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Editorial

Special Issue on Optical Communications and Networking: Prospects in Industrial Applications

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1. Introduction

In the past two decades, Internet traffic has increased by over 10,000 times by taking advantage of both efficient information processing technology in the electronic domain and efficient transmission technology in the optical domain, which are the foundation of today's Internet infrastructure [1,2]. The advancement of electronics processing circuits has followed Moore's law, and perhaps will continue this exponential growth for years to come. This may make the electrical systems significantly outpace the advancement of optical systems in information and communications technologies. To support the ever-growing Internet traffic, optical communication systems face a great challenge in transporting information processed by electronic systems for sustained exponential growth. The industry has explored multiple degrees of freedom of the photon (time, wavelength, amplitude, phase, polarization, and space) to significantly reduce the cost/bit for data transmission by increasing the capacity/fiber through multiplexing and reducing the size and power through integration.

This Special Issue aims to explore the latest advancements in the optical communication industry. The applications range from short-reach chip-to-chip interconnections to the long-haul backbone communications at the trans-oceanic distance, including the technologies used in devices, systems, and networks levels. It focuses on state-of-the-art advances and future perspectives in commercially deployed systems.

2. Special Issue Papers

In this Special Issue, we have carefully selected nine articles, including one invited and eight contributed papers. These papers cover advanced techniques for short-reach applications, such as data centers, long-distance applications such as trans-oceanic links from systems that use single mode fibers, and the systems use free-space transmission, such as visible light communication (VLC) systems and satellite-to-sea laser communications.

The following are the summary of these papers:

- Phase Noise Cancellation in Coherent Communication Systems Using a Radio Frequency Pilot Tone [3]

In long-haul optical fiber communication, DSP-based (digital signal processing) dispersion compensation can be distorted by the equalization-enhanced phase noise (EEPN), due to the reciprocities between the dispersion compensation unit and the local oscillator (LO) laser phase noise (LPN). In this invited paper, the authors demonstrated a unique approach for phase noise cancellation using a radio

frequency pilot tone. They showed that the RF pilot tone can entirely eliminate the LPN and efficiently suppress the EEPN when it is applied prior to the carrier phase recovery.

- 400GbE Technology Demonstration Using CFP8 Pluggable Modules [4]

In this paper, the authors reviewed the current status of 400GBASE client-side optics standards and multi-source agreements (MSAs). They then compared different form factors for 400GE modules, including CFP8, OSFP, and QSFP-DD. The essential techniques used to implement 400GE, such as pulse amplitude modulation (PAM4), forward error correction (FEC), and a continuous time-domain linear equalizer (CTLE), are also discussed. In addition, a 400GE physical interface card (PIC) in Juniper's PTX5000 platform has been developed, conforming to the latest IEEE802.3bs standard. To validate the PIC's performance, a commercial optical network tester (ONT) and the PIC are optically interconnected through two CFP8-LR8 modules. The CFP8-LR8 module utilizes eight optical wavelengths through coarse wavelength division multiplexing (CWDM). Each wavelength carries a 50 Gb/s PAM4 signal. The signal transmits through 10 km of single mode fiber (SMF). The ONT generates framed 400GE signal and sends it to the PIC through the first CFP8 module. The PIC recovers the signal, performs an internal loopback, and sends 400GE signal back to the ONT through the second CFP8 module. The optical spectrum, eye diagram, receiver sensitivity, long time soaking results, and internal digital diagnosis monitoring (DDM) result are fully characterized. The pre-FEC bit error rate (BER) is well below the KP4 FEC threshold of 2.2×10^{-4}. After KP4 FEC, an error-free performance over 30 km of SMF is achieved. At the end, the authors demonstrated both the interoperation between the PIC and the ONT, as well as the interoperation between the two CFP8 modules. This demonstration represents the successful implementation of the 400GE interface in the core IP/MPLS router.

- Power and Signal-to-Noise Ratio Optimization in Mesh-Based Hybrid Optical Network-on-Chip Using Semiconductor Optical Amplifiers [5]

To address the performance bottleneck in metal-based interconnects, hybrid optical network-on-chip (HONoC) has emerged as a new alternative. However, as the size of the HONoC grows, insertion loss and crosstalk noise increase, leading to excessive laser source output power and performance degradation. In this paper, the authors proposed a low-power scalable HONoC architecture by incorporating semiconductor optical amplifiers (SOAs). An SOA placement algorithm is developed considering insertion loss and crosstalk noise. Moreover, the authors establish a worst-case crosstalk noise model of SOA-enabled HONoC and induce optimized SOA gains with respect to power consumption and performance, respectively. Simulation results show that the proposed SOA-enabled HONoC architecture and the associated algorithm help sustain the performance as network size increases without the need for additional laser source power.

- Two-Dimensional Constellation Shaping in Fiber-Optic Communications [6]

Constellation shaping has been widely used in optical communication systems. The authors reviewed recent advances in two-dimensional constellation shaping technologies for fiber-optic communications. The system architectures that are discussed include probabilistic shaping, geometric shaping, and hybrid probabilistic-geometric shaping solutions. The performances of the three shaping schemes are also evaluated for Gaussian-noise-limited channels.

- Joint Probabilistic-Nyquist Pulse Shaping for an LDPC-Coded 8-PAM Signal in DWDM Data Center Communications [7]

M-ary pulse-amplitude modulation (PAM) has useful applications in data center communication due to its simplicity and low cost. The challenge in PAM systems include providing dynamic bandwidth and reaching the Shannon capacity limit. One potential solution is probabilistic shaping distribution with Nyquist pulse shaping for fine entropy granularity and reaching the Shannon limit. In this paper,

the authors demonstrated the joint usage of probabilistic shaping and Nyquist pulse shaping with low-density parity-check (LDPC) coding to improve the bit error rate (BER) performance of 8-PAM signal transmission. They optimized the code rate of the LDPC code and investigated different Nyquist pulse shaping parameters using simulations and experiments. They achieved a 0.43 dB gain using Nyquist pulse shaping, and a 1.1 dB gain using probabilistic shaping, while the joint use of probabilistic shaping and Nyquist pulse shaping achieved a 1.27 dB gain, which offers an excellent improvement without upgrading the transceivers.

- Adaptive Compensation of Bandwidth Narrowing Effect for Coherent In-Phase Quadrature Transponder through Finite Impulse Response Filter [8]

In optical coherent communication systems, the transmitted signals may experience bandwidth narrowing effects after passing through multiple reconfigurable optical add-drop multiplexers (ROADMs), or due to coherent in-phase quadrature (IQ) transponder aging. In this paper, the authors demonstrated a method using a post ADC adaptive finite impulse response (FIR) filter in coherent optical receivers to dynamically compensate for the bandwidth narrowing effect. The influence of chromatic dispersion, polarization mode dispersion, and polarization dependent loss were also investigated comprehensively. Furthermore, the bandwidth information of the transmitted analog signal can be fed back to the coherent optical transmitter for signal optimization, and the transmitter-side FIR filter thus can be changed accordingly.

- A Novel Coding Based Dimming Scheme with Constant Transmission Efficiency in VLC Systems [9]

Visible light communications (VLC) has attracted tremendous attention due to two functions: communication and illumination. Both reliable data transmission and lighting quality need to be considered when the transmitted signal is designed. To achieve the desired levels of illumination, dimming control is an essential technology applied in VLC systems. In this paper, the authors proposed a block coding-based dimming scheme to construct the codeword set, where dimming control can be achieved by changing the ratio of two levels (ON and OFF) based on on-off keying (OOK) modulation. Simulation results show that the proposed scheme can maintain good error performance with constant transmission efficiency under various dimming levels.

- Low-Complexity Hybrid Optical OFDM with High Spectrum Efficiency for Dimming Compatible VLC System [10]

In this paper, the authors proposed a novel dimming compatible hybrid optical orthogonal frequency division multiplexing (DCHO-OFDM) method to fulfil the requirements for both communications and illuminations. Explicitly, the signal branch of the unclipped asymmetrically clipped O-OFDM (ACO-OFDM) and the down/upper-clipped pulse-amplitude-modulated discrete multitone (PAM-DMT) are adaptively combined to increase the spectrum efficiency. The chromaticity-shift-free and pulse width modulation (PWM) are adopted for the precisely dimming control, and a time-varying biasing scheme is used to mitigate the non-linear distortion. As the different signal components in DCHO-OFDM are combined in an interference-orthogonal approach, the transmitted symbols can be readily detected by a standard OFDM receiver. The simulation demonstrated that a high spectrum efficiency of the conceived DCHO-OFDM scheme can be achieved with less fluctuation in a wide dimming range.

- Shipborne Acquisition, Tracking, and Pointing Experimental Verifications towards Satellite-to-Sea Laser Communication [11]

Acquisition, tracking, and pointing (ATP) with high precision is a key technology in free space laser communication. In this paper, the authors report the acquisition and tracking of low-Earth-orbit satellites using shipborne ATP and verify the feasibility of establishing optical links between laser

communication satellites and ships in the future. They developed a shipborne ATP system for satellite-to-sea applications in laser communications. The proposed acquisition strategy improves shipborne ATP pointing accuracy. They acquired and tracked some low-Earth-orbit satellites at sea, achieving a tracking accuracy of about 20 μrad. The results achieved in this work experimentally demonstrate the feasibility of ATP in satellite-to-sea laser communications.

3. Future Perspectives

Optics in the information and communication industry has a wide range of applications. It has experienced enormous growth in the past decades. Current communication systems and networks utilize the preeminent property of lightwaves for information transmission. To support the continuous exponential Internet traffic growth for many newly-emerging and unanticipated applications in the future, such as new services in the 5G network, we anticipate that the evolution of optical transmission technology will continue in order to meet the challenge ahead, probably through parallel process and integration [1,12]. On the other hand, many other emerging technologies, such as optical quantum communication and optical computing, promise to provide a number of new services and applications, and possibly to change future information infrastructure significantly [13]. This certainly requires more innovations and breakthroughs in optical signal processing technology.

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