaofeng Duan, and Xiaomin Ren (Beijing Univ. of Posts and Telecommunications, China)

In this paper, simulations are conducted to investigate high speed uni-traveling-carrier photodiodes (UTC-PDs). The Gaussian doping profile, which can introduce potential gradient and electric field, is presented to be used in the absorption layer. Compared to constant doping and step-graded doping, bandwidth of UTC-PD with Gaussian doping is improved substantially.

TP-10

17:15-18:30

**Fabrication and Characterization of Waveguide Photodetector Array for Coherent Optical Communication Application**

Joong-Seon Choe, Won-seok Han, Chun Ju Youn, Duk Jun Kim, Jong-Hoi Kim, Dong-Young Kim, and Yong-Hwan Kwon (ETRI, Korea)

Waveguide photodetector array was developed to be applicable to advanced modulation formats like QPSK, DPSK, and 16-QAM. The devices have spot-size converter for butt-coupling with PLC devices, and on-chip by-pass capacitor for DC bias. Coherent receiver made of the fabricated chips showed clear constellation for 30 Gbaud DP-QPSK OFDM signal.

TP-11

17:15-18:30

**Measurement of Effective Refractive Index of Nematic Liquid Crystal**

Myeong Ock Ko, Sung-Jo Kim, Jong-Hyun Kim (Chungnam Nat'l Univ., Korea), Bong Wan Lee (FiberPro Inc., Korea), and Min Yong Jeon (Chungnam Nat'l Univ., Korea)

We report a measurement of effective refractive index of a nematic liquid crystal Fabry-Perot etalon according to the applied static electric field intensity. The effective refractive index decreases from 1.67 to 1.51 as the applied electric field intensity is increased.

TP-12

17:15-18:30

### **Development for Smart Green City: Review of the Smart Green City Cases**

**Sungmin Rue, Haeju Jung, Namkyun Kim, and Yoonkee Kim (KT, Korea)**

The world is facing the challenge of climate change and the population growth. Also, the rapid increase of city inflow is forcing to suggest a new model of city infra. Therefore, Smart Green City is proposed as the alternative, and the relative projects are being propelled around the world. Smart Green City is able to provide three things: sustainability, energy efficiency, and pleasant. Those benefits are being made to solve the problems which we are facing. In this paper, the study of smart green city is dealt with. At first, the smart green city cases are described, and then the model of it is suggested.

TP-13

17:15-18:30

### **Hybird Optical Switching in Clustered Architecture ChinaNet/CN2 Network**

**Changxing Liu, Yu Ma, Jiuru Yang, Erfu Wang, and Qun Ding (Heilongjiang Univ., China)**

We simplify the routing of ChinaNet/CN2 network by clustered architecture regionally. We implement a novel hybrid circuit/burst switching scheme in such clustered core network. The assessments in terms of loss, edge-to-edge delay and energy consumption are conducted by simulation.

TP-14

17:15-18:30

### **OAM and Protection Mechanisms for MPLS-TP Packet Transport Networks**

**Dae-ub Kim, Yeon-Cheol Ryoo (ETRI, Korea), Byungchul Kim, and Jae Yong Lee (Chungnam Nat'l Univ., Korea)**

MPLS Transport Profile (TP) uses a subset of the existing MPLS toolkit which represents the minimal amount of functionality that is needed in a transport network environment. MPLS-TP delivers the richness and reliability of operations, administration and maintenance (OAM) mechanisms that are characteristics of transport technology at the same time as it will support packet-based services more efficiently than conventional transport networks. Also, MPLS-TP protection switching technologies in the area of packet transport networks have been developed to meet the requirement of sub 50ms traffic recovery in case of a link failure. This paper discusses the MPLS-TP OAM and protection mechanisms that are available and introduces the MPLS-TP equipment of ETRI.

TP-15

17:15-18:30

**Design of Smart RN Architecture for Real Time ODN Management**

Jaein Kim, Sungchang Kim, Geunyoung Kim, and Dongsu Lee (ETRI, Korea)

Passive network elements such as splitter which compose ODN for PON provide advantages on the optical access network installation and management. However, as new customers for FTTH service are increasing, needs to manage ODN more intelligently is growing. In this paper, we introduce about Smart RN(Remote Node) and design its architecture. To gather the data about branching and connection information from Smart RN, we have employed CoAP protocol to consider constrained computing environment. And we design the Smart Connector and patch code based on RFID technology to get branching and connection information. Finally, we introduce scenarios about Smart RN usages.

TP-16

17:15-18:30

**Implement of Interpolation on Multi-touch Screen to Trace the Movement of Finger**

Young-jin Park, Hong-Kun Lyu, and Hui-Sup Cho (DGIST, Korea)

In this paper, we apply an interpolation algorithm that rectifies smooth connection between two points on multi-touch screen. The fundamental concept underlying the implemented system is detection the coordinates and connection between the coordinates smoothly. The resultant image, which creates after applying interpolation algorithm, can be used to trace the movement of fingers on a touch screen.

TP-17

17:15-18:30

**Spectrum and Energy-Efficient Routing Algorithm in Survivable and Elastic Optical Network**

Yitong Yang, Weigang Hou, and Lei Guo (Northeastern Univ., China)

The elastic optical network can improve spectrum utilization because it allocates an appropriate number of continuous and partially overlapped subcarriers according to each traffic demand. In this paper, we study path protection under an adaptive modulation with the consideration of spectrum defragmentation and energy consumption.

TP-18

17:15-18:30

**Switching System Architecture for Optical-Circuit-Pcket Converged Transport Network**

Tae-Kyu Kang, Bheom-Soon Joo, Jong-Hyun Lee (ETRI, Korea), and Hong-Ju Kim (Coweaver, Korea)

This paper presents the optical-circuit-packet integrated switching system. It enables to unify the optical transport network layer, circuit network layer and packet transport network layer into single platform. It uses an opticalcircuit-packet converged switching technology, a unified control and management technology. It will solve the problem such as explosion of traffic, the lack of transmission capacity. As a result, it will save the cost to build the converged network.

TP-19

17:15-18:30

### Architecture of Switch Fabric Module in the Optic-Circuit-Packet Converged Transport Network System

Chang-ho Choi, Bheom-soon Joo, Jong-hyen Lee (ETRI, Korea), and Whan-woo Kim (Chungnam Nat'l Univ., Korea)

This paper presents architecture of the PTN-OTN integrated switch fabric module which supports 3.2 terabit switching capabilities in optical-circuit-packet converged transport network systems. The switch fabric module supports not only PTN-OTN converged switching function between integrated line cards that support PTN and OTN traffics, but also provides system timing synchronization function to each line cards and mate switch fabric cards.

TP-20

17:15-18:30

### Measurement of Single-Photon Detection Efficiency of InGaAs/InP Avalanche Photodiodes in Wavelength-Division-Multiplexed Schemes

Heung-sun Jeong, Dong Wook Kim, Seoung Hun Lee, and Kyong Hon Kim (Inha Univ, Korea)

We report on experimentally measured detection efficiency of single-photon detectors (SPDs) based on wavelength-division-multiplexed (WDM) InGaAs/InP avalanche photodiodes (APDs). Multiple SPDs combined in a WDM scheme can be used to overcome the detection speed limit of a single SPD. There is a tradeoff between the detection efficiency of parallel SPDs in the WDM scheme and the optical loss caused by the WDM devices.

TP-21

17:15-18:30

### Implementation of ODUk Linear Protection Switching in the Packet Optical Transport System

Jesoo Ko, Ji-wook Youn, Ho-gun Kim, Seung-woo Lee, Wonkyoung Lee, and Bheom-soon Joo (ETRI, Korea)

In the P-OTS, OTN line signal of the OTN line card contains packet signals within ODU frame. To protect an ODU path, an ODUk path protection function is required. The proposed ODUk linear protection function is implemented based on the hardware within the OTN line card. We presented the operation of 1+1 unidirectional ODUk SNC protection switching. The measured protection time is less than 13ms.

TP-22

17:15-18:30

### Energy Consumption Study based on the Immunization Algorithm in Optical Network

Dongyan Zhao, Keping Long, Dongxue Wang, Xian Zhou, and Yichuan Zheng (Univ. of Science and Technology Beijing, China)

The immunization algorithm is from the theory of complex network. The algorithm is simple, highly feasible based on scale-free network model. This paper uses a targeted immunization for optical network energy issues. This paper selects the service to be the operator and to save energy through node immunization. The simulation results show the algorithm can be implemented. This paper provides another possibility on optical networks energy saving.

TP-23

17:15-18:30

**Transport SDN Architecture for Distributed Cloud Services**

Bin Yeong Yoon, Sun-Me Kim, and Jong-hyun Lee (ETRI, Korea)

Distributed cloud services provide clients with optimal computing and storage resources over many micro datacenters remotely scattered. It requires networking technologies to connect micro datacenters. This paper addresses transport SDN requirements necessary for distributed cloud services, and then suggests architecture of T-SDN controller.

TP-24

17:15-18:30

**Experimental Report of Elastic Lambda Aggregation Network (E $\lambda$ AN) Control Method for SDN-based Carrier Class Network**

Teppei Yamaguchi, Takehiro Sato, Hidetoshi Takeshita, Satoru Okamoto, and Naoaki Yamanaka (Keio Univ., Japan)

The unified control of core / metro / access networks using Software-Defined Networking (SDN) is effective for providing services flexibly. In this paper, experimental results of the unified control by hierarchized Controller utilizing OpenFlow protocol and abstracted network are presented.

TP-25

17:15-18:30

**Processor Time Synchronization in Packet-optic Data Transport System**

Bup-Joong Kim, Yong-Wook Ra, Bheom-Soon Joo, Jong-Hyun Lee (ETRI, Korea), and Kyoungrok Cho (Chungbuk Nat'l Univ., Korea)

The following description relates to a processor time synchronization apparatus and method in a packet-optic data transport system which includes a plurality of processors and line interfaces, the apparatus and method capable of performing reliable system's external and internal high timeresolution time synchronization, and sharing time information by use of a simple structure at a low cost.

TP-26

17:15-18:30

**Placement Strategy for Survivable Hybrid WOBAN against Multi-Fibre Failure**

Yinpeng Yu, Yejun Liu, Lei Guo, and Bing Li (Northeastern Univ., China)

This paper focuses on the survivability of citywide hybrid Wireless-Optical Broadband Access Network (WOBAN). A protection scheme is proposed to tolerate the failure of multiple distribution fibers considering capacity and coverage problem. Simulation results show good performance of this scheme.

TP-27

17:15-18:30

### **OFDM-PON Supporting Heterogeneous Access Techniques: Survey and Challenges**

Xiaoxue Gong, Yejun Liu, and Lei Guo (Northeastern Univ., China)

Due to the high spectrum efficiency and the flexible resource allocation, Orthogonal Frequency Division Multiplexing Passive Optical Network (OFDM-PON) support heterogeneous access techniques but it will face many challenges. Thus in this paper, we review and discuss some challenging issues about the OFDM-PON supporting heterogeneous access techniques.

TP-28

17:15-18:30

### **Green IP Network Design: Oriented Line-card Model**

Jing Wu and Hongfang Yu (Univ. of Electronic Science and Technology of China, China)

In this paper, we focus on power saving in green IP network by closing devices based on oriented line-card model. We propose our heuristics which sequentially closes links and line-cards while satisfying constraints by adjusting link weight to minimize power consumption in green IP network. Simulations show that our heuristics performs well.

TP-29

17:15-18:30

### **LSP Merge in Point to Multipoint In-band OAM**

Dong-Myung Sul, Sun-Me Kim, and Jong-Hyun Lee (ETRI, Korea)

This paper discusses the P2MP in band OAM framework primarily related to OAM and related management in MPLS-TP networks. The P2MP network MPLS-TP data transfer scheme from the root node to the leaf nodes of the Inband OAM because it supports, MPLS-TP OAM 50ms time, one of the requirements in the OAM packet can be processed.

TP-30

17:15-18:30

### **A New Multi-Thread Polling based Dynamic Bandwidth Allocation in Long-Reach PON**

Su-il Choi (Chonnam Nat'l Univ., Korea)

Long-Reach PON (LR-PON) is a broadband access network using passive optical network (PON) technology which the reach is extended to 100 km or higher. A major challenge in LR-PON is that the propagation delay between OLT and ONUs is increased by a very significant amount. To effectively and fairly distribute the upstream bandwidth dynamically in LR-PON, we propose a new multi-thread polling based dynamic bandwidth allocation (DBA) algorithm. We compare the proposed algorithm with traditional DBAs, and show its advantage on average packet delay. Numerical results are analyzed under varying offered loads.

TP-31

17:15-18:30

**Understanding TCP Throughput Performance in TDM-PONs with Sleep Mode**

Alaelddin Fuad Yousif Mohammed, S.h. Shah Newaz, and Jun Kyun Choi (KAIST, Korea)

Energy saving paradigm is a global issue, and the access network consumes a significant portion of entire network-energy consumption. In the literature survey, we can find several research outcomes presenting several ground breaking solutions to minimize energy consumption in access networks (e.g. TDM-PONs). One promising energy saving technique is sleep-mode which aims to put transceiver of an Optical Network Unit into sleep whenever possible. However, in this environment TCP experiences long round trip time causing reduction of TCP throughput significantly. In this paper, our simulation results obtained through OPNET simulator show how sleep interval length can influence TCP throughput in a TDM-PON.

TP-32

17:15-18:30

**Scalable Wireless-Optical Broadband Access Network Using Reconfigurable Optical Backhaul and Gateway Selection Method**

Youngjun Kim, Taekook Kim, Myeongyu Kim, Yeunwoong Kyung, and Jinwoo Park (Korea Univ., Korea)

We propose a scalable optical-wireless access network that is composed of reconfigurable passive optical network and wireless mesh network architectures, which is to flexibly adapt to a large scale of traffic variation in the mobile networks. The reconfigurable PON is equipped with dynamic bandwidth reallocation capability by the arrayed waveguide grating, so that it can provide improved bandwidth efficiency and graceful scalability. Furthermore, a selection method of optical-wireless integrated gateway is included to balance the network load between the two architectures. The proposed network can enhance the network capacity and decrease the congestion probability of optical-wireless access network.

TP-33

17:15-18:30

**Complexity-reduced Analog Predistortion using Schottky Diode for Radio-over-fiber Systems**

Byung-Hee Son, Kwang-Jin Kim, Ye Li, and Young-Wan Choi (Chung-Ang Univ., Korea)

In this paper, we propose a novel and simple predistortion method using schottky diode to compensate the nonlinear characteristics of the DFB-LD for RoF systems. The experimental results show that the enhancement of about 30 dB in the third-order intermodulation distortion (IMD3) and about 10 dB in the spurious-free dynamic range (SFDR) are achieved at 2.4 GHz.

TP-34

17:15-18:30

**Effect of Rotational Misalignment in Phase-plate Based Mode Multiplexer**

Changyo Han, Hwan Seok Chung, Sun Hyok Chang, Kwangjoon Kim, and Jonghyun Lee (ETRI, Korea)

We experimentally investigate the optical signal-to-noise ratio penalty induced by the rotational misalignment of the phase plates in phase-plate based mode multiplexer.

TP-35

17:15-18:30

**A PDE-based Adaptive Median Filter to Process UV Detecting Image Generated by ICCD**

Zhenzhen Lu, Weiyu Liu, Min Zhang, and Dahai Han (Beijing Univ. of Posts and Telecommunications, China)

Intensifier Charge Couple Device (ICCD) is widely used in ultraviolet (UV) detection to amplify weak UV signal. While we amplify weak signal, the noise will also be amplified. In this paper, according to the characteristic of UV detection image, a Partial Differential Equation of Adaptive Median Filter (AMF-PDE) algorithm is proposed to process the output image of UV ICCD camera. The results show that AMF-PDE is able to recover submerged signal and preserve details of UV detection image efficiently.

TP-36

17:15-18:30

**Generation of 40GHz Ultra-low Timing-jitter Pulses by Dual-loop Optoelectronic Oscillator with Balanced-Detection**

Miao Yu, Yan Li, Jizhao Zang, Deming Kong, Jifang Qiu, Wei Li, and Jian Wu (Beijing Univ. of Posts and Telecommunications, China)

Generation of 40GHz optical pulses with ultra-low phase noise is demonstrated experimentally by a self-starting dual-loop OEO with balanced detection. The pulses are achieved with the full-width-at-half-maximum of 7.23ps, extinction ratio of 19.8dB, optical signal to noise ratio of 45dB and timing-jitter of 25.4fs in the 100Hz to 10MHz range.

TP-37

17:15-18:30

**Enhancement of Practically Deployable Indoor VLC System with LDPC Code**

Xiang Zhang, Min Zhang, Dahai Han, Qing Li (Beijing Univ. of Posts and Telecommunications, China), and Feng Zhang (North China Univ. of Technology, China)

The enhanced visible light communications (VLC) system with transmission distance of 6m is demonstrated using transmission path design and forward error correction code in this paper. The experimental results suggest that based on the given power and  $10^{-3}$  bit error rate, in comparison with uncoded system, average communication distance increases 45%, communication area increases 236% with LDPC code.



TP-38

17:15-18:30

**Comparison of Implicit Training and Implicit Pilot in Coherent Optical Transmission****Sujie Fan, Yan Li, Lidong Wang, Wentao Du, Jian Wu, and Jintong Lin (Beijing Univ. of Posts and Telecommunications, China)**

Performance of implicit training and implicit pilot is compared in detail in 112-Gb/s 16QAM coherent optical system by simulation. Q factor performance after 18 spans of SSMF transmission results in proper size of implicit training and pilot. Simulation results demonstrate that implicit pilot based channel estimation outperforms implicit training based channel estimation about 6% because it has a better range for averaging in the process of abstracting the known information.

TP-39

17:15-18:30

**LS Channel Estimation Performance Analysis for RoF Channel Environment in the OFDM System****Yong Su Lee, Young Jo Bang, Jong Hyun Lee, and Youn Ok Park (ETRI, Korea)**

Generally in real implementation of OFDM system, the simple and fast LS channel estimation method has been used for the wireless channel in the OFDM systems. If the wireless channel environment were mixed with RoF (Radio Over Fiber) channel, could we still use the conventional least square (LS) channel estimation method for proper communication? Therefore, in this paper, we analyzed that the performance of LS channel estimation where both wireless and RoF channel are coexisted in the OFDM based mobile communication system.

TP-40

17:15-18:30

**Real-time FPGA Transmitter and Receiver for Coherent Optical OFDM****C. J. Youn, H-Y. Rha, J.-H. Kim, J.-S. Choe, D. J. Kim, Y.-H. Kim, and E. S. Nam (ETRI, Korea)**

We demonstrate a real-time FPGA implementation of coherent optical OFDM transmitter and receiver. It is implemented using two 2.5 GS/s DACs and one FPGA for transmitter, two ADCs and one FPGA for receiver, and FPGA based real-time digital signal processing for coherent optical OFDM transmission.

TP-41

17:15-18:30

**Nonlinearity Compensation in Radio over Fiber Systems using a Monitoring Channel****Sung-man Kim (Kyungsoong Univ., Korea), Seung-Hyun Cho, Sangsoo Lee, and Jong Hyun Lee (ETRI, Korea)**

We propose a nonlinearity compensation scheme using a monitoring channel in radio over fiber (RoF) systems. Our simulation results show that the proposed scheme can almost remove the error vector magnitude (EVM) degradation induced by the nonlinear function of a laser.

TP-42

17:15-18:30

**A Blind Calibration Scheme using a Graph Model for Optical Mobile Sensor Network**

Seung-Chul Son, Byung-Tak Lee (ETRI, Korea), and Kyungran Kang (Ajou Univ., Korea)

The optical sensor calibrations are crucial to obtain the correct measured values in the measurement system like as the optical sensors. We propose a new blind calibration scheme for a massive mobile sensor network. The mutual calibration relationships between co-located sensors are utilized in a densely deployed sensor network.

TP-43

17:15-18:30

**Implementation of Real-Time Indoor Positioning System Using Carrier Allocation Visible Light Communication**

Hyun-Seung Kim, Do-Hoon Kwon, Se-Hoon Yang, Yong-Hwan Son, and Sang-Kook Han (Yonsei Univ., Korea)

We propose received-signal-strength based real-time indoor positioning system in carrier allocation - visible light communication. The experimental result shows that estimated position errors are within 7 centimeters in 100cm x 100cm x 275cm space.

## August 29, 2014 (Fri.)

[FA1] TWDM-PON Technology

[FB1] Advanced Optical Transmission

[FC1] Optical Convergence Networks

[FA2] Advanced Modulation Format for NGA

[FB2] Transport SDN

[FC2] Emerging Photonic Technologies

[FA3] Future Technologies For Optical Internet

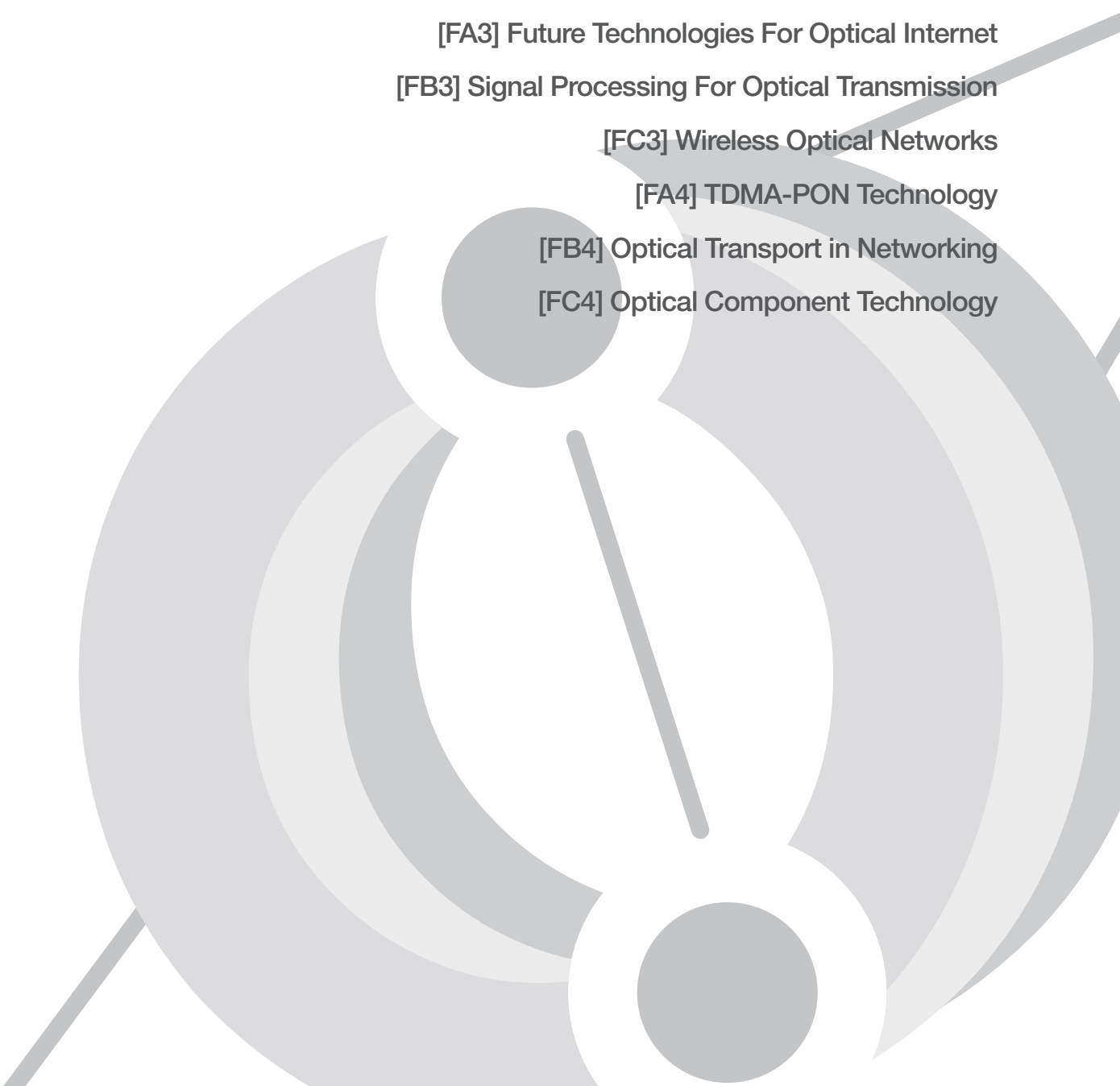
[FB3] Signal Processing For Optical Transmission

[FC3] Wireless Optical Networks

[FA4] TDMA-PON Technology

[FB4] Optical Transport in Networking

[FC4] Optical Component Technology





Session Title	<b>[FA1] TWDM-PON Technology</b>
Date	August 29, 2014 (Fri.)
Time	08:30-10:00
Room	Room A
Session Chair	Hiroaki Mukai (Mitsubishi Electric Corp., Japan)

**FA1-1****08:30–09:00****[Invited] TWDM PON with WDM Overlay for Converged Broadband Services****Ning Cheng (Huawei Technologies, USA)**

TWDM PON with WDM overlay is demonstrated for converged services, where 40Gb/s TWDM PON provides shared capacity for residential broadband and WDM overlay supports 1.25Gb/s dedicated bandwidth for business customers. Pluggable optical transceivers for TWDM PON are developed for future large scale deployment, and self-seeded RSOAs are used in colorless ONUs for WDM overlay.

**FA1-2****09:00–09:15****40Gbps Double-sided Multiband OFDM-PON Based on Polarization Interleaving and Direct Detection****Junfei Shi, Xian Zhou, and Keping Long (Univ. of Science and Technology Beijing, China)**

We present a cost-effective 40Gb/s transmission scheme for OFDM-PON over 100km SSMF based on double-sided multiband and polarization interleaving, which significantly reduce the complexity of the system with only one optical carrier at the transmitter. The optimum frequency interval between two sidebands is small and spectral efficiency reaches 2.1b/s/Hz.

**FA1-3****09:15–09:30****Upstream Transmission of 5.35-Gb/s Spectrum-Sliced Incoherent Light Signal using RSOA****Qikai Hu (Nat'l Univ. of Singapore, Singapore) and Hoon Kim (KAIST, Korea)**

We demonstrate the upstream transmission of a 5.35-Gb/s signal over a loopback configured 20-km link using an ultra-narrow spectrum-sliced incoherent light source and a reflective semiconductor optical amplifier. With the aid of transmitter de-emphasis and offset optical filtering, we achieve an uncorrected bit-error rate lower than  $10^{-3}$  after transmission.

FA1-4

09:30-09:45

**Cost Effective VCSEL Array Based 80-Gb/s TOSA for NG-PON2**

Eun-Gu Lee, Sil-Gu Mun, Sang Soo Lee, Jong Hyun Lee, and Jyung Chan Lee (ETRI, Korea)

The 8×10 Gb/s TOSA based on a VCSEL array was successfully developed for NG-PON2 application. For the cost effectiveness, direct optical coupling without lens array was used to package the TOSA. We have found that an optical and electrical crosstalk was small enough not to effect on a transmission performance.

FA1-5

09:45-10:00

**Silicon AWG as a Tunable Filter in Tunable ONU for TWDM-PON Application**

Jie Hyun Lee, Heuk Park, Sae-Kyoung Kang, Jong Hyun Lee, and Jyung Chan Lee (ETRI, Korea)

We have proposed to use a silicon AWG as a tunable filter for TWDM-PON ONU. Feasibility of the proposed ONU configuration was experimentally demonstrated using the cyclic and the thermally tuned properties of silicon AWG.

Session Title	<b>[FB1] Advanced Optical Transmission</b>
Date	August 29, 2014 (Fri.)
Time	08:30-10:00
Room	Room B
Session Chair	Hwan Seok Chung (ETRI, Korea)

**FB1-1****08:30-09:00****[Invited] Phase Sensitive Amplifiers based on PPLN Waveguides for Optical Communication**

T. Umeki, M. Asobe, O. Tadanaga, H. Takara, Y. Miyamoto, and H. Takenouchi (NTT Corp., Japan)

We review the capabilities of phase sensitive amplifiers based on periodically poled LiNbO<sub>3</sub> (PPLN) waveguides for optical communication. Specifically, we discuss their unique low noise amplification, Phase and amplitude regeneration in multi-span transmissions, and multilevel phase coding signal amplification.

**FB1-2****09:00-09:30****[Invited] Fiber Nonlinearity Mitigation Using Phase-Conjugated OFDM Subcarriers**

Xingwen Yi, Dengke Zeng, Xuemei Chen, Jing Zhang, and Kun Qiu (Univ. of Electronic Science and Technology of China, China)

Digital coherent superposition (DCS) provides an interesting approach to combat the fiber nonlinearity by trading off the spectrum efficiency. In this paper, we apply DCS of phaseconjugated OFDM subcarriers in two approaches. One is the DCS of OFDM subcarriers in the single polarization, denoted as SP-DCS-OFDM. The other is in the dual polarizations, or DPDCS-OFDM. We show that both of them can cancel the fiber nonlinearity to the first order. We compare their performance in a simulation of long-distance nonlinear transmissions. With some difference, both approaches improve the Q-factor by much larger than 3 dB.

**FB1-3****09:30-09:45****Tbps Optical Super-Channel Receiver Models for Partial Demultiplexing of OFDM Spectrum**

Ahmed Galib Reza and June-Koo Kevin Rhee (KAIST, Korea)

In an elastic optical super-channel environment, partial demultiplexing of sub-band with minimum power can be a challenging issue. We investigate the performance comparisons of partial demultiplex between all-optical and coherent OFDMs.

FB1-4

09:45-10:00

**Experimental Study of the Nonlinearity Tolerance of a 100 Gbps Dual-Carrier DP-BPSK Signal on a 3,080 km In-line Dispersion Compensated Fiber Link**

**M. Binkai, K. Matsuda, T. Yoshida, K. Onohara, T. Sugihara, H. Goto, K. Ishida, and T. Mizuochi (Mitsubishi Electric Corp., Japan)**

We investigated experimentally the transmission performance of 100 Gbps dual-carrier DP-BPSK signals transmitted on a 3,080 km in-line chromatic dispersion compensated fiber link with real-time digital signal processing. Its doubled phase margin and nonlinear noise squeezing achieved 2 dB greater robustness to fiber nonlinearity effects compared to single-carrier DP-QPSK signal.



Session Title	<b>[FC1] Optical Convergence Networks</b>
Date	August 29, 2014 (Fri.)
Time	08:30-10:00
Room	Room C
Session Chair	Tae-Hyung Kim (KT, Korea)

**FC1-1****08:30-09:00****[Invited] Wired and Wireless Seamless Links for Resilient and Low-Latency Networks****Tetsuya Kawanishi (NICT, Japan)**

This presentation describes a concept of wired and wireless seamless links which can transfer waveforms over various transmission media including optical fibers, millimeter-waves, etc. The seamless links would enhance resilience and reduce latency.

**FC1-2****09:00-09:30****[Invited] Improvement of Channel Bandwidth in Optical Wireless OFDM Link based on Visible Light Emitting Diode using Compressive Sensing****Yong-Yuk Won (Yonsei Univ., Korea) and Sang Min Yoon (Kookmin Univ., Korea)**

The data rate of VLC link is increased using an adaptive sampling and inverse discrete cosine transform based on a compressive sensing. At the compression ratio of 30 %, the measured EVM of QPSK is 22.39 %.

**FC1-3****09:30-10:00****[Invited] Photon Pair Sources for Quantum Information Networks and Remote Sensing Systems****Jae-Ho Han (Korea Univ., Korea)**

Photon entanglement has revolutionized the implementation of quantum information, a hybrid configuration of quantum mechanics and information theory. In this talk, as one of the key enabling optical components, the development and features of the photon pairs for advances in quantum communication networks and sensing systems will be mainly covered.

Session Title	<b>[FA2] Advanced Modulation Format for NGA</b>
Date	August 29, 2014 (Fri.)
Time	10:15-11:45
Room	Room A
Session Chair	Seunghyun Cho (ETRI, Korea)

**FA2-1**

**10:15-10:45**

**[Invited] Application of Hierarchical Modulation to Optical Access Network**

**Noriko Iiyama, Naotaka Shibata, Jun-ichi Kani, Jun Terada, and Hideaki Kimura (NTT Corp., Japan)**

Hierarchical modulation is a technology for point-to-multipoint architectures that can simultaneously transmit multiple independent signals using a single wavelength/frequency. This paper reviews the principle of hierarchical modulation and introduces some application examples. For this interesting technology, we have proposed its use for coexistence of different generation passive optical networks (PONs). The validity of combining hierarchical modulation with star quadrature amplitude modulation (QAM) format in migrating the conventional 10G/channel class PON to the future digital coherent PON is shown.

**FA2-2**

**10:45-11:00**

**Influence of I/Q imbalance on Multi-level modulated Signals Interleaved with Reference Light**

**Yasuhiro Okamura, Atsushi Takada (The Univ. of Tokushima, Japan), and Masanori Hanawa (Univ. of Yamanashi, Japan)**

Effect of I/Q imbalance on multi-level modulated signals interleaved with reference light is analytically investigated. We show that received signals are degraded by the I/Q imbalance resulting from optical-frequency misalignment between a light source and an optical delay interferometer. Then, quality of the received signals is evaluated by numerical simulations.

**FA2-3**

**11:00-11:15**

**1.5- $\mu$ m, 10-Gbps 4-PAM VCSEL Transmission for Optical Access Networks**

**Jingjing Zhou, Changyuan Yu (Nat'l Univ. of Singapore, Singapore), and Hoon Kim (KAIST, Korea)**

We study the transmission performance of a 10-Gbps 4-PAM signal generated from a 1.54- $\mu$ m VCSEL. With the aid of optimized extinction ratio and post-detection electronic equalization, we successfully transmit the signal over 30-km standard single-mode fiber.

FA2-4

11:15-11:30

**Optical Transmission of Baseband OFDM in IM/DD System by PDM based I/Q Channel Separation**

Sun-Young Jung, Sang-min Jung, and Sang-Kook Han (Yonsei Univ., Korea)

We proposed baseband AMO-OFDM transmission using PDM based I/Q separation in IM/DD system. In compare with up-conversion, we experimentally verified performance. As a result, optical spectral efficiency was better as 7.2bit/s/Hz. It has simpler hardware and reduces complexity compared to IF up-conversion or Hermitian symmetry in IM/DD based PDM-OFDM system.

FA2-5

11:30-11:45

**Single Wavelength OFDMA PON Uplink Optical Beat Interference Noise Reduction using RF Clipping Tone**

Sang-Min Jung, Seung-Min Yang, Kyung-Hak Mun, and Sang-Kook Han (Yonsei Univ., Korea)

A novel technique for mitigating the OBI noise in optical OFDMA-PON uplink transmission is presented. By using out of signal band RF clipping tone to optical seed carrier, OBI noise has been reduced and resulting throughput and spectral efficiency has been doubled up.

Session Title	<b>[FB2] Transport SDN</b>
Date	August 29, 2014 (Fri.)
Time	10:15-11:45
Room	Room B
Session Chair	Weigang Hou (Northeastern Univ., China)

**FB2-1**

**10:15-10:45**

**[Invited] Energy Efficient Data-centric Network on the Optical Network Virtualization Platform**

**Satoru Okamoto, Shanming Zhang, and Naoaki Yamanaka (Keio Univ., Japan)**

The network architecture called Energy Efficient and Enhanced-type Data-centric Network (E<sup>3</sup>-DCN) is proposed for a new information centric network (ICN). E<sup>3</sup>-DCN not only realizes ICN but also has the ability of data generation by organizing and combining relevant resource such as original data and kinds of processing services. In addition, in order to improve energy efficiency of data transmission, E<sup>3</sup>-DCN chooses optimal transmission path to transmit data based on electrical packet switching and optical path switching. E<sup>3</sup>-DCN achieves an energy efficient network and is designed to fit with the network virtualization platform in JGN-X.

**FB2-2**

**10:45-11:00**

**Cognitive Routing and Wavelength Assignment Algorithm for Dynamic Optical Networks**

**Zonglong Chen, Shuang Wang (Univ. of Science and Technology Beijing, China), Hao Zhang (Institute of Microelectronics of Chinese Academy of Sciences, China), Yumin Liu, and Yunfeng Peng (Univ. of Science and Technology Beijing, China)**

In this paper, we present a cognitive routing and wavelength assignment (RWA) algorithm for dynamic optical networks, named CRWA algorithm. Different from the traditional RWA algorithm, a cognitive model derived from the Case-Based Reasoning (CBR) is introduced into the proposed algorithm to reduce computing complexity. Simulation results show that the computational time of CRWA is reduced about 25% compared to that of traditional RWA algorithm.

**FB2-3**

**11:00-11:30**

**[Invited] Dynamic Optical Path Network: A Network Beyond SDN and SDM**

**Shu Namiki, Kiyo Ishii, Junya Kurumida, Haruhiko Kuwatsuka, Hitoshi Kawashima, and Tomohiro Kudoh (AIST, Japan)**

Dynamic optical path network (DOPN) is a network based on hierarchical multi-granular fast circuit switching, mostly in optical domain. We discuss how this network technology is sustainable, eliminating energy and capacity crunch in the future network.

FB2-4

11:30-11:45

**A PCE-based Provisioning Controller for Software-defined Transport Networks**

Jin Seek Choi, S. Kang, B. W. Jang, Delphine, S. I. Kim, and S. Y. Kim (Hanyang Univ., Korea)

In this paper, we present a path computation element (PCE) based provisioning controller coupled with a OpenFlow (OF) controller for software-defined transport networking (SDTN). The main concept of the proposed approach is a unified provisioning controller based on a PCE that enables fast and error-free methods for path computation, provisioning, and configuration in SDTNs. The coordinating work between the provisioning controller and the OF controller improves the network programmability and reduces the operational expenditure to the network operators.

Session Title	<b>[FC2] Emerging Photonic Technologies</b>
Date	August 29, 2014 (Fri.)
Time	10:15-11:45
Room	Room C
Session Chair	Jonghoi Kim (ETRI, Korea)

**FC2-1**

**10:15-10:45**

**[Invited] Photonics Solution for Single Chip Terahertz Transceiver**

**Kyung Hyun Park, Namje Kim, Kiwon Moon, Eui Su Lee, Il-Min Lee, Hyunsung Ko, Jeong-Woo Park, and Sang-Pil Han (ETRI, Korea)**

Semiconductor devices based on photonics for the tunable continuous-wave THz generation and detection are explored. A tunable single-chip terahertz transceiver consists of beating source, broadband photomixer, and THz detector is developed. The realizable possibility of monolithically integrated single-chip THz transceiver which is main building block for the wide spread industrial applications will be addressed.

**FC2-2**

**10:45-11:00**

**Optical Cross-Connects Switches for Multiple Stacked Rings Interconnected Datacenter Networks**

**Li Zhao, Weiqiang Sun, and Weisheng Hu (Shanghai Jiao Tong Univ., China)**

Multiple stacked rings provide high bandwidth communications for large datacenters. This paper is interested in designing fully/partial non-blocking optical cross-connect switches using microsecond wavelength selective switches.

**FC2-3**

**11:00-11:15**

**VLC Based Indoor Positioning using Single-Tx and Rotatable Single-Rx**

**Se-Hoon Yang and Sang-Kook Han (Yonsei Univ., Korea)**

We proposed a two-dimensional positioning system and an algorithm using single transmitter and receiver. The system is using modeled characteristics of device which is based on the experimentally measured. We were able to obtain the estimated position with less than 3 cm of error when polar angle was 15 degrees and the azimuth angles of PD were 45, 315, and 135 degrees.

FC2-4

11:15-11:30

**Multi-function Time-frequency Transmission System over Optical Fiber**

Haijie Yu, Yitang Dai, Feifei Yin, Anxu Zhang, Zhongze Jiang, Wenhui Hao, Qizhuang Cen, Jianqiang Li, and Kun Xu (Beijing Univ. of Posts and Telecommunications, China)

We propose a fiber-based, multi-function timefrequency delivery system assisted by active fiber delay compensation and the wavelength division multiplexing (WDM) technology. Experimentally, three signals with different functions are transferred from the center to the remote end, while a simulated receiving signal is transferred back. All channels are delay stabilized simultaneously.

FC2-5

11:30-11:45

**Failure Detection of Mobile Nodes in Medical Asset Tracking System**

Kwangsoo Kim, Dong-Hwan Park (ETRI, Korea), and Seong-il Jin (Chungnam Nat'l Univ., Korea)

A medical asset tracking system monitors the in/out status of a medical asset with a mobile node which moves around a monitoring area, leaves it, and then returns to the region repeatedly. Due to failure of the mobile nodes, the system may determine that a mobile asset is outside the region despite the fact that the mobile asset is inside. In this paper, a novel failure detection method is proposed to resolve this problem. It uses two properties of the neighboring nodes of a mobile node disconnected from a sensor network. One is the trend of the neighbor counts; the other is that of the ratios of the boundary nodes contained in the neighbors. With these trends, the proposed method detects failed nodes from mobile nodes disconnected from a sensor network. The experimental results show that the proposed method can detect most failures of mobile nodes, including those that the conventional approaches fail to observe.

Session Title	<b>[FA3] Future Technologies For Optical Internet</b>
Date	August 29, 2014 (Fri.)
Time	12:45-14:15
Room	Room A
Session Chair	Jongwon Kim (GIST, Korea)

### FA3-1

#### **[Tutorial] Swarm Intelligence: Fundamental Principles and Optimization Approaches**

**Zhongshan Zhang (University of Science and Technology Beijing, China)**

Inspired by swarm intelligence observed in social species, the artificial self-organized networking (SON) systems are expected to exhibit some intelligent features (e.g., flexibility, robustness, decentralized control, and self-evolution, etc.) that may have made social species so successful in the biosphere. Self-organized networks with swarm intelligence as one possible solution have attracted a lot of attention from both academia and industry. In this tutorial, we first different aspects of bio-inspired mechanisms and examine various algorithms (e.g., pulse-coupled oscillators (PCO)-based synchronization, ant- and/or bee-inspired cooperation and division of labor, immune systems inspired network security and Ant Colony Optimization (ACO)-based multipath routing) that have been applied to artificial SON systems. Then, we give some open research issues in detail.

### FA3-2

**13:45-14:15**

#### **[Invited] Flexible and Robust Optical Network Technologies for SDN and Network Virtualization**

**Takafumi Tanaka (NTT Corp., Japan)**

This paper reviews the progress of flexible and robust technologies for a reliable optical network infrastructure that can be used for software defined networking (SDN) and network virtualization. We focus on the elastic optical network (EON), which will play an important role in achieving both flexibility and robustness, and introduce our current works on fault tolerance.



Session Title	<b>[FB3] Signal Processing For Optical Transmission</b>
Date	August 29, 2014 (Fri.)
Time	12:45-14:15
Room	Room B
Session Chair	Takeshi Umeki (NTT Photonics Labs., Japan)

**FB3-1****12:45-13:15**

**[Invited] Long-haul Quasi-Single-Mode Transmission using Few-Mode Fiber with Multi-Path Interference Compensation**

Alan Pak Tao Lau, Qi Sui, Hwa-Yaw Tam, Chao Lu, P. K. A. Wai (Hong Kong Polytechnic Univ., Hong Kong), John D. Downie, William A. Wood, Jason Hurley, and Snigdharaj Mishra (Corning Incorporated, USA)

We investigate quasi-single-mode (QSM) transmissions with multi-path interference(MPI) cancellation using DSP and experimentally demonstrate 256 Gb/s PM-16-QAM transmission up to 2600 km by using 100-km spans of fewmode fibers (FMF).

**FB3-2****13:15-13:30**

**Low-biased Analog Photonic Link Capable of Multi-octave Span RF Signal Delivery**

Xi Liang, Xiaodong Liang, Yitang Dai, Feifei Yin, Jianqiang Li, and Kun Xu (Beijing Univ. of Posts and Telecommunications, China)

We propose and experimentally demonstrate a novel low-biased intensity-modulated directly-detected (IM-DD) analog photonic link with suppressed relative intensity noise (RIN) and second-order harmonic distortions (SHD) for multi-octave span RF signal delivery. Experiment results show 19 dB suppression of the SHD, compared with the traditional low-biased IM-DD link.

**FB3-3****13:30-13:45**

**Mode Multiplexing/Demultiplexing by Fiber Mode Selective Couplers and MIMO Signal Processing**

Sun Hyok Chang, Hwan Seok Chung, Kwangjoon Kim, Jyung Chan Lee, and Jong Hyun Lee (ETRI, Korea)

The use of the fiber mode selective coupler (MSC) for mode multiplexing and demultiplexing is investigated. The signals in two separate modes excited by the MSCs are successfully recovered by 4x4 MIMO signal processing.

FB3-4

13:45-14:15

**[Invited] Advanced Modulation in Optical Transmission**

Xiangjun Xin and Dong Guo (Beijing Univ. of Posts and Telecommunications, China)

A number of advanced modulation formats are available for optical transmission to reduce the transmission loss, improve the spectral efficiency and transmission capacity. In this paper, we will introduce some of them with their development and application in recent years.

Session Title	<b>[FC3] Wireless Optical Networks</b>
Date	August 29, 2014 (Fri.)
Time:	12:45-14:15
Room	Room C
Session Chair	Yong-Yuk Won (Yonsei Univ., Korea)

**FC3-1****12:45-13:15****[Invited] Dynamic IQ Compression Technique in Mobile Front-Haul for Mobile Optical Network**

Naotaka Shibata, Shigeru Kuwano, Jun Terada, and Hideaki Kimura (NTT Corp., Japan)

Dynamic IQ-data compression is essential in the mobile front-haul for cost-effective mobile optical network. We briefly introduce the compression technique, and show our recent research results.

**FC3-2****13:15-13:45****[Invited] Practical Perspective of Artificial Neural Networks as a Function Approximator, not an Almighty Black Box**

Tae-Hyung Kim (KT, Korea)

In the realm of Computational Intelligence/Machine Learning (CI/ML), artificial neural networks (ANNs) are believed to have potential to mimic human brain. As a researcher, maintaining this dream is important. However, one should realize an artificial neuron is a model, not an actual biological neuron. This paper indicates the logical leap why ANNs are not like human brain.

**FC3-3****13:45-14:00****Efficient Cross-Room Handoff Mechanism for Indoor Visible Light Communication Network**

Zhitong Huang, Jianfeng Li, and Yuefeng Ji (Beijing Univ. of Posts and Telecommunications, China)

We present an efficient protection-area based handoff mechanism to solve the cross-room movement problem in room division multiplexing (RDM) indoor visible light communication (VLC) network. Experimental platform demonstrates the RDM-deployed VLC network, and validates the performance of the presented handoff mechanism.

**FC3-4****14:00-14:15****Transmit Power Control for Small Cell Networks in Urban, Suburban, and Rural Environments**

Sandu Abeywickrama and Elaine Wong (Univ. of Melbourne, Australia)

We solve an optimization problem for small cell power control considering the hourly network capacity demand of mobile access networks. The model is evaluated under urban, suburban and rural test cases to evaluate optimal transmit powers and corresponding power savings.

Session Title	<b>[FA4] TDMA-PON Technology</b>
Date	August 29, 2014 (Fri.)
Time	14:30-16:00
Room	Room A
Session Chair	Sang Soo Lee (ETRI, Korea)

**FA4-1**

**14:30-15:00**

**[Invited] Generic Remote ONU Management for Various Optical Access Systems**

**Hiroaki Mukai (Mitsubishi Electric Corp., Japan)**

In future, various optical access systems will be deployed depending on the required data transmission capacity. For smooth migration, generic network management scheme is desired. In this paper, generic remote ONU management scheme by adopting the virtualization of logical channel in various optical access systems is described.

**FA4-2**

**15:00-15:15**

**Performance Analysis of Legacy E-PON System at the Transmission Environment of 1:64@50km**

**Kwang-Ok Kim, Sang-Soo Lee, Jong-Hyun Lee (ETRI, Korea), and Youn-Seon Jang (Chungnam Nat'l Univ., Korea)**

We analyze the performance of existing E-PON system that support a 64-way split and transmission distance of 50km using a reach extender. We experimentally demonstrated that it can provide a 950 Mbps and 860 Mbps throughputs at a down-/upstream direction.

**FA4-3**

**15:15-15:30**

**On Understanding the Influence Sleep Mode on Packet Delay Variation in TDM-PONs**

**S.h. Shah Newaz, Alaeiddin Fuad Yousif Mohammed (KAIST, Korea), Gyu Myoung Lee (Telecom SudParis, France), and Jun Kyun Choi (KAIST, Korea)**

Sleep mode has been widely applied in TDM Passive Optical Networks for maximizing energy saving. However, it can significantly influence QoS performance of traffic. In this article, we present an insightful study results which comprehend how delay variation performance of a flow can be influenced under different length of sleep intervals used in Optical Network Units.

FA4-4

15:30-15:45

**Resolution Enhancement of Correlated OTDR Using Eigen-Decomposition Based Algorithm**

Wonkyoung Lee, Hun-Sik Kang, and Bheom Soon Joo (ETRI, Korea)

This paper investigates the resolution enhancement of correlated OTDR using Eigen-decomposition based algorithm. The algorithm separates the space spanned by the measured data into what are called noise and signal subspace and then pseudospectrum is calculated by using signal steering vector and noise subspace matrix. Attenuation dead zone of the correlated OTDR is improved up to 45 % by the Eigen-decomposition based algorithm.

FA4-5

15:45-16:00

**Spectrum-Sliced Incoherent Channel Receiver using a Polarization-independent Optical Modulator**

Hyung Hwan Kim, Dipen Manandhar, and Jae Seung Lee (Kwangwoon Univ., Korea)

We propose a spectrum-sliced incoherent channel receiver using a polarization-independent optical modulator (PIOM). Applying a 12.5-GHz sliced channel that has a 3 dB bandwidth of 0.1 nm, we have the error floor at  $9.2 \times 10^{-4}$  without the PIOM. With the PIOM, the bandwidth of the received 12.5-GHz sliced channel increases up to 1.5 nm and the error floor decreases to  $1.2 \times 10^{-7}$ .

Session Title	<b>[FB4] Optical Transport in Networking</b>
Date	August 29, 2014 (Fri.)
Time	14:30-16:00
Room	Room B
Session Chair	Chul Han Kim (Univ. of Seoul, Korea)

**FB4-1**

**14:30-15:00**

**[Invited] 1-Exabit/s-km Super-Nyquist-WDM Transmission using Multi-Core Fibers**

**Koji Igarashi, Takehiro Tsuritani, and Itsuro Morita (Osaka Univ., Japan)**

We review trans-oceanic-class multi-core fiber transmission systems with Super-Nyquist-WDM technique, in which optical signals are multiplexed with frequency spacing of less than baudrate. The capacity-distance product over 1 Exabit/s-km has been achieved.

**FB4-2**

**15:00-15:15**

**Analysis of PAM-N (N=4, 5, 6, 7, and 8) Signals Operating at 103.125 Gbps for Next Generation Ethernet**

**Joon Young Huh, Joon Ki Lee, Sae-Kyung Kang, and Jyung Chan Lee (ETRI, Korea)**

We compare optical PAM-N (N=4, 5, 6, 7, and 8) signals operating at 103.12-Gbps. From the results, PAM-5 signal is more appropriate than other PAM-N signals by considering the effect of chromatic dispersion for 10-km SMF transmission using wavelength of LAN-WDM.

**FB4-3**

**15:15-15:30**

**A Study of Rapid Defragmentation by Re-assigning Spectrum to Fewer Paths in Elastic Optical Networks**

**Hitomi Yoshimura, Sota Yoshida, and Takashi Mizuochi (Mitsubishi Electric Corp., Japan)**

An algorithm for network defragmentation which re-assigns spectrum to fewer spectral paths in an elastic optical network using the notion of "occupation rate" is proposed. A simulation indicates that it reduces the time to defragment a complete network by 56% at a threshold occupation rate of 50% in a JPN25 network.

FB4-4

15:30-15:45

**Design and Implementation of Correlation-based Optical Time-Domain Reflectometer Transceiver**

Hun Sik Kang, Seung Il Myong, Jong Hyun Lee, and Jyung Chan Lee (ETRI, Korea)

Design and implementation of a correlationbased OTDR (C-OTDR) transceiver is discussed. The C-OTDR uses a high-power low noise avalanche photo diode detector and transimpedance and variable gain amplifiers with correlation-based OTDR FPGA modem. A dynamic range of approximately 38 dB is demonstrated. Spatial resolution of 5 meter and event dead zone of 10 meter are achieved.

FB4-5

15:45-16:00

**The Four Wave Mixing Effects in Quantum Key Distribution based on Conventional WDM Network**

Lichao He, Jianing Niu, Yongmei Sun, and Yuefeng Ji (Beijing Univ. of Posts and Telecommunications, China)

With the escalating applications of the Internet, its security has been an increasingly important issue. Quantum key distribution (QKD) has been studied for the last three decades and is a potential way to safeguard the Internet security. As to make QKD more acceptable in Internet applications, we study how to make it integrated to conventional optical network. In the conventional optical networks, WDM is a typical technique to save the fiber resources. In this paper, we analyze the effects of WDM on quantum signal, especially the four wave mixing (FWM) effects. We also propose an unequally spaced channels scheme to decrease the impact of FWM and demonstrate it in simulation.

Session Title	<b>[FC4] Optical Component Technology</b>
Date	August 29, 2014 (Fri.)
Time	14:30-16:00
Room	Room C
Session Chair	Hirochika Nakajima (Waseda Univ., Japan)

**FC4-1**

**14:30-15:00**

**[Invited] Progress of Space Division Multiplexing Technology for Future Optical Networks**

Jun Sakaguchi, Werner Klaus, Benjamin J. Puttnam, José Manuel Delgado Mendinueta, Yoshinari Awaji, and Naoya Wada (NICT, Japan)

We review research progress on new optical devices for SDM networks. Component sharing is expected to be effective for cost reduction, but further improvement of SDM device performance is needed to realize practical SDM networks.

**FC4-2**

**15:00-15:30**

**[Invited] Spatial Light Modulators for Space-Division Multiplexing**

Joel Carpenter, Benjamin J. Eggleton, and Jochen Schröder (Univ. of Sydney, Australia)

The applications of spatial light modulators for mode division multiplexing will be discussed, including multiplexing, characterization and wavelength switching and filtering.

**FC4-3**

**15:30-15:45**

**High Precision Measurement of Free Spectral Range of a Fabry-Perot Etalon**

D. S. Seo (Myongji Univ., Korea), D. E. Leaird, and A. M. Weiner (Purdue Univ., USA)

We suggest a novel technique to measure the free spectral range of a Fabry-Perot etalon (FPE). The technique utilizes a Pound-Drever-Hall method using both reflected and transmitted lights of an FPE. We improve the measurement accuracy ~2 dB by using both of the lights.

**FC4-4**

**15:45-16:00**

**Simplified Crosstalk Floor Representation for a Design Parameter of Silicon AWG**

Heuk Park, Sae-Kyoung Kang, Jong Hyun Lee, and Sangsoo Lee (ETRI, Korea)

The relation between the width variation and the crosstalk floor is derived assuming the fabrication imperfection dominates the phase error. The calculated crosstalk shows linear dependence with the measured crosstalk floor. This reveals the calculated crosstalk floor would be a useful design parameter of AWG to predict the limit of channel isolation.