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

Geoffrey Y. Li, *Fellow, IEEE*, Walid Saad, Ayfer Ozgur, Peter Kairouz, Zhijin Qin, Jakob Hoydis, Zhu Han, Deniz Gunduz, and Jaafar Elmirghani

I. Introduction

The fourth 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 16 original contributions in this issue. In the following, we provide a brief review of these papers according to their topics.

II. Signal Processing

This issue consists of three papers that address various problems in signal processing using machine learning. In [A1], Yang *et al.* adopt the dynamic neural network into wireless communications systems, which allocates different samples with computation resources based on dynamic inferences. It is shown to reduce the redundant computational cost and enhance network efficiency. Over-the-air tests are conducted to validate the effectiveness of the proposed detectors in practical systems. In [A2], Guo *et al.* propose a data-hiding-based channel state information (CSI) feedback framework, namely, EliCsiNet, to eliminate the CSI feedback overhead in frequency division duplexing systems. The key is to hide or superimpose CSI in the transmitted messages (e.g., images) with no transmission resource occupation and few effects on message semantics. The simulation results demonstrate that the proposed EliCsiNet framework can eliminate the CSI feedback overhead with few effects on the feature properties of transmitted images, including image quality and bit length. In [A3], Xiao *et al.* develop a novel physics-inspired generative approach to predict the static channel impulse response with only the user's position information and a set of channel instances obtained within a certain wireless communication environment. Key performance measures, including prediction accuracy, convergence speed, network scale, and robustness to channel estimation error, are evaluated, showing the proposed network is efficient in representing, learning, and predicting wireless channels in a given communication environment.

Geoffrey Y. Li and Deniz Gunduz are with the Department of Electrical and Electronic Engineering, Imperial College London, London SW7 2BT, U.K. (e-mail: geoffrey.li@imperial.ac.uk).

Walid Saad is with the Electrical and Computer Engineering Department, Virginia Tech, Blacksburg, VA 24060 USA.

Ayfer Ozgur is with the Department of Electrical Engineering, Stanford University, Stanford, CA 94305 USA.

Peter Kairouz is with Google AI, Mountain View, CA 94043 USA.

Zhijin Qin is with the School of Electronic Engineering and Computer Science, Queen Mary University of London, London E1 4NS, U.K.

Jakob Hoydis is with NVIDIA Research, 06906 Sophia Antipolis, France.

Zhu Han is with the Electrical and Computer Engineering Department, University of Houston, Houston, TX 77004 USA.

Jaafar Elmirghani is with the School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, U.K.

Digital Object Identifier 10.1109/JSAC.2022.3181863

III. Learn to Transmit and Semantic Communications

There are three articles in the category of learn to transmit and semantic communications. In [A4], Dai *et al.* study deep-learning-aided joint source-channel coding for context-aware semantic communications. Specifically, the system design is formulated as an optimization problem whose goal is to minimize the end-to-end transmission rate-distortion performance under established perceptual quality metrics. In [A5], Liu *et al.* investigate integrated sensing and communication in vehicular networks and develop a data-driven learning approach to design predictive beamforming to maximize the sum-rate while ensuring sensing performance. In [A6], Wang and Zhang develop a model-free design of intelligent reflecting surface control that is independent of the sub-channel channel state information. The authors leverage deep reinforcement learning and extreme seeking control to perform real-time coarse phase control and fine phase control. The numerical results demonstrate the superiority of the proposed scheme.

IV. Resource Management and Network Optimization

We have three articles in this issue that deal with resource management and network optimization using machine learning techniques. In [A7], Wang *et al.* formulate the dynamic resource configuration provided by the hybrid edge server provision under two decentralized task migration schemes as an online cost minimization problem, and a mean-field learning approach is proposed to solve it. The numerical results show that the mean-field model significantly improves the convergence speed. In [A8], Wang *et al.* investigate federated learning over a multi-cell wireless network, where each cell performs a different federated learning task and over-the-air computation (AirComp) is adopted to enable fast uplink gradient aggregation. The results demonstrate that the proposed algorithm achieves much better average learning performance over multiple cells than non-cooperative baseline schemes. In [A9], Wang *et al.* formulate the link-level slice enforcement as a resource allocation problem that maximizes throughput while ensuring link-level soft slice isolation, guaranteeing users' diverse requirements, and conforming to slicing policies. The formulated problem is solved by deep reinforcement learning, and shown to improve system throughput while gracefully tackling the main challenges of network slice enforcement.

V. Distributed/Federated Learning and Communications

Three articles in this issue study distributed or federated learning in communications and networks. In [A10], Guo *et al.* study the joint device selection and power control scheme for wireless federated learning, considering both the downlink and uplink communications. The proposed method enables the model aggregation weights to be directly determined by the uplink transmit power values of the selected devices, which facilitates the joint learning and communication optimization simply by the device selection and power control. In [A11], Wang *et al.* present an online preemptive scheduling framework to dispatch machine learning jobs to workers and parameter servers to minimize the average job completion time. The authors prove that the proposed algorithm achieves a bounded competitive ratio with speed augmentation. Both trace-driven simulations and testbed experiments are performed to evaluate the proposed solution. In [A12], Zhu *et al.* propose a learning auction mechanism for resource allocation in code distributed computing. Multiple personalized models are learned simultaneously to address the challenges such as communication efficiency and heterogeneity of the users.

VI. Selected Topics

We have four articles in this issue using machine learning to deal with various issues in communications that do not fall into the above categories. In [A13], Zhang *et al.* propose an unsupervised KPI anomaly detection approach, named AnoTransfer, by combining a novel variational auto-encoder (VAE)-based KPI clustering algorithm with an adaptive transfer learning strategy. Extensive evaluation experiments using real-world data collected from several large-scale Web service providers demonstrate that AnoTransfer reduces the average initialization time by 65.71% and improves the training efficiency by 50.62 times, without significantly degrading anomaly detection accuracy. In [A14], Knofczynski *et al.* propose ARISE, a multi-task weak supervision framework for network measurements. ARISE adopts the use of weak supervision-based data programming strategies to label vast quantities of network measurements. The proposed framework can address practical networking issues and demonstrates the advantages of multi-task learning models in convergence and learning performance. In [A15], Wang *et al.* develop a sensitivity-aware algorithm to address the conflict between the limited network bandwidth and high accuracy demand for live video analytics. It incorporates sensitivity into the design of spatial quality adaptation, including video zoning and quality selection. Extensive experiments show that the proposed algorithm improves accuracy by up to 14.1% with comparable bandwidth usage or reduces bandwidth usage by up to 44.2% while maintaining higher accuracy compared to baselines. In [A16], Huang *et al.* propose a method called A2BR, which uses two reinforcement learning (RL) technologies, i.e., meta-RL as well as offline safety-RL, to construct an adaptive bit rate algorithm for video streaming scenarios. The simulation results show that A2BR rapidly adapts to the personalized and specific network conditions, outperforming recent schemes in terms of video bitrate, stall ratio and quality-of-experience metric.

Acknowledgment

The authors would like to express their gratitude to all authors for their submissions and over 400 anonymous reviewers for their insightful reviews within a short period of time which have helped maintain the high quality of the Series. The authors would also like to thank Prof. Robert Schober (Past IEEE ComSoc VP for Publications), Prof. Raouf Boutaba [Past EiC of the IEEE Journal on Selected Areas in Communications (JSAC)], and Prof. Petar Popovski (the EiC of the IEEE JSAC) for their support and guidance. Finally, the authors would like to acknowledge their series editorial board for their diligent work during the review and decision process. The editorial board of the authors' series is as follows.

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

Appendix: Related Articles

[A1] Y. Yang, F. Gao, M. Wang, J. Xue, and Z. Xu, "Dynamic neural network for MIMO detection," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180794.

[A2] J. Guo, C. K. Wen, and S. Jin, "Eliminating CSI feedback overhead via deep learning-based data hiding," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180806.

[A3] Z. Xiao, Z. Zhang, C. Huang, X. Chen, C. Zhong, and M. Debbah, "C-GRBFnet: A physics-inspired generative deep neural network for channel representation and prediction," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180800.

[A4] J. Dai *et al.*, "Nonlinear transform source-channel coding for semantic communications," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180802.

[A5] C. Liu *et al.*, "Learning-based predictive beamforming for integrated sensing and communication in vehicular networks," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180803.

[A6] W. Wang and W. Zhang, "Intelligent reflecting surface configurations for smart radio using deep reinforcement learning," *IEEE J. Sel. Areas Commun.*, early access, Jun. 10, 2022, doi: 10.1109/JSAC.2022.3180787.

[A7] Z. Wang, J. Ye, and J. C. S. Lui, "Towards large-scale hybrid edge server provision: An online mean field learning approach," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180781.

[A8] Z. Wang, Y. Zhou, Y. Shi, and W. Zhuang, "Interference management for over-the-air federated learning in multi-cell wireless networks," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180799.

[A9] T. Wang, S. Chen, Y. Zhu, A. Tang, and X. Wang, "LinkSlice: Fine-grained network slice enforcement based on deep reinforcement learning," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180776.

[A10] W. Guo, R. Li, C. Huang, X. Qin, K. Shen, and W. Zhang, "Joint device selection and power control for wireless federated learning," *IEEE J. Sel. Areas Commun.*, early access, Jun. 10, 2022, doi: 10.1109/JSAC.2022.3180807.

[A11] N. Wanng, R. Zhou, L. Jiao, R. Zhang, B. Li, and Z. Li, "Preemptive scheduling for distributed machine learning jobs in edge-cloud networks," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180772.

[A12] K. Zhu, J. Liang, J. Li, and C. Yi, "Coded distributed computing with predictive heterogeneous user demands: A learning auction approach," *IEEE J. Sel. Areas Commun.*, early access, Jun. 13, 2022, doi: 10.1109/JSAC.2022.3180811.

[A13] S. Zhang *et al.*, "Efficient KPI anomaly detection through transfer learning for large-scale web services," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180785.

[A14] J. Knofczynski, R. Durairajan, and W. Willinger, "ARISE: A multitask weak supervision framework for network measurements," *IEEE J. Sel. Areas Commun.*, early access, Jun. 8, 2022, doi: 10.1109/JSAC.2022.3180783.

[A15] W. Wang, B. Wang, L. Zhang, and H. Huang, "Sensitivity-aware spatial quality adaptation for live video analytics," *IEEE J. Sel. Areas Commun.*, early access, Jun. 10, 2022, doi: 10.1109/JSAC.2022.3180801.

[A16] T. Huang, C. Zhou, R.-X. Zhang, C. Wu, and L. Sun, "Learning tailored adaptive bitrate algorithms to heterogeneous network conditions: A domain-specific priors and meta-reinforcement learning approach," *IEEE J. Sel. Areas Commun.*, early access, Jun. 15, 2022, doi: 10.1109/JSAC.2022.3180804.