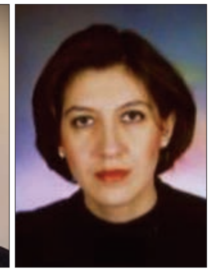
Artificial Intelligence and Data Science for Communications





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Welcome to the July issue of the Artificial Intelligence and Data Science for Communications Series of *IEEE Communications Magazine*. The Series continues its growth in popularity among academicians, researchers, and practitioners, as well as its increase in diversity in the topics it handles that relate to theory and applications of artificial intelligence (AI) and machine learning (ML) techniques to many communications systems and network domains. Due to the abundant availability of data, and the continued development and refinement of AI and ML techniques to process this data, AI and ML have established themselves as practical and viable approaches to provide efficient and practical solutions to many of the challenges in tethered and untethered communications environments at different scales and in different domains.

This issue includes three articles that have been reviewed and approved for publication by experts in their respective fields. The first article deals with federated learning (FL) and how to optimize FL at the client side. The second article addresses how network architectures can better support ML. The third and final article applies AI at the physical layer in order to deal with nonlinearities arising in multiple-input multiple-output (MIMO) channel models due to the use of one-bit analog-to-digital converters.

FL is a privacy preserving distributed ML technique in which training is performed by several devices. In the first article, "Client-Side Optimization Strategies for Communication-Efficient Federated Learning" by J. Mills *et al.*, the optimization of FL is considered. The authors address several FL challenges including the huge wireless parallelism with possibly large latency and low bandwidth, the heterogeneity of client data that can affect storage efficiency, performance and training time, as well as the large communication cost due to the excessive number of transmissions of parameters between clients and servers. In order to optimize FL performance, the article focuses on client side optimization. The article provides a survey of client side optimization techniques, and discusses the trade-offs between communication cost, hyperparameter selection, and convergence. It also conducts a simulation study of a subset of client side optimization techniques in order to obtain insights of their benefits to communications. Future research directions are also presented.

ML techniques, which learn from past scenarios, including near real-time physical operating scenarios, are expected to become a powerful technique for substantially improving network performance. The article "Network Architecture for Machine Learning: A Network Operator's Perspective" by C. V. Murudkar *et al.*, addresses how network operators need to upgrade standard networks by applying ML in order to address complexities of next generation networks' deployment and operation. In particular, they focus on the interplay between ML and wireless communication networks such that appropriate network architectures can be developed to facilitate where and how ML functionalities should be located inside the network. The article presents an ML-driven network architecture for 5G and beyond systems that considers the computing-driven network infrastructure and how it should help ML by achieving scalability and real-time performance. An illustrative example of the radio-access-network-based notification areas (RNAs) is presented, and a performance evaluation study is conducted. Future directions for research are also provided.

Current trends in wireless communications include using high carrier frequencies, such as terahertz, which results in the availability of higher bandwidth channels, as well as increasing the number of antenna elements. Both of these trends result in increasing the power consumption of RF and digital circuits. The use of one-bit analog-to-digital converters (ADCs) at receivers is a cost- and power-efficient solution to this problem. However, there are several issues with using this ADC including the result of a nonlinear MIMO channel model. To solve those problems, AI can be used to estimate a nonlinear input-output relationship of a MIMO system with one-bit ADC. The article "Artificial Intelligence for Physical-Layer Design of MIMO Communications with One-Bit ADCs" by Y.-S. Jeon *et al.* provides an overview of AI-based PHY design frameworks for MIMO systems with one-bit ADCs. Then the article describes two frameworks for AI-based PHY design: the first learns the behavior of one-bit received signals using a parametric model, while the second learns the input-output relationship of the MIMO system using a classifier based on a deep neural network. Case studies are presented, and the advantages and disadvantages of the different approaches are summarized. The article also introduces a detailed list of remaining challenges in PHY design.

We thank all the authors and reviewers for contributing to the Series. We also thank the Editor-in-Chief of *IEEE Communications Magazine*, Dr. Antonio Sanchez-Esguevillas, and Associate Editor-in-Chief, Dr. Alberto Perotti, for their strong support and guidance as well as the *IEEE Communications Magazine* staff for efficient processing of the articles.

Biographies

Yongmin Choi [M] (yongminc@hotmail.com) received his B.S. and M.S. degrees in electronic engineering from Seoul National University, Korea, and his Ph.D. degree in electrical engineering from the University of Southern California, Los Angeles. His professional career has spanned diverse fields in the telecommunications industry. His current interests include architecture and technologies for future networks including 6G, inductive analysis and modeling of network traffic, and application of machine learning and artificial intelligence to network analytics. He is with the Network Operations Business Unit at KT Corporation. He is a member of Phi Kappa Phi and Eta Kappa Nu.

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