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Introduction to the Photonic Networks and Devices (NETWORKS) Special Issue

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This special issue comprises extended versions of some of the top-scored papers that were presented at the OSA Photonic Networks and Devices (NETWORKS) meeting that was part of the OSA's Advanced Photonics Congress held in Burlingame, USA, July 29 – August 1, 2019. Here, we highlight relevant topics from included papers relating to photonic communication network development.

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As guest editors, it is our pleasure to introduce the special issue dedicated to the Photonic Networks and Devices (NETWORKS) topical meeting, part of the OSA's Advanced Photonics Congress (APC) held in Burlingame, USA, July 29 – August 1, 2019. The goal of the meeting is to facilitate new breakthroughs in photonic communication networks and devices by bringing together researchers from intersecting physical-layer and network management communities.

Novel techniques for building and operating photonic communication networks are needed to address relentless traffic growth coupled with increasing dynamicity and heterogeneity of services that have challenging performance requirements in terms of latency, reliability, and security. Coping with these demands while maintaining good cost-efficiency calls for profound innovation across many domains, including device design, advanced transmission techniques, network architecture and intelligent network management.

To keep ahead of the growing demand for bandwidth, researchers are investigating new transmission bands and combining them with advanced modulation techniques to increase aggregate capacity. This requires careful theoretical and experimental investigation of a host of complex system trade-offs between symbol rates, modulation formats, practical transceiver limitations, physical-layer impairments, and cost. For example, for SNR-limited dual-polarization large-constellation QAM transmission, it is well known that as the channel symbol rate is increased, the number of required transceivers to cover the transmission window is reduced but the overall capacity is reduced as well. The ability to accurately model and experimentally quantify such effects can help guide the design and better assess cost and complexity considerations in the planning and deployment of future high-capacity transmission systems.

Alternative communications techniques may also be considered for certain wide-band cost-constrained systems. For example, spectrally-sliced broadband sources may be used to achieve high data rates, but such systems employing simple intensity modulation formats such as on-off keying using low-cost transmitters with limited modulation extinction ratio can be plagued by high error floors and poor performance due to non-Gaussian noise statistics. However, given recent theoretical and experimental investigation that provides new insights into spectrally-sliced communications performance, such impairments can be avoided by using straightforward polarization modulation techniques that may make these transmission schemes more viable.

Support of high-performance services is accompanied by the development of flexible and reconfigurable network architectures. However, the demands of high-performance computing applications often surpass the interconnection capabilities of existing solutions that rely on static network topologies and are unable to accommodate unbalanced spatially-varying traffic demands. Therefore, datacenter solutions that enable full flexibility using a combination of commercial electrical packet and optical circuit switches for faster flow completion may offer significant performance benefits.

Besides having strong implications for datacenter network architecture, network segments closest to the end users are also significantly affected by the ongoing network evolution. The parallelism introduced by space division multiplexing (SDM) combined with analog radio-over-fiber (RoF) solutions can alleviate the bandwidth and latency requirements critical for 5G fronthaul solutions. Advanced software solutions for network slicing, achieved by network function virtualization and orchestration, in concert with Software Defined Networking (SDN) control, can enable full utilization of the potential of the SDM-RoF-based architecture.

Virtualization also plays a key role in enabling multi-service operation of passive optical networks (PONs) in true multi-tenant environments. Virtual dynamic bandwidth allocation (DBA) can allow the different tenants sharing a PON to precisely schedule their capacity and can support the 5G applications that require sub-millisecond latency. For latency-critical applications such as human-to-machine

interactions that require haptic feedback for the Tactile Internet, low-latency performance can also be enhanced through intelligent bandwidth allocation based on machine learning. As application of these techniques proliferates, deep insights into their comparative performance, benefits and drawbacks are necessary to make informed design choices and steer the development of future high-performance networks.

The challenges posed to modern photonic communication networks also include the need for verifiable security-enhancing techniques in virtualized environments. Quantum key distribution (QKD), for example, can provide quantum-safe generation of encryption keys at remote locations. In addition to protecting communication confidentiality, QKD can also play an important role in validating traffic flow forwarding across network nodes that host physical or virtual network functions. Such enhancement of existing approaches for proof-of-transit in service function chains has the potential to resolve existing vulnerabilities by using per-hop encryption to capture the order of transit.

The findings related to the above topics were presented in the dynamic environment of the APC NETWORKS meeting that served as a platform for the exchange and enrichment of the ideas, and subsequently extended into the seven papers included in the special issue. We thank the authors for putting the effort into expanding their papers, the expert reviewers for their detailed and knowledgeable feedback, Jane Simmons, the JOCN Editor-in-Chief, for her initiative and support in organizing this special issue, and the JOCN Staff for their assistance. We hope that the diversity of topics and contributions included in this special issue conveys the spirit of the meeting and that the shared findings may inspire new research efforts.

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