JOURNAL OF
Optical Communications
and Networking

Introduction to the ONDM2020 special issue

Ramon Casellas,[1,*] Raul Muñoz,[1] Marija Furdek,[2] Salvatore Spadaro,[3] and Zuqing Zhu[4]

[1]Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Av. Carl Friedrich Gauss n7, Castelldefels, Barcelona, Spain
[2]Chalmers University of Technology, Gothenburg, Sweden
[3]Universitat Politècnica de Catalunya (UPC), Barcelona, Spain
[4]University of Science and Technology of China (USTC), Hefei, Anui, China
*Corresponding author: ramon.casellas@cttc.es

Received 19 April 2021; published 29 April 2021 (Doc. ID 428373)

This JOCN special issue includes extended versions of selected papers that were presented at the *24th International Conference on Optical Network Design and Modeling* (ONDM2020), which took place virtually on May 18–21, 2020. The topics covered by the papers represent clear trends in current optical networking research including filterless optical networks and their applicability in metropolitan scenarios; programmable, software-defined-networking-enabled sliceable bandwidth variable transceivers supporting multi-dimensionality; and two applications of machine learning—the cognitive reconfiguration of data-center networks in support of high-performance computing, and quality of transmission estimation for reduced margins.

https://doi.org/10.1364/JOCN.428373

This JOCN special issue includes extended versions of selected papers that were presented at the *24th International Conference on Optical Network Design and Modeling* (ONDM2020), which took place, virtually, on May 18–21, 2020. As in previous years, ONDM addressed cutting-edge research in established areas of optical networking and communications and its adoption in support of a wide variety of new services and applications. This includes the most recent trends such as new architectures and photonic technologies for 5G and beyond, data-center networking, cloud/edge computing, data analytics, network telemetry and machine learning. ONDM2020 keynote speakers covered the topics of optical FPGAs, the evolution of optical networking, and quantum cryptography. The technical sessions included tutorials on machine learning, quantum networking, telemetry, and 5G slicing, plus 14 invited talks, 27 oral papers, and 11 posters.

The topics covered by the papers in this issue represent clear trends in current research in optical networking including filterless optical networks and their applicability in metropolitan scenarios; programmable, software-defined-networking (SDN)-enabled sliceable bandwidth variable transceivers (S-BVTs) supporting multi-dimensionality; and two applications of machine learning (ML)—the cognitive reconfiguration of data-center (DC) networks in support of high-performance computing (HPC), and quality of transmission (QoT) estimation for reduced margins.

Filterless Networks

Filterless networks potentially offer a low-cost alternative to networks encompassing active switching devices such as reconfigurable optical add/drop multiplexers or wavelength selective switches. Filterless networks are based on a combination of passive optical devices (such as splitters or couplers), interconnectors, advanced transmission systems, and associated routing algorithms. Although the main concepts and initial work on filterless networks date back to the early 2000s, the interest in filterless networks has been renewed in view of their use in 5G metro and x-haul networks. Additionally, supporting bidirectional connections on a single fiber is of interest in the case of scarce fiber availability.

In the paper "Bidirectional single-fiber filterless optical networks: modeling and experimental assessment" by Dimitris Uzunidis *et al.*, the design and validation of a metropolitan network using filterless technology is presented, focusing on the use of a single fiber to support bidirectional transmission, using optical circulators. The paper presents the corresponding node architectures, a methodology to study the physical layer performance, and includes an experimental validation of a portion of the considered horseshoe metro network supporting bidirectional transmission.

Machine Learning

The use of ML in applications related to optical transmission, quality of service validation, fault localization, or in support of network operations is growing, largely due to the benefits of ML approaches (such as deep reinforcement learning) in complex scenarios. Two papers of the special issue fit in this category.

The first application is related to HPC. There has been a significant amount of architectural and experimental research in optical switching and interconnects for DC and HPC systems, aimed at improving metrics such as the scalability and performance of large-scale cloud computing systems, and reducing cost, power consumption, and operational expenses. To a large extent, such works replace (partially or completely) electronic switches, including the use of optical circuit switching where there is a clear benefit in doing so, e.g., in traffic offloading use cases.

The paper "Machine-learning-aided cognitive reconfiguration for flexible-bandwidth HPC and data center networks" by Xiaoliang Chen *et al.*, addresses the use of ML-aided cognitive mechanisms in optical interconnected DCs and HPC scenarios. After formulation of the routing-scheme optimization as a mixed-integer linear programming model and the use of a classical joint optimization and two-phase heuristic, an ML-based end-to-end performance estimator is proposed to assist the network control plane.

Another clear domain of ML applicability is related to the estimation of QoT parameters. Optical network design typically includes the planning of links and the estimation of per-demand metrics such as bit error rate. Despite the availability of advanced tools to compute such values, network operators often add "design margins," thus overengineering the links, to account for factors such as model inaccuracies, lack of detailed data, or equipment aging. Improvement in the accuracy of QoT estimation directly benefits network operators in terms of more efficient capacity utilization. In this regard, the paper "Associating machine-learning and analytical models for quality of transmission estimation: combining the best of both worlds" by Emmanuel Seve *et al.* associates ML with the Gaussian Noise model, to reduce uncertainties in the output power profile and noise figure of each amplifier. The learning process is based on a gradient-descent algorithm where all of the uncertain input parameters of the analytical model are iteratively modified from their estimated values to match with the signal-to-noise ratio of lightpaths, achieving design margin reductions to 0.1 dB for new traffic demands.

Sliceable Bandwidth-Variable Transceivers

In optical networking, partial disaggregation refers to the decoupling of the transceivers and of the (open) line system, so that operators have greater flexibility with respect to equipment deployment, resulting in benefits in cost, efficiency, flexibility, and programmability. Disaggregation is a common scenario for SDN and data-model developments.

In this context, SDN-enabled S-BVTs are proposed for metro networks to provide sustainable capacity growth. In the paper "Programmable disaggregated multi-dimensional S-BVT as an enabler for high capacity optical metro networks" by Laia Nadal *et al.*, transceiver multi-dimensionality is presented, exploiting spatial, polarization, and spectral information as a solution to support network capacity and bandwidth scaling for 5G requirements. In this work, multi-band transmission is assessed by exploiting the C-band and L-band. The paper analyzes and experimentally demonstrates different S-BVT advanced functionalities, including rate/distance adaptability, programmability/configurability, disaggregation, and multi-dimensionality. Different network scenarios have been considered to assess the S-BVT functionalities, enabling Tb/s optical transmission.