# ARTIFICIAL INTELLIGENCE AND DATA SCIENCE FOR COMMUNICATIONS


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Welcome to the June issue of the Artificial Intelligence and Data Science for Communications Series of *IEEE Communications Magazine*. The Series Editors would like to introduce and welcome Dr. Yulin Shao and Prof. Jie Zhang, who recently joined our efforts as members of the editorial team for the Series.

Artificial Intelligence (AI) and machine learning (ML) are generally applied to diverse fields to support intelligent complex decision making in real time, enabling strategies to autonomously learn and adapt to different conditions experienced, allowing for efficient and effective accomplishment of specific end-to-end goals and objectives. Yet, many challenges and issues are still open and should be efficiently addressed.

This issue includes five articles that have been reviewed and approved for publication by experts in the respective fields. The first two articles in the current issue bring to the foreground a machine learning framework and a data driven simulator as enablers for network performance optimization. The other two articles propose the application of deep reinforcement learning for efficiently solving resource allocation in IoT networks and intelligent offloading in Blockchain-based crowdsensing systems, while the fifth article falls within wireless channel charting.

The optimization of real-world wireless network performance is a challenging task. Traditional approaches for network optimization involve measurement campaigns, trial-and-error processes and engineering experience that are costly, time-consuming and possibly sub-optimal. The first article "SRCON: A Data-Driven Network Performance Simulator for Real-World Wireless Networks" by Zhi-Quan Luo, Xi Zheng, David Lopez-Perez, Qi Yan, Xin Chen, Nanbin Wang, Qingjiang Shi, Tsung-Hui Chang and Adrian Garcia-Rodriguez, presents a data-driven network simulator called simulated reality of communication networks (SRCON), that relies on the utilization of measurement data and integrates white-box models and machine learning techniques to accurately simulate the stochastic behavior of 4G/5G mobile networks and enable more effective optimization strategies. This is accomplished through network performance prediction, even for configurations that have not been implemented before.The authors as a first step discuss main challenges in wireless network performance optimization such as the huge problem size to be considered for acquiring the best combination of network parameters, network coupling (with the selection of a parameter in a specific BS impacting the experience of neighboring cells), heterogeneity and complexity of devices and stochasticity. The authors illustrate how SRCON can be used to optimize mobile network performance effectively and present the performance improvement obtained by SRCON for various metrics including network spectral efficiency, rate maximization for 4G/5G co-coverage, load balancing, cell-edge experience enhancement, Physical Cell Identifier (PCI) collision and interference reduction. Data driven simulation frameworks such as SRCON could constitute a powerful tool for the efficient management and optimization of mobile communication systems.

In order to develop the next-generation networks, it is necessary to create customized AI/ML models that are specifically designed for communication networks. The second article, "Accordion: A Communication-Aware Machine Learning Framework for Next Generation Networks" by Fadhel Ayed, Antonio De Domenico, Adrian Garcia-Rodriguez and David Lopez-Perez, highlights the significance of communication-aware machine learning and introduces a new framework called Accordion that allows for an efficient transfer of AI/ML models. The article as a first step reviews the key operations identified by the third generation partnership project (3GPP) for transferring AI/ML models through 5G networks and existing techniques to reduce their communication overheads and computational requirements. The Accordion framework modifies the AI/ML model training phase so that UEs can execute a fraction of the AI/ML models with adequate performance, supporting stringent application latency constraints and incrementally receive additional parts to further enhance accuracy, whenever necessary. The article showcases the communication-related benefits of Accordion, analyzes key performance trade-offs, and discusses potential research directions in this area. Most importantly, the proposed framework exhibits enhanced flexibility as it enables dynamic adaptation of the AI/ML model fraction to be executed by the UE, following UE's requirements, without resending a new model from scratch. Frameworks, such as Accordion, that enable dynamic adaptation of AI/ML models based on stringent application requirements and current communication resource availability could help achieve increased accuracy for the problems at hand.

The number of complex and heterogeneous Internet of Things (IoT) applications has been vastly growing, thus, imposing a high demand for scarce communications and computing resources. In this respect, resource allocation is a challenging problem to address in the context of IoT network design and optimization. Motivated by the aforementioned, in the third article, "Deep Reinforcement Learning for Online Resource Allocation in IoT networks: Technology, Development, and Future Challenges" by Peng Cheng, Youjia Chen, Ming Ding, Zhuo Chen, Sige Liu and Yi-Ping Phoebe Chen, the authors propose a framework based on deep reinforcement learning (DRL) for efficient online resource allocation in IoT networks. The article provides an overview of DRL basics and recent applications, introduces two new DRL algorithms that

- Address optimization problems with mixed action spaces and non-linear quality-of-service constraints
- Extend single-agent DRL to multi-agent DRL using a novel semi-distributed architecture

Finally, the authors discuss challenges and future visions of DRL application to real-world IoT networks. AI and DL technologies are promising enablers to achieve efficient resource optimization in IoT networks. Deep reinforcement learning techniques explored and presented in the manuscript could be the basis for efficient and effective IoT networks.

Secure payment transactions between participants and cloud service providers is a significant challenge in mobile crowdsensing (MCS) systems. Traditional transaction-management systems that store payment transactions in a centralized manner pose significant security risks and performance bottlenecks, making blockchain technology an attractive solution for securing transactions in MCS systems. The fourth article "Intelligent Offloading in Blockchain-Based Mobile Crowdsensing Using Deep Reinforcement Learning" by Zheyi Chen and Zhengxin Yu, explores the use of deep reinforcement learning (DRL) in the context of mobile crowdsensing (MCS) systems. proposing a new DRL-based framework to address the computational challenges of the proof-of-work (PoW) mechanism in blockchain-based MCS systems. The proposed framework offloads computation-intensive PoW tasks to edge servers, enabling optimal offloading policies to be obtained employing an actor-critic based hybrid RL algorithm, under complex and dynamic MCS environments. The simulation results demonstrate that the proposed method can achieve lower weighted costs of latency and power consumption compared to benchmark methods. Task offloading to edge is of outmost importance in order to bring blockchain potentials to MCS systems. Deep reinforcement learning techniques as the ones presented in the specific manuscript could provide promising solutions in this respect.

Channel charting has emerged as an alternative to classical localization techniques for applications/services not requiring absolute position information, but a pseudo-location that characterizes short distance neighboring relationships. Thus, channel charting is a framework that adopts dimensionality reduction techniques to channel state information in wireless systems, with the primary objective of assigning a pseudo-position to each mobile user in a low-dimensional space. The fifth article "Wireless Channel Charting: Theory, Practice, and Applications" by Paul Ferrand, Maxime Guillaud, Christoph Studer, and Olav Tirkkonen, provides a comprehensive overview of the concept of channel charting in wireless systems. The authors introduce the theoretical foundations of channel charting and present an overview of recent algorithmic advancements and experimental findings in the field. They also examine specific application examples of channel charting to network- and user-related applications such as mmWave beam discovery and proximity detection and provide a perspective on future developments and challenges (such as real-time implementation of machine learning algorithms, distributed implementation and privacy preservation) as well as the role of channel charting in next-generation wireless networks. The specific manuscript nicely introduces readers to recent advances and specific examples of channel charting that enables a range of location-based services exploiting channel state information built in a semi supervised manner.

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. Last, but not least, we thank the *IEEE Communications Magazine* staff for efficiently processing the articles.

The Series Editors want to express their deep sadness for the sudden loss of Prof. Ahmed Kamal (Willard and Leitha Richardson Professor in Electrical and Computer Engineering, Iowa State University), former Lead Editor of the Series. He has served *IEEE Communications Magazine* exemplarily, with diligence and professionalism. Our community has lost a devoted colleague, an outstanding scientist. We express our sincere condolences to his family and friends.

## 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, the USA. 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 cryptocurrency. He is a member of Phi Kappa Phi and Eta Kappa Nu.

Ahmed E. Kamal [F'12] (kamal@iastate.edu) obtained his B.Sc. and M.Sc. from Cairo University in Egypt, and the M.A.Sc. and Ph.D. from the University of Toronto in Canada, all in Electrical Engineering. He is the Richardson Professor of Electrical and Computer Engineering at Iowa State University in the USA. He served the IEEE Communications Society as a Distinguished Lecturer, as the chair of the technical committee on Transmission, Access and Optical Systems (TAOS), as a chair or co-chair of several conferences and symposia, and as the lead editor of the *IEEE Communications Magazine* series on Artificial Intelligence and Data Science for Communications from 2019 to 2022. Kamal's current research interests include wireless networks and machine learning applications in communications and networking.

Malamati Louta [SM'14] (louta@uowm.gr) received the M.Eng. and Ph.D. degrees in electrical and computer engineering in 1997 and 2000, respectively, and the M.B.A. degree in 2004 from the National Technical University of Athens. She is the Director of Telecommunication Networks and Advanced Services Laboratory and an Associate Professor with the Electrical and Computer Engineering Department, School of Engineering, University of Western Macedonia, Greece. Her research interests include telecommunication networks and advanced services engineering. She serves as an associate editor, general chair, technical program committee chair and member, session organizer and a reviewer for a number of international conferences and journals. She is member of the ACM and the Technical Chamber of Greece.