Data Science and Artificial Intelligence for Communications




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Future networks, empowered with Artificial Intelligence (AI) and Machine Learning (ML) capabilities, are expected to become cognitive, autonomously thinking, learning, remembering and adapting to ever changing conditions. Knowledge acquisition and intelligent decision making are enabled, effectively supporting next generation networks in achieving their end-to-end goals and objectives in a highly dynamic and heterogeneous environment of increasing complexity. AI/ML and data science are generally considered key technologies for communications; still, many research challenges need to be adequately addressed, before they can evolve to their full potential.

This Series is dedicated to presenting new trends, approaches, methods, frameworks, and systems, applying AI, ML, and data analytics, to address different problems of communications systems for efficiently managing and optimizing networks related operations. For this issue, four articles were accepted following a rigorous review process by experts in the area in order to ensure that the best possible papers were selected. The first three articles fall within future wireless systems (5G and beyond) design, while the last paper applies AI/ML to promote near field communication (NFC) security.

The first article, "Toward a 6G AI-Native Air Interface" by Jakob Hoydis, Fayçal Ait Aoudia, Alvaro Valcarce, and Harish Viswanathan, presents a vision of a new air interface, partially designed by AI (the so called AI-AI), enabling optimized communication schemes for any hardware, radio environment and application. Specifically, besides providing solutions to specific problems, AI/ML is envisioned to design parts of the physical and MAC layers, specifying at an ultimate level the procedures that can be used to optimize several aspects of the air interface at deployment time, instead of specifying the parameters/schemes themselves. The authors provide a summary of possible benefits of AI-AI, then discuss three important phases in the development and transition to AI-AI, and finally present a case study from neural receivers to pilotless transmissions which exemplifies the respective potential performance gains and advantages. Finally, they advocate exploitation of learning to communicate (L2C) field advancements in order to train wireless devices to learn communication protocols.

Federated Learning (FL) is an emerging distributed ML paradigm. In the context of wireless federated learning, which is envisioned to be of key importance in edge ML, early research demonstrates the potential of jointly optimizing communication and computation. However, communication design has not been tailored to the unique characteristics of FL that consists of many learning rounds of varying significance, collectively determining the learning outcome. In light of the aforementioned, in the second article, "Resource Rationing for Wireless Federated Learning: Concept, Benefits, and Challenges" by Cong Shen, Jie Xu, Sihui Zheng, and Xiang Chen, a novel resource allocation framework for wireless FL is proposed, termed resource rationing, to emphasize allocation of different resources across learning rounds with the goal of maximizing the final ML model accuracy and convergence rate. Its core design follows the so called "latter is better" principle, utilizing fewer resources at the beginning and gradually increasing their usage toward the end, achieving an overall improved learning performance. The authors demonstrate its benefits considering three specific examples (bandwidth allocation on the physical layer, client selection strategies on the MAC layer, and joint client selection, bandwidth allocation and power control) and also discuss several technical challenges and research directions (including temporal variation of wireless channels, complexity and scalability issues, and potential generalization and extension of resource rationing even beyond communication resources) to advance resource rationing and wireless FL in general.

5G systems advancement has called for AI-powered Zero-touch network and Service Management (ZSM) solutions to support next-generation highly heterogeneous applications and services. Key ZSM capabilities contributing to smarter network dimensioning and service provisioning include run-time prediction of user demands and corresponding network resources' usage at various management and coverage levels, facilitated by data-driven and ML methods. Among others, bio-inspired Artificial Neural Networks (ANNs) have gained particular interest for their ability to model noisy and nonlinear systems. In this respect, the third article, "ANNs Going Beyond Time Series Forecasting: An Urban Network Perspective" by Jane Frances Pajo, George Kousiouris, Dimosthenis Kyriazis, Roberto Bruschi, and Franco Davoli, proposes combined usage of genetic algorithm (GA) based structure optimized ANNs with a novel set of generic inputs that capture both multi-seasonal and calendar effects so as to remove the dependence of the modeling and forecasting steps on the temporal succession of input data samples and forecast horizon. In this way, time series forecasting is transformed into a simpler multivariate regression problem, yielding improved performance prediction compared to the state-of-the-art Multi-seasonal

Time Series (MSTS) and Long Short-Term Memory (LSTM) forecasting methods.

The security of near field communication (NFC) systems is becoming increasingly important. Radio frequency (RF) fingerprinting, an identification scheme based on RF unique characteristics observed in signal transmission, regarded as the fingerprint of the device, is exploited to provide guarantees of authenticity and security. Deep learning has recently been applied in RF fingerprinting in NFC in order to attain high accuracy of identification. To this end, the feasibility of RF fingerprinting assisted by deep learning for identifying NFC tags is discussed in the fourth article, "Deep Learning-aided RF Fingerprinting for NFC Security" by Woongsup Lee, Seon Yeob Baek, and Seong Hwan Kim. The authors implement a hardware testbed with an off-the-shelf NFC reader and a software defined radio (SDR), supported by a deep neural network (DNN) structure. The performance of deep learning-aided RF fingerprinting for NFC tag identification is evaluated adopting various DNN models, including fully connected layer-based neural network (FNN), convolutional neural network (CNN), and recurrent neural network (RNN), and compared against conventional machine learning algorithms. Finally, key technical challenges involved in the use of deep learning-based RF fingerprinting for improving security in NFC tag identification are discussed.

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Biographies

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Malamati Louta [SM'14] 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 an associate professor and Director of the Telecommunication Networks and Advanced Services Laboratory (TELNAS) of 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.