Introduction to the JOCN Special Issue on Optimized and AI/ML Enabled Future Optical Networks

Citation for the original published paper (version of record):
Zhu, Z., Wosinska, L., Kilper, D. (2025). Introduction to the JOCN Special Issue on Optimized and AI/ML Enabled Future Optical Networks. Journal of Optical Communications and Networking, 17(10): FON1-FON2. http://dx.doi.org/10.1364/JOCN.579867

(article starts on next page)

JOURNAL OF
Optical Communications and Networking

Introduction to the JOCN Special Issue on Optimized and AI/ML Enabled Future Optical Networks

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Received 22 September 2025; published 1 October 2025

This special issue contains a collection of extended papers presented at the Future Optical Networks and Communications (FONC) Symposium in the IEEE Future Network World Forum (FNWF), 15–17 October 2024, Dubai, UAE, as well as papers from the open call. We present a brief introduction followed by an overview of the topics covered in the papers.

https://doi.org/10.1364/JOCN.579867

Optical networks are a vital part of the global digital infrastructure. They offer ultra-high capacity transmission supporting new and emerging online services, future generations of mobile communications and cloud computing, and critical government services.

Traditionally, optical network management has been a largely manual and reactive process. Network operators have relied on systems that use static, pre-defined thresholds on performance parameters to trigger alarms. This process is relatively slow, complex, and prone to human error. As optical networks grow in scale, complexity, and dynamicity to meet the demands of next-generation online services, these conventional methods become increasingly inadequate.

The limitations of traditional approaches are leading to a paradigm shift towards automation of network operations. Artificial intelligence (AI) and machine learning (ML) have emerged as the key enablers to revolutionize optical network management and control. Modern optical network equipment is now fitted with sophisticated monitoring capabilities, generating enormous volumes of telemetry data. ML algorithms are uniquely suited to learn from this vast amount of historical and real-time data, identifying complex patterns, correlations, and anomalies that are invisible to human operators and static rule-based systems.

In this special issue, we include five papers that were extended from the conference papers presented at the Future Optical Networks and Communications (FONC) Symposium in the IEEE Future Network World Forum (FNWF) 2024 as well as papers from the open call.

In the first contribution entitled "Multi-task localization based on Φ-OTDR: composite vibration recognition, synchronous localization, and co-trench position," the authors propose a Φ-OTDR-based multi-task localization framework integrating composite vibration event recognition, synchronous localization, and co-trench position detection.

In the second contribution entitled "OpenNOP: an open source network observability platform enabling multi-vendor multi-layer monitoring and ML analysis," the authors introduce OpenNOP, an open-source, multi-layer, and multi-vendor observability platform designed for fault detection, configuration tracking, and performance monitoring.

In the third contribution entitled "Reinforcement learning-based complex-valued space-time MIMO 2D-LSTM nonlinear equalizer for photonics-assisted THz indoor optical wireless access networks," the authors propose a complex-valued space-time multiple-input multiple-output two-dimensional long short-term memory neural network (ST-MIMO 2D-LSTM) equalizer that can simultaneously process the polarization division multiplexed signals.

In the fourth contribution entitled "Performance investigation on disaggregated artificial intelligence data centers beyond rack scale with optical switching," the authors investigate exploiting optical switching in a resource disaggregated AI data center.

The fifth contribution entitled "Toward scalable passive optically powered fronthaul networks" focuses on the power-enabled optical fronthaul design (POFD) problem. The authors propose two comprehensive heuristic-based approaches and benchmark their performance against clustering-based methods such as k-means clustering and genetic algorithms to address new challenges in designing efficient and cost-effective fronthaul networks.

In the sixth contribution entitled “Multi-entity cooperation platform facilitating network-cloud recovery,” the authors experimentally demonstrate a proof-of-concept DLT-based MCP on a testbed. They showcase a DCP-carrier cooperative planning process, and the corresponding recovery in the data plane shows the possibility of multi-entity cooperation for quick recovery of network-cloud ecosystems.

In the seventh contribution entitled “Cost-effective and reliable multi-period optical network planning comparing capacity and topology upgrades,” the authors investigate cost-effective and reliable multi-period planning of optical networks meeting the expected demand increase. Three planning optimization approaches are proposed and compared: spatial division multiplexing using the C-band (SDM-CB), ultra-wideband transmission in the C + L bands (UWB-MB), and topology upgrade (TopUp-CB).

In the eighth contribution entitled “Explainable AI-assisted low-latency haptic feedback prediction for human-to-machine applications over passive optical networks,” the authors study human-to-machine applications, such as robotic teleoperation, which require ultra-low latency for real-time interaction. To reduce latency while preserving predictive performance, this paper proposes an eXplainable AI-assisted (XAI) low-latency haptic feedback prediction framework, using XAI for feature selection, reducing inference time.

In the ninth contribution entitled “Generalized few-shot transfer learning architecture for modeling the EDFA gain spectrum,” the authors propose a generalized few-shot transfer learning architecture based on a semi-supervised self-normalizing neural network (SS-NN) that leverages internal EDFA features, such as VOA input/output power and attenuation, to improve the gain spectrum prediction.

In the tenth contribution entitled “DRAMA-PRO+: disaster recovery algorithm with mitigation awareness for protected translucent elastic optical networks,” the authors consider multi-class traffic that includes a mix of protected and unprotected lightpaths and allow lightpaths to be recovered with degraded service with an appropriate penalty by leveraging the concept of a mitigation zone introduced in previous work.

In the eleventh contribution entitled “Supervised and unsupervised learning for classifying changes in optical time-domain reflectometer traces,” the authors demonstrate the effectiveness of supervised and unsupervised learning models in accurately categorizing changes observed in in-service OTDR traces.

In the twelfth contribution entitled “Incremental planning with dual-fiber distributed Raman amplification in (C + L + S) networks,” the authors investigate the benefits of selectively upgrading a subset of the fiber spans with an additional fiber, which makes it possible to separate spectrum bands and apply dual-fiber distributed Raman amplification (DF-DRA) in a C + L + S system.

In the thirteenth contribution entitled “Confidentiality-preserving real-time localization of soft failures in optical networks based on PCA and MLaaS,” the authors propose a method exploiting machine learning as a service (MLaaS), limiting data exchange, and guaranteeing monitored data confidentiality for soft failure localization in optical networks.

Guest Editors:
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