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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

The invited paper, "Edge Artificial Intelligence for 6G: Vision, Enabling Technologies, and Applications" by Letaief *et al.*, explores 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. The paper, "Learning and Adaptation in Millimeter-Wave Networks: A Dual Timescale Variational Framework" by Hussain *et al.*, provides 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. The paper, "Low Complexity Joint Impairment Mitigation of I/Q Modulator and PA Using Neural Networks" by Wu *et al.*, proposes a neural network to compensate for 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 tradeoff the computational complexity and accuracy. The authors also provide effective pruning methods for the proposed neural network structure. The paper, "Adaptive MIMO Detector Based on Hypernetwork: Design, Simulation, and Experimental Test" by Zhang *et al.*, proposes 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. The paper, "Signal Processing Based Deep Learning for Blind Symbol Decoding and Modulation Classification" by Hanna *et al.*, deals with the blind symbol decoding and modulation classification. To exploit the interpretability of digital signal processing and 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 the paper "Efficient Residual Soft-Thresholding CNN Denoiser Design for Intelligent Signal Processing: Modulation Recognition, Detection and Decoding", 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. The paper, "Prior Information Aided Deep Learning Method for Grant-free NOMA in mMTC" by Bai *et al.*, proposes 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. The paper, "Fast MIMO Beamforming via Deep Reinforcement Learning for High Mobility Communications" by Fozi *et al.*, develops 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. The paper, "DELUXE: A DL-based Link Adaptation for URLLC/eMBB Multiplexing in 5G NR" by Huang *et al.*, describes 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. The paper, "Two-Timescale End-to-End Learning for Channel Acquisition and Hybrid Precoding" by Hu *et al.*, develops

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 the paper "AI Empowered RIS-Assisted NOMA Networks: Deep Learning or Reinforcement Learning?" by Zhong *et al.*, a deep learning approach and a reinforcement learning approach are provided to maximize the effective throughput of a reconfigurable intelligent surfac -assisted multiuser downlink communication system, 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. The paper, "Learning Task-Oriented Communication for Edge Inference: An Information Bottleneck Approach" by Shao *et al.*, investigates 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 a 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 tradeoff than baseline methods and significantly reduces the feature transmission latency in dynamic channel conditions. The paper, "Deep Learning-Aided Optical IM/DD OFDM Approaches the Throughput of RF-OFDM" by Luong *et al.*, investigates 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. The paper, "Dynamic Scheduling for Over-the-Air Federated Edge Learning with Energy Constraints" by Sun *et al.*, discusses 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. The paper, "Information Freshness-Aware Task Offloading in Air-Ground Integrated Edge Computing Systems" by by Chen *et al.*, optimizes the information freshness-aware task offloading in an air-ground integrated MEC system. The interactions among the noncooperative multiusers 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 the paper "Graph-Embedded Multi-Agent Learning for Smart Reconfigurable THz MIMO-NOMA Networks", 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 the paper "A Deep Reinforcement Learning based Dynamic Traffic Offloading In Space-Air-Ground Integrated Networks (SAGIN)" by Tang *et al.*, a reinforcement learning based traffic offloading strategy for space-air-ground integrated networks (SAGIN) is proposed. A double Q-learning algorithm with delay-sensitive replay memory is developed for offloading decision. A joint information gathering algorithm is proposed to assist the traffic offloading.

VI. Distributed/Federated Learning and Communications

Five papers in this issue study distributed or federated learning (FL) in communications and networks. In the paper, "Low-Latency Federated Learning over Wireless Channels with Differential Privacy", 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. The paper, "Deep Reinforcement Learning with Communication Transformer for Adaptive Live Streaming in Wireless Edge Networks" by Wang *et al*, considers 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. The paper, "Quantized Federated Learning under Transmission Delay and Outage Constraints" by Wang *et al.*, studies federate learning in a non-ideal wireless channels 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. The paper, "Optimized Power Control Design for Over-the-Air Federated Edge Learning" by Cao *et al.*, proposes 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 the paper, "A Hierarchical Incentive Design Towards Motivating Participation in Coded Federated Learning", 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. The paper "Enabling Robust DRL-driven Networking Systems via Teacher-Student Learning " by Zheng *et al.* develops 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 in video streaming, load balancing, and TCP congestion control issues. The standard deviation is reduced while the tail performance is increased. The paper, "Resilient UAV Swarm Communications with Graph Convolutional Neural Network" by Mou *et al.*, studies 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 on-line 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 on-line executions of the GCN. In the paper, "Online Spatial Crowdsensing with Expertise-aware Truth Inference and Task Allocation", 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 paper "Performance and Features: Mitigating the Low-Rate TCP-targeted DoS Attack via SDN" by Tang *et al.* is 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.