DATA SCIENCE AND ARTIFICIAL INTELLIGENCE FOR COMMUNICATIONS


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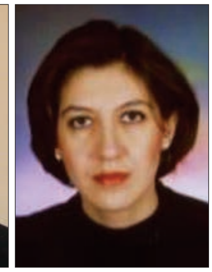
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Welcome to the October issue of the Data Science and Artificial Intelligence for Communications Series. The popularity of this Series continues to grow, attracting a lot of attention from both researchers and practitioners who are working to address various challenges in the network field through the advances of artificial intelligence (AI), machine learning (ML), and big data analysis. This trend toward learning-based, data-driven approaches has been mainly motivated by two things: the amount of available data retrieved from devices and network equipment, and the need to tune large numbers of network operational parameters in order to meet the frequently changing needs of the services. Indeed, 5G and the rise of new services — the Internet of Things (IoT), connected vehicles, augmented and virtual reality (AR/VR), and so on — are expected to make traffic much more dynamic, thus requiring frequent network reconfiguration. Although AI/ML/deep learning (DL) technologies promise to shed light on this huge amount of data and provide the means for automation, significant challenges remain. Smart and scalable approaches are needed to activate their potential gains in the complex real-world scenarios spanning wireless, edge, and cloud computing infrastructures today. In addition, fundamental questions and challenges related to embedding of these technologies in the wireless context, and especially in the lower layers of the protocol stack, need to be overcome to truly enable the "pervasive intelligence" promised by future beyond 5G networks. This issue has everything mentioned above!

A number of challenges set physical layer deep learning (PHY-DL) apart from other learning domains where digital signal processing (DSP) constraints and hardware limitations have to be considered down to the clock cycle level. The first article, "Deep Learning at the Physical Layer: System Challenges and Applications to 5G and Beyond" by Francesco Restuccia and Tommaso Melodia, discusses a series of system-level issues for real-time PHY-DL and overviews the state of the art in addressing these challenges. Through their millimeter-wave (mmWave) testbed, the authors present preliminary results in the area of adaptive beam alignment and consider a roadmap of future research opportunities.

One area in which PHY-DL is making strides is RF fingerprinting. This technology is aimed at developing a distinctive RF fingerprint for a wireless device and holds promise for important applications in wireless security. The second article, "More Is Better: Data Augmentation for Channel-Resilient RF Fingerprinting" by Nasim Soltani, Kunal Sankhe, Jennifer Dy, Stratis Ioannidis, and Kaushik Chowdhury, proposes a novel methodology for data augmentation in the RF domain as a way to make the trained deep neural network (DNN) generalized and robust to channel variations and noise levels. Performance gains of the proposed method are shown in the form of up to 75 and 51 percent increase in signal classification accuracy over nonaugmented case in a custom dataset and in a DARPA dataset, respectively.

As large-scale commercial deployments of 5G are underway, researchers are beginning to look forward into future wireless communications, from 6G and beyond. To this end, the third article, "Artificial Intelligence Enabled Air Interface for 6G: Solutions, Challenges, and Standardization Impact" by ShuangFeng Han, Tian Xie, Chih-Lin I, Li Chai, Liu Zhiming, Yifei Yuan, and Chunfeng Cui, explores a compelling prospect for the traditionally intensive standardization efforts to be greatly alleviated by AI technologies on physical and higher layers. Such a paradigm shift could lead to substantive reduction of the standardization efforts and costs in deploying new network infrastructures. To alleviate the burden of standardization and maximize the potential gain of AI-enabled network optimization, the authors examine fully AI-enabled RAN architecture solutions and explore future challenges therein.

The next two articles address the challenges of integrating scalable intelligence into the design and operation of future wireless networks. In the article "Scalable Learning Paradigms for Data-Driven Wireless Communication," Yue Xu, Feng Yin, Wenjun Xu, Chia-Han Lee, Jiaru Lin and Shuguang Cui describe several scalable learning frameworks involving the use of the computational resources at the device, edge, and cloud levels, desirable benefits, and unsolved challenges. The authors also illustrate two use cases as a quantitative demonstration of how to apply the presented scalable learning techniques to specific wireless applications and highlight several promising research directions to inspire future research.

Federated learning (FL) is a scalable learning framework that has attracted great attention recently and can be a promising solution for enabling IoT-based smart applications. In the article "Federated Learning for Edge Networks: Resource Optimization and Incentive Mechanism," Latif U. Khan, Shashi Raj Pandey, Nguyen Tran, Walid Saad, Zhu Han, Minh

Nguyen, and Choong Seon Hong begin with a discussion of the key design aspects for enabling FL at network edge. The discussion is followed by a presentation of mechanisms that incentivize users to participate in FL. The authors propose a game-theoretic incentive mechanism to select a set of IoT devices willing to join the model training process. Then the selected set collaboratively trains a global model while minimizing the overall training costs.

The last article of this issue is "Intelligent Resource Scheduling Based on Locality Principle in Data Center Networks." Contributed by Weibei Fan, Jing He, Zhijie Han, Peng Li, and Ruchuan Wang, this article addresses the application of artificial intelligence to the allocation of resources in data centers while taking the locality principle into consideration. The authors provide a synopsis of challenges and an overview of the most prominent approaches for resource scheduling in data center networks. A new AI algorithm for resource discovery and scheduling based on the locality principle and docker container is subsequently developed. Performance evaluation of execution time and resource utilization rate under various loads and computational tasks demonstrate the merit of the proposed approach.

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