Series Editorial
The Fourth Issue of the Series on Machine Learning in Communications and Networks

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I. Introduction

THE third call for papers of the Series on Machine Learning in Communications and Networks has continued to receive a great number of high-quality papers covering various aspects of intelligent communications, from which we have included 26 original contributions in this issue. In the following, we provide a brief review of key contributions of papers in this issue according to their topics.

II. Invited Papers

In the invited paper [A1], Letaief *et al.* explore the scalable and trustworthy edge artificial intelligence for 6G. It puts particular focus on the new design principles, service-driven resource allocation, end-to-end structure, implementations, and standardization of edge AI communication systems.

III. Signal Processing

This issue consists of six papers that address various problems in signal processing using machine learning. In [A2], Hussain and Michelusi provide an approach for beam training technique in mm-Wave systems with low overhead. Specifically, a dual-timescale design framework is adopted where the long-timescale corresponds to a frame duration while the short-timescale corresponds to a slot duration. It has been verified that the proposed design outperforms the benchmarks significantly. In [A3], Wu *et al.* propose a neural network to compensate for the non-linearity of the power amplifier and in-phase and quadrature imbalance. The proposed architecture uses a novel design providing a shortcut for the input. Weight punning is used to trade-off the computational complexity and accuracy. The authors also provide effective pruning methods for the proposed neural network structure. In [A4], Zhang *et al.* propose a novel unfolding-based framework for MIMO detectors, which can automatically determine internal parameters of an unfolding-based MIMO detector to adapt to the varying conditions. The proposed design is verified to be effective by both the simulation and experiments. In [A5], Hanna *et al.* deal with the blind symbol decoding and modulation classification. To exploit the interpretability of digital signal processing and the power of deep learning to solve the complex problem, a dual path network is proposed. It is demonstrated that the proposed design outperforms the state-of-the-art methods. In [A6], Zhang *et al.* propose an efficient residual soft-thresholding convolution network aided denoiser for modulation recognition, detection, and decoding. The proposed design outperforms benchmarks but with lower complexity. In [A7], Bai *et al.* propose a novel deep learning (DL)-based framework for grant-free non-orthogonal multiple access (GF-NOMA). It utilizes the information distilled from the initial data recovery phase to further enhance channel estimation, which in turn improves data recovery performance. Besides, it develops an interpretable and structured Model-driven Prior Information Aided Network (M-PIAN) and demonstrates that the proposed M-PIAN converges faster and supports more users.

IV. Learn to Transmit and Semantic Communications

There are six papers in the category of learn to transmit and receive. In [A8], Fozi *et al.* develop a deep reinforcement learning-based approach for fast beamforming in mmWave MIMO channels in millimeter vehicular communications. Reinforcement learning is leveraged to maximize the network's energy efficiency subject to the quality-of-service (QoS) constraint for each user equipment (UE) and obtain its hybrid beamforming matrices. In [A9], Huang *et al.* describe a mechanism to multiplex ultra-reliable low-latency communications (URLLC) traffic with enhanced mobile broadband (eMBB) traffic. To achieve this, the authors propose a novel deep-learning-based modulation and coding selection (MCS) scheme for link adaptation of eMBB users. In [A10], Hu *et al.* develop an end-to-end deep learning-based joint transceiver design algorithm for millimeter-wave massive multiple-input multiple-output systems, comprising deep neural network (DNN)-aided pilot training, channel feedback, and hybrid precoding. A novel two-timescale training method is also developed for the proposed DNN with a binary layer. Simulation results show that the proposed technique significantly outperforms conventional schemes in terms of bit-error-rate performance with less signaling overhead and shorter pilot sequences. In [A11], Zhong *et al.* provide a deep learning approach and a reinforcement learning approach to maximize the effective throughput of a reconfigurable intelligent surface-assisted multiuser downlink communication system,

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where both non-orthogonal multiple access (NOMA) and orthogonal multiple access (OMA) schemes are employed. The representative superiority and inferiority of both approaches are investigated and compared. In [A12], Shao *et al.* investigate task-oriented communication for edge inference, where a low-end edge device transmits the extracted feature vector of a local data sample to a powerful edge server for processing. The learning-based communication scheme in the paper jointly optimizes feature extraction, source coding, and channel coding in a task-oriented manner, i.e., targeting the downstream inference task rather than data reconstruction. Extensive experiments show that the proposed task-oriented communication system achieves a better rate-distortion trade-off than baseline methods and significantly reduces the feature transmission latency in dynamic channel conditions. In [A13], Luong *et al.* investigate deep-learning-aided optical orthogonal frequency division multiplexing (O-OFDM) for intensity-modulated direct detection transmissions. It employs deep neural networks (DNNs) for converting a complex-valued signal into a non-negative signal in the time-domain at the transmitter and vice versa at the receiver. The simulation results show that the scheme improves both the uncoded and coded bit-error rate as well as reducing the peak-to-average power ratio compared to the benchmarks at the cost of a moderate additional DNN complexity.

V. Resource Management and Network Optimization

We have four papers in this issue that deal with resource management and network optimization using machine learning techniques. In [A14], Sun *et al.* discuss the over-the-air federated edge learning system with analog gradient aggregation. To optimize the training performance under energy constraints of devices, the energy-aware dynamic device scheduling algorithm in the paper could improve the accuracy by 4.9% while satisfying the energy constraints. In [A15], Chen *et al.* optimize the information freshness-aware task offloading in an air-ground integrated MEC system. The interactions among the noncooperative multi-users across the infinite time-horizon are formulated as a stochastic game, then an online deep reinforcement learning scheme, which maintains two separate DQNs for each MU to approximate the Q-factor and the post-decision Q-factor, is derived. In [A16], Xu *et al.* propose a novel smart reconfigurable THz MIMO-NOMA framework, which can realize customizable and intelligent communications by flexibly and coordinately reconfiguring hybrid beams through the cooperation between access points (APs) and reconfigurable intelligent surfaces (RISs). The novel multi-agent deep reinforcement learning (MADRL) algorithm, namely, graph-embedded value-decomposition actor-critic (GE-VDAC), embeds the interaction information of agents, and learns a locally optimal solution through a distributed policy. In [A17], Tang *et al.* propose a reinforcement learning-based traffic offloading strategy for space-air-ground integrated networks (SAGIN). A double Q-learning algorithm with delay-sensitive replay memory is developed for offloading decisions. A joint information gathering algorithm is proposed to assist traffic offloading.

VI. Distributed/Federated Learning and Communications

Five papers in this issue study distributed or federated learning (FL) in communications and networks. In [A18], Wei *et al.* minimize federated learning training delay over wireless channels, constrained by overall training performance as well as each client's differential privacy requirement. The problem is solved in the framework of multi-agent multi-armed bandit to deal with the situation where there are multiple clients' confronting different unknown transmission environments. In [A19], Wang *et al.* consider the problem of achieving the best trade-off between quality-of-experience (QoE) maximization and consumed energy minimization in live streaming applications in wireless edge networks. A combination of state-of-the-art methods in the machine learning literature, namely, Soft-Actor Critic (SAC) reinforcement learning agents and the attention-based transformer architecture, is leveraged to address the problem by optimizing the streamer's encoding bitrate, the uploading power, and the edge transcoding bitrates and frequency. It is shown, via numerical results, that the proposed method significantly outperforms the baseline state-of-the-art approaches. In [A20], Wang *et al.* study federate learning in a non-ideal wireless channel considering quantization error (QE) and transmission outage (TO). Since the FL convergence can be severely jeopardized by TO and QE, a robust FL scheme, named FedTOE, performs joint allocation of wireless resources and quantization bits across the clients to minimize the QE while making the clients have the same TO probability. In [A21], Cao *et al.* propose a transmission power control policy to combat against the aggregation error in over-the-air federated edge learning (Air-FEEL) that maximizes the convergence speed, considering the aggregation errors at different communication rounds.

In [A22], Ng *et al.* consider a three-layer federated learning (FL) framework that addresses the straggler problem using coded FL. To optimize the system performance, the evolutionary game and deep-learning-based auction are leveraged to dynamically select data owners and FL workers.

VII. Selected Topics

We have four papers in this issue using machine learning to deal with various issues in communications that do not fall into the above categories. In [A23], Zheng *et al.* develop a teacher–student reinforcement deep-learning framework, where domain-specific knowledge is leveraged to enhance robustness. Confidence check, reward shaping, and prioritized experience replay are included in the proposed method. The experiments are conducted on video streaming, load balancing, and TCP congestion control issues. The standard deviation is reduced while the tail performance is increased. In [A24], Mou *et al.* study the self-healing problem of unmanned aerial vehicle (UAV) swarm network (USNET) required to rebuild the communication connectivity under unpredictable external disruptions (UEDs). To cope with the on-off UEDs, it proposes a graph convolutional neural network (GCN) and finds the recovery topology of the USNET in an online manner. To cope with general UEDs, the GCN-based trajectory planning algorithm in the paper can make UAVs rebuild the communication connectivity during the self-healing process. A meta-learning scheme has been developed to facilitate the online executions of the GCN. In [A25], Wang *et al.* design a novel dynamic expertise-aware truth inference and task allocation in a spatial crowdsensing system, which can unify truth discovery for both numerical and categorical tasks. In particular, task allocation collects observations that serve as the raw inputs for truth inference while truth inference estimates worker expertise and task truth that are involved in task allocation. By designing the inference algorithm and allocation scheme in a coupled manner, the paper provides a new and comprehensive framework for collecting high-quality sensing data so as to mutually improve the accuracy of inferred results. The main contribution of [A26] by Tang *et al.* is a real-time framework for detection and mitigation of Low-rate Denial of Service (LDoS) attacks in software-defined networking (SDN). The proposed approach classifies the features of LDoS into two categories: Attack-Performance (P) and Attack-Features(F). By analyzing the performance of normal traffic under attack state, the proposed method determines whether LDoS attacks take effect based on machine learning. The developed approach is implemented on the SDN controller. The offline-data detection experiment and the online attack mitigation experiment are conducted to evaluate the defense system.

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Finally, we wish the contents of our series will inspire the readers to investigate the challenging and open problems in the field of machine learning in communications.

APPENDIX: RELATED ARTICLES

[A1] K. B. Letaief, Y. Shi, J. Lu, and J. Lu, "Edge artificial intelligence for 6G: Vision, enabling technologies, and applications," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126076.

[A2] M. Hussain and N. Michelusi, "Learning and adaptation for millimeter-wave beam tracking and training: A dual timescale variational framework," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126086.

[A3] Y. Wu, U. Gustavsson, A. G. I. Amat, and H. Wymeersch, "Low complexity joint impairment mitigation of I/Q modulator and PA using neural networks," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126024.

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[A11] R. Zhong, Y. Liu, X. Mu, Y. Chen, and L. Song, "AI empowered RIS-assisted NOMA networks: Deep learning or reinforcement learning?" *IEEE J. Sel. Areas Commun.*, early access, Nov. 25, 2021, doi: 10.1109/JSAC.2021.3126068.

[A12] J. Shao, Y. Mao, and J. Zhang, "Learning task-oriented communication for edge inference: An information bottleneck approach," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126087.

[A13] T. Van Luong *et al.*, "Deep learning-aided optical IM/DD OFDM approaches the throughput of RF-OFDM," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126080.

[A14] Y. Sun, S. Zhou, Z. Niu, and D. Gunduz, "Dynamic scheduling for over-the-air federated edge learning with energy constraints," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126078.

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[A24] Mou *et al.*, "Resilient UAV swarm communications with graph convolutional neural network," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126047.

[A25] Wang *et al.*, "Online spatial crowdsensing with expertise-aware truth inference and task allocation," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126045.

[A26] Tang *et al.*, "Performance and features: Mitigating the low-rate TCP-targeted DoS attack via SDN," *IEEE J. Sel. Areas Commun.*, early access, Nov. 13, 2021, doi: 10.1109/JSAC.2021.3126053.