**Top Level Newsletter:** **Connected Vehicle**

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**Vol 9.1**

Editor-in-Chief: Kay Das, IEEE Life Member,

Systems Research Development and Innovation

**Vol 9.1: Data Science and AI for Communications (multiple articles from IEEE Communications magazines, May/November 2019 – January/March/June 2020)**

Previous issues:

Vol 8.0: Cloud-Based AI (ABI Research publication)

Vol 7.0: COVID-19 and Connected Vehicle

Vol 6.0: Proceedings of the IEEE, Internet of Vehicles,

Vol 5.1: Co-operative Automated Driving

Vol 4.0: Current sensor technology

This newsletter is intended to provide the IEEE member with a top level briefing of the subject under review. Instead of a cumulative approach, as adopted previously, it will now only feature new content. Vol 9.1 will only contain chosen material related to Data Science and AI for Communication. For older content, please access previous volumes.

The objective is to provide a platform for fast learning and quick overview so that the reader may be guided to the next levels of detail and gain insight into correlations between the entries to enable growth of the technology. Intended audiences are those that desire a quick introduction to the subject and who may wish to take it further and deepen their knowledge. This includes those in industry, academia or government and the public at large. Descriptions will include a range of flavors from technical detail to broad industry and administrative issues. A (soft) limit of 200 to 300 words is usually set for each topic, but not rigorously exercised. As descriptions are not exhaustive, hyperlinks are occasionally provided to give the reader a first means of delving into the next level of detail. However, it is not the intent to make this a forest of hyperlinks. The reader is encouraged to develop a first level understanding of the topic in view. The emphasis is on brief, clear and contained text. There will be no diagrams in order to keep the publication concise. Related topics in the case of Connected Vehicle technology, such as 5G cellular and the Internet of Things will be included. The terms Connected Vehicle and Automated Driving will be used inter-changeably. The publication will be updated periodically. Articles from other published sources than IEEE that add to the information value will occasionally be included.

This newsletter forms part of the regional Advanced Technology Initiative (ATI) of which connected vehicles form a constituent part. Technical articles solely from IEEE journals/magazines are referred to by their Digital Object Identifier (DOI) or corresponding https link. The link for each article is provided. Those readers who wish to delve further to the complete paper and have access to IEEE Explore ([www.ieeexplore.ieee.org](http://www.ieeexplore.ieee.org)) may download complete articles of interest. Those who subscribe to the relevant IEEE society and receive the journal may already have physical or electronic copies. In case of difficulty please contact the editor at kaydas@mac.com. The objective is to provide top level guidance on the subject of interest. As this is a collection of summaries of already published articles and serves to further widen audiences for the benefit of each publication, no copyright issues are foreseen.

Readers are encouraged to develop their own onward sources of information, discover and draw inferences, join the dots, and further develop the technology. Reading the full articles summarized here is recommended.

**IEEE Communications May 2019, Vol 57, No 5**

**Abstract:**

The five articles in this special section focus on data science and artificial intelligence (AI) for generalized communications systems. The innovation in AI, machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world’s communications systems and user experience. Through gathering, processing, learning, and controlling the vast amounts of information in an intelligent manner, these analytics tools enable the possibility to automate and optimize systems in a way that was not previously possible. This is particularly important as the communications infrastructures evolve to support increasingly more complex human type as well as machine type communications and enable, through the connectedness of meters, sensors, and things, a plethora of new services. Supporting such immensely diverse traffic patterns and applications will require dynamic, highly adaptive network environments, all the while ensuring highly reliable, secure, and ultra-low-latency service performance guarantees. The connected vehicle is a major application.

**Editorial (pp 56-56) (Irena Atov et al):**

Welcome to the inaugural issue of the Data Science and Artificial Intelligence for Communications Series!

The innovation in artificial intelligence (AI), machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world's communications systems and user experience. Through gathering, processing, learning, and controlling the vast amounts of information in an intelligent manner, these analytics tools enable the possibility to automate and optimize systems in a way that was not previously possible. This is particularly important as the communications infrastructures evolve to support increasingly more complex human type as well as machine type communications and enable, through the connectedness of meters, sensors, and things, a plethora of new services. Supporting such immensely diverse traffic patterns and applications will require dynamic, highly adaptive network environments, all the while ensuring highly reliable, secure, and ultra-low-latency service performance guarantees.

For this first issue, we accepted five articles after a thorough review process. These all feature new opportunities to develop and advance various areas of communications through the use and applications of AI/ML/deep learning technologies. Topics covered range from computational offloading in mobile edge computing (MEC), deep space communications (with experimentation aboard the International Space Station), and encrypted traffic classification, through to hardware design of encoders and decoders, and characterization and prediction of the wireless RF environment.

There is also a present need to map the latest learning algorithms to physical hardware in order to achieve significant improvements in speed, performance, and energy efficiency. However, their computational complexity still presents challenges to practical deployment.

**Article 1 (pp 57-63): “Toward the Realization of Encoder and Decoder Using Deep Neural Networks,” M. Kim *et al.***

**DOI:** [**https://doi.org/10.1109/MCOM.2019.1900093**](https://doi.org/10.1109/MCOM.2019.1900093)

The article presents the design and implementation of a low-complexity deep neural network (DNN)-based encoder and decoder for real-time operation. By performing link-level verification through the implementation of digital circuits using hardware description language (HDL), the authors confirm the feasibility of DNNs in practice for communications systems where real time operation is inevitably required.

A**rticle 2 (pp 64-69)**: **“Computation Offloading in Multi-Access Edge Computing Using Deep Sequential Model Based on Reinforcement Learning”, J. Wang *et al.*,**

**DOI:** [**https://doi.org/10.1109/MCOM.2019.1800971**](https://doi.org/10.1109/MCOM.2019.1800971)

Mobile edge computing (MEC) is positioned to deliver cloud computing capabilities at the edge of the cellular network, to store and process content closer to the user for faster response times. The article examines the challenging problem of computation offloading in MEC. The authors propose a deep reinforcement learning (DRL)-based offloading framework, which can efficiently learn the offloading policy represented by a specially designed sequence-to-sequence neural network. Performance gains of the proposed method are shown in the form of reduction in latency over two heuristic baselines in various network conditions and scenarios.

A**rticle 3 (pp 70-75)**: **“Reinforcement Learning for Satellite Communications: From LEO to Deep Space Operations,” P. R. Ferreira *et.al***

**DOI:** [**https://doi.org/10.1109/MCOM.2019.1800796**](https://doi.org/10.1109/MCOM.2019.1800796)

Future space-based wireless communications systems could be able to operate close to their optimum performance by autonomously allocating radio resources while handling multiple conflicting goals as part of a communication mission. The highly time-varying challenges imposed by spacecraft orbital dynamics and radio propagation characteristics in space make programming each radio configuration a very complex task. A novel algorithm is presented that uses reinforcement learning and deep neural network ensembles to manage and control the radio communication parameters without human intervention. The proposed algorithm was successfully tested on orbit, and the results are expected to serve as a benchmark for future research on cognitive engines for space-based communications systems.

A**rticle 4 (pp 76-81)**: **“Deep Learning for Encrypted Traffic Classification: An Overview,” S. Rezaei *et al.***

**DOI:** [**https://doi.org/10.1109/MCOM.2019.1800819**](https://doi.org/10.1109/MCOM.2019.1800819)

Categorizing network traffic into desirable classes, called traffic classification, has been used for more than two decades for various applications. A wide range of approaches have been extensively deployed, although their efficacy and accuracy have declined as network traffic on the Internet has become more obfuscated and encrypted. New approaches are needed to capture the more complex patterns and characteristics of traffic today.

The article explores the potential use and possibilities of deep learning methods for traffic classification. The authors introduce a general framework to devise a classifier for any traffic classification task and provide guidelines for several key questions: (a) how/where to capture data (b) model/architecture to use (c) what type of feature is suitable, and so on.

A**rticle 5 (pp 82-87)**: **“Machine Learning in Adversarial RF Environments,” D. Roy *et al.***

**DOI:** [**https://doi.org/10.1109/MCOM.2019.1900031**](https://doi.org/10.1109/MCOM.2019.1900031)

The article surveys different kinds of ML approaches that can be applied to RF parameter learning. In reviewing the various learning strategies, the authors observe some of their inherent vulnerabilities to attackers and situations where the trained data might be compromised. They motivate the design of adversarial ML algorithms that can combat the presence of adversaries during and/or after the training phase. The efficacy of a proposed generative adversarial network (GAN)-based approach for identification of transmitters in adversarial RF environments is demonstrated experimentally. Overall, their proposed model is able to recognize rogue transmitters as well as categorize the trusted ones with similar accuracy.

**IEEE Communications November 2019, Vol 57, No 11**

**Abstract:**

This is the second issue of the Data Science and Artificial Intelligence for Communications Series. The innovation in artificial intelligence (AI), machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world’s communications systems and user experience. Through gathering, processing, learning, and controlling the vast amounts of information in an intelligent manner, these analytics tools enable the possibility to automate and optimize systems in a way that was not previously possible. This is particularly important as the communications infrastructures evolve to support increasingly more complex communications and enable, through the connectedness of meters, sensors, and things, a plethora of new services. Supporting such immensely diverse applications with equally diverse traffic characteristics will require dynamic, highly adaptive network environments, while ensuring highly reliable, secure, and ultra-low-latency service performance guarantees. For this second issue, we accepted six articles.

**Editorial (pp 82-83) (Irena Atov et al):**

The series, despite its short lifetime, is proving to be very popular, and is receiving many submissions. These submissions undergo a rigorous review process in order to ensure the high quality of the papers selected for publication.

The innovation in artificial intelligence (AI), machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world's communications systems and user experience. Through gathering, processing, learning, and controlling the vast amounts of information in an intelligent manner, these analytics tools enable the possibility to automate and optimize systems in a way that was not previously possible. This is particularly important as the communications infrastructures evolve to support increasingly more complex communications and enable, through the connectedness of meters, sensors, and things, a plethora of new services. Supporting such immensely diverse applications with equally diverse traffic characteristics will require dynamic, highly adaptive network environments, while ensuring highly reliable, secure, and ultra-low-latency service performance guarantees.

For this second issue, we accepted six articles after a thorough review process. These all feature new opportunities to develop and advance various areas of communications through the use and applications of AI/ML/deep learning technologies. Topics covered range from emotion sensing and monitoring, neural network-based robust IoT networking, channel state information estimates verification in device-to-device communications, deep reinforcement learning-based Service Function Chain allocation in IoT networks, using machine learning for channel modeling in vehicle-to-vehicle communications, and data security issues in clouds providing Machine Learning as a Service.

A**rticle 1 (pp 84 - 89) “Emotion Sensing for Mobile Computing,” by J. Shu et al**

**DOI: <https://doi.org/10.1109/MCOM.001.1800834>**

Emotion is a complex mental state that guides people's thoughts and behaviors. The ability to recognize one's own emotions and to understand others' emotions helps people manage their personal lives and social relations more successfully. Mobile and wearable devices have become ubiquitous, and they provide great opportunities for building emotional intelligent applications. The authors introduce how mobile and wearable devices work as “emotion sensors” by leveraging their sensing, computing, and communication capabilities. This helps in monitoring people's mental health, facilitating social interactions, and improving user experience.

The article introduces a general emotion sensing framework that consists of sensing, inferring, and responding steps. The article discusses how various sensing modalities enabled by mobile and wearable devices can be used, and describes the widely used inferring procedures and methods. The authors present three solutions for facial expression recognition on smartphones as a case of emotion inference. Emerging emotion sensing applications are introduced, and finally challenges and opportunities are presented.

**Article 2 (pp 91-95)**: **“An Intelligent Robust Networking Mechanism for the Internet of Things,” by N. Chen**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900094**](https://doi.org/10.1109/MCOM.001.1900094)

An important application of IoT is in smart cities, and in this case many low-powered devices are widely deployed, and networked. It is important for these devices and their interconnections to be resilient to all attacks, and especially malicious ones that can cause nodes, and in particular high-degree nodes, to fail, hence causing communications disruption. There is, therefore, a strong motivation for improving the robustness of IoT topology and maintaining a high communication capacity in cases of node failure. However, existing robustness optimization algorithms have a prohibitively high computational cost that is an obstacle to efficient topology self-optimization in IoT systems. This problem is addressed here. The article proposes a solution to this problem by introducing a robust networking model based on artificial intelligence that improves IoT topology robustness protecting its communications. Using the Back-Propagation neural network learning algorithm, the model extracts topology features from a dataset by supervised training. The experimental results show that the model achieves better prediction accuracy, thereby optimizing the topology with minimal computation overhead.

A**rticle 3 (pp 96-101)**: **“Heuristic-Learning-Based Network Architecture for Device-to-Device User Access Control,” by D. Lin et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1800862**](https://doi.org/10.1109/MCOM.001.1800862)

Device-to-device (D2D) communications is used in various applications using wireless communications. With limited wireless resource, and in data intensive applications, data transmission requirements may not be guaranteed for all users. Some users must therefore temporarily disconnect from a network to guarantee the normal operation of the network. The user access control strategy depends on the authenticity of channel state information (CSI) estimation, as users with higher CSI values may be allocated more wireless resource and be allowed to stay in the network with higher probabilities. The authors propose a heuristic learning method in which each user's CSI needs to be verified, and the users advocating a larger CSI may be detected to be fraud. The results indicate that a dramatic increase of network performance can be captured by the proposed algorithm.

A**rticle 4 (pp 102 – 1080)**, **“Service Function Chain Embedding for Network Function Virtualization-Enabled IoT Based on Deep Reinforcement Learning” by X. Fu** **et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900097**](https://doi.org/10.1109/MCOM.001.1900097)

Network Function Virtualization (NFV) is now being used in many communications networks, including IoT networks, due to its prospect of achieving efficient resource management. In an NFV-enabled IoT infrastructure, a Service Function Chain (SFC) consists of an ordered set of Virtualized Network Functions (VNFs) that are connected based on the business logic of service providers. However, due to the dynamic nature of IoT networks, and the large number of IoT devices, the SFC embedding process for IoT networks can become inefficient. Motivated by this problem, and by the fact that VNF nodes and physical network devices are usually heterogeneous.

This article introduces a solution to this problem in which the complex VNFs are decomposed into smaller VNF components (VNFCs) in order to make more effective decisions. A deep reinforcement learning (DRL)-based scheme with experience replay and target network is also proposed as a solution that can efficiently handle complex and dynamic SFC embedding scenarios. Simulation results present the efficient performance of the proposed DRL-based dynamic SFC embedding scheme.

**Article 5 (pp 109 – 115) “Machine-Learning-Based Data Processing Techniques for Vehicle-to-Vehicle Channel Modeling,” by C. Huang et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900124**](https://doi.org/10.1109/MCOM.001.1900124)

Vehicle-to-vehicle (V2V) communications have become a major research topic in the last decade because of their many potential applications and opportunities, including being part of the intelligent transportation system. However, the performance of V2V communications fundamentally depends on the propagation channels in which they are operating. The development and analysis of V2V systems thus requires suitable channel models.

This article deals with channel modeling for V2V communications, and in particular machine-learning based techniques. The article reviews some state-of-the-art applications including identification of channel line-of-sight situations, tracking of Multipath Components (MPCs), and MPC clustering. The data obtained with these methods form the basis for accurate channel models. Some challenges of machine-learning-based data processing for V2V channel research are discussed as the basis for future studies.

**Article 6 (pp 116 – 122) “Data Security Issues in Deep Learning: Attacks, Countermeasures, and Opportunities,” by G. Xu et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900091**](https://doi.org/10.1109/MCOM.001.1900091)

Machine Learning as a Service (MLaaS) is provided by several cloud service providers, such as Google, Amazon and Microsoft. MLaaS acts as cloud-assisted machine learning services. MLaaS provides a range of customized training and prediction services that only require users to upload local data. However, outsourced deep learning also brings about various privacy and security concerns.

This article addresses data security issues in deep learning, and investigates the potential threats of deep learning. The article then presents the latest countermeasures based on various underlying technologies, where the challenges and research opportunities on offense and defense are also discussed. Then they propose the SecureNet protocol, which is presented as the first verifiable and privacy-preserving prediction protocol to protect model integrity and user privacy in deep neural networks.

**IEEE Communications January 2020, Vol 58, No 1**

**Abstract:**

The six papers in this special section address the application of artificial intelligence, machine learning, and data analytics at different layers and different applications of different types of communications networks. The objective of using these tools is the optimal design and improved operation of networks. These articles feature new opportunities to develop and advance various areas of communications through the use and applications of AI/ML/ deep learning technologies.

**DOI:** [**https://doi.org/10.1109/MCOM.2020.8970159**](https://doi.org/10.1109/MCOM.2020.8970159)

**Editorial (pp10-11) (Irena Atov et al)**

Research in artificial intelligence (AI) has been active for several decades, but lately, and with the exponential increase in the amounts of available data, new directions of AI, such as machine learning (ML) and data analytics that learn from data, have emerged and have impacted many fields in science and engineering. This Series is dedicated to exploring these new trends, their latest developments, and their applications in the field of communications. This is the third issue of the Data Science and Artificial Intelligence for Communications Series, and the first in 2020. The Series has been steadily receiving many submissions which are reviewed by experts in the area in order to select the best papers for publication.

For this issue we selected six articles. These articles address the application of artificial intelligence, machine learning, and data analytics at different layers and different applications of different types of communications networks. The objective of using these tools is the optimal design and improved operation of networks. These articles feature new opportunities to develop and advance various areas of communications through the use and applications of AI/ML/deep learning technologies.

**Article 1 (pp 12-18): “Spectrum Intelligent Radio: Technology, Development, and Future Trends”** **by P. Cheng et al**

The article deals with machine learning applications at the physical layer in wireless networks. The article addresses the significant spectrum strains imposed by information collection and decision making in Industry 4.0, which is also known as the fourth industrial revolution. The article focuses on machine-learning-based intelligent radios as a viable solution to this problem and proposes a new radio architecture consisting of three hierarchical forms: perception, understanding, and reasoning. The purpose of these three forms is accurate spectrum sensing, accurate prediction of primary users' coverage, and optimal idle channel selection. The challenges and opportunities introduced by this framework are discussed.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900200**](https://doi.org/10.1109/MCOM.001.1900200)

A**rticle 2 (pp 19-25)**, **“Toward an Intelligent Edge: Wireless Communication Meets Machine Learning” by G. Zhu** **et al**

This article also deals with wireless networks in an environment with massive numbers of edge devices that collect data and upload this data to edge servers that learn from the data and distill intelligent decisions. Examples of such scenarios include sensors in IoT networks, auto-driving cars, and so on. The article proposes a framework that includes a set of new design guidelines for wireless communications in edge learning, which is referred to as learning-driven communication. The article discusses research directions emerging under this framework and provides illustrative examples that cover key communication aspects including multiple access, resource allocation, and signal encoding.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900103**](https://doi.org/10.1109/MCOM.001.1900103)

A**rticle 3 (pp 26-32)**, **“Programmable Multilayer INT: An Enabler for AI-assisted Network Automation” by S. Tang et al.**

The article addresses traffic monitoring over optical networks. Advances in optical networks have increased the complexity of traffic monitoring, and the article proposes a programmable multilayer in-band network telemetry system, which can visualize a packet-over-optical network in real time, hence enabling performance monitoring and troubleshooting. This system applies artificial intelligence for the accurate identification and classification of root causes of exceptions in packet-over-optical networks in a timely manner.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900365**](https://doi.org/10.1109/MCOM.001.1900365)

**Article 4 (pp 33-39)**, **“Evolving Switch Architecture toward Accommodating In-Network Intelligence,” by S. Chen et al.**

This work proposes to replace traditional dumb switches, which only implement the forwarding function, with intelligent switches. Switches are therefore augmented with an intelligence plane which, together with the data and control planes, implements a sensing-cognizing-acting closed loop to understand and react automatically to the potential network events and dynamics. The authors implement the intelligence plane as a pluggable module consisting of an integrated solution of “X86 CPU+G-PU+DPDK,” and demonstrate potential applications for this intelligent switch, including in-network application identification and in-network anomaly detection.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1800923**](https://doi.org/10.1109/MCOM.001.1800923)

A**rticle 5 (pp 40-46)**, **“Machine Fault Detection for Intelligent Self-Driving Networks,” by H. Huang et al**

The article deals with self-driving networks (SelfDNs), which are autonomous networks that are capable of making predictive and adaptive responses to their environment. The article focuses on fault detection in SelfDNs, and proposes a new fault detection architecture for SelfDNs. Under this architecture, an algorithm, named Gaussian Bernoulli restricted Boltzmann machines (GBRBM)-based deep neural network with autoencoder (i.e., GBRBM-DAE), is proposed with the objective of transforming the fault detection problem into a classification problem. Several classification mechanisms are considered and compared using traces from real-world experimental results, and it is shown that the proposed algorithm outperforms other popular machine learning algorithms, such as linear discriminant analysis, support vector machine, and pure deep neural network.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900283**](https://doi.org/10.1109/MCOM.001.1900283)

**Article 6 (pp 47-53)** **“SecCL: Securing Collaborative Learning Systems via Trusted Bulletin Boards,” by Z. Zhang et al,**

The collection of training data is difficult, especially if the amount of needed data is massive and the data is diverse, such as the sensitive data needed for applications that include facial recognition, natural language processing, and medical image processing. Collaborative learning addresses this issue by allowing participants to train a global model by uploading subsets of parameter changes to a centralized server instead of centralized data collection. This approach can leak private data if the involved entities are not trusted.

The article addresses this issue. It proposes a secure collaborative learning system called SecCL. SeCL provides strong privacy protection in collaborative learning, and this is done by ensuring authentic and correct message interaction. SeCL uses a trusted bulletin board (TBB) built upon blockchain. Moreover, a smart contract for SecCL is developed in order to allow participants to achieve consensus to restrain malicious behaviors. Therefore, servers and participants cannot behave in a deceptive manner. The authors also implement a prototype to evaluate the performance of SecCL, and show that SecCL can throttle malicious behaviors, and can also guarantee the accuracy of the global model.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900130**](https://doi.org/10.1109/MCOM.001.1900130)

**IEEE Communications March 2020, Vol 58 , No 3**

**Abstract:**

The articles in this special section present new technical advancements in applying AI and data science for communications.

**Editorial pp10-10 (Irena Atov et al)**

Advances in artificial intelligence (AI), particularly taking advantage of rapidly increasing network and user behavior data, indicates a new technological frontier of communications and networking, not only in new methodology in systems and network design, but also in new network architecture accommodating machine learning (ML) for broader and efficient services. This series is dedicated to introducing new trends, approaches, methods, systems, as well as network architecture, applying AI, ML, and data analytics.

Since the creation of this series, a great number of manuscripts have been submitted. With the remarkable assistance from reviewers, the series editors commit the best possible selection of articles to accommodate the readers' technical interest. In this issue, just two months away from an earlier issue, three articles are selected to present new technical advancement in applying AI and data science for communications.

**Article 1 (pp11-17):** **“On Leveraging Machine and Deep Learning for Throughput Prediction in Cellular Networks: Design, Performance, and Challenges,” Darijo Raca et al**.

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900394**](https://doi.org/10.1109/MCOM.001.1900394)

An immediate application of machine learning to networks is to predictively comprehend the throughput in a cellular network and thus toward better network design and performance. It is difficult due to highly dynamic wireless communication environments and complex traffic services to users. The article proposes throughput prediction and cellular resource scheduling. By establishing the system model, random forest, support vector machine, and long short-term memory are considered to implement machine learning. HTTP adaptive video streaming is further selected as the use case of interest to verify the methodology, with further suggested open issues.

**Article 2 (pp 18-24):** **“Big Data-Driven and AI-based Framework to Enable Personalization in Wireless Networks”, Rawan Alkurd et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900533**](https://doi.org/10.1109/MCOM.001.1900533)

Among the broad services to users in the state-of-the-art communication networks, the technology to tailor the services for each person while keeping the privacy emerges as a great challenge for the operators. Utilizing the technologies of AI, big data analytics, and real-time non-intrusive user feedback we can develop the framework for personalization. Based on each user's personal QoS requirements, a multi-objective optimization is formed together with a user satisfaction model. An experiment using a synthesized dataset successfully demonstrates the proposed framework.

**Article 3 (pp25-31):** **“A Flexible Machine Learning-Aware Architecture for Future WLANs,” Francesc Wilhelmi et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900637**](https://doi.org/10.1109/MCOM.001.1900637)

In addition to applying ML technology to communication networks, the appropriate network architecture emerges as a critical technological stage. A Focus Group on Machine Learning for Future Network Architecture (ML5G) has been established under the Standardization Sector in the International Telecommunication Union - Telecommunication (ITU-T) during 2017–2020. In the article the authors successfully demonstrate logic operation of applying ML to wireless LANs to illustrate the ML5G unified architecture.

**IEEE Communications June 2020, Vol 58, No 6**

**Abstract:** The articles in this special section are dedicated to the application of artificial intelligence AI), machine learning (ML), and data analytics to address different problems of communication systems, presenting new trends, approaches, methods, frameworks, systems for efficiently managing and optimizing networks related operations. Even though AI/ML is considered a key technology for next generation networks, still many research challenges need to be solved before it could reach its full potential.

**Editorial: (pp 10-11), Irene Atov et al**

Future communication systems will be increasingly complex and heterogeneous, involving multiple networking technologies with different capabilities and characteristics and heterogeneous nodes with diverse features. All constituent elements will effectively interwork with the aim of advanced, high-quality service provisioning in a cost efficient manner, any time, any place in a seamless and transparent way, maintaining consistency, robustness/availability and service continuity. Diverse requirements should be satisfied, stringent performance metrics should be guaranteed, while systems should be enabled to adapt and efficiently evolve to ever changing conditions in a quick pace.

Lately, the unprecedented amount of data availability in conjunction with the advancement in data analytics algorithms and computing processing have acted as a catalyst, allowing for the incorporation of artificial intelligence (AI) and machine learning (ML) capabilities into networks. In this way, knowledge acquisition and intelligent decision making support is enabled, considered to be a viable solution toward efficient network management, handling effectively increasing complexity, heterogeneity and highly dynamic networks' nature. AI/ML empowered future networks are enabled to sense their context of operation, analyze, reason and plan, make a decision, and act in accordance with the decision reached, while they learn from previous experience, thus optimizing their operation. Future networks are expected to have the ability to autonomously think, learn, remember, and adapt to changing conditions in order to achieve end-to-end goals and objectives.

This Series is dedicated to the application of AI, ML, and data analytics to address different problems of communication systems, presenting new trends, approaches, methods, frameworks, systems for efficiently managing and optimizing networks related operations. Even though AI/ML is considered a key technology for next generation networks, still many research challenges need to be solved before it could reach its full potential. This Series has been increasingly popular, steadily receiving a greater number of submissions, despite its short lifetime. For this issue, only three months after the most recent one, eight articles were accepted following a rigorous review process by experts in the area in order to ensure the best possible papers were selected. The first six articles fall within future wireless systems (5G and beyond) design, while the last two apply AI/ML to promote security related solutions to defense mechanisms and end-to-end congestion control.

**Article 1 (pp 12-18), “When Machine Learning Meets Wireless Cellular Networks: Deployment, Challenges, and Applications” by Ursula Challita et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900664**](https://doi.org/10.1109/MCOM.001.1900664)

The article provides an overview of the main requirements and key factors identified for efficiently deploying and integrating AI functionalities in 5G and beyond networks. To this respect, authors discuss the distribution of network intelligence, introducing three main types, as well as the challenges posed by a ML-based air interface supporting efficient data transmission, reducing energy consumption, while also satisfying latency requirements of different applications. Data acquisition, data security and integrity, and AI implementation are highlighted as key areas to be further investigated for a successful integration of AI in future wireless networks, while specific properties necessitated for AI-based systems include robustness and efficiency, AI goal alignment, active learning and explainable AI techniques. A diverse set of use case applications of AI to different networking problems are presented, including mobility management, wireless security, localization and physical layer, while the benefits that such techniques can bring to the network are highlighted. The authors conclude that an ML-based architecture for end-to-end communication system design along with an ML-based air interface are open research problems to be further investigated for initial deployments of AI-enabled wireless networks.

**Article 2 (pp 20-25) “A Machine Learning-based Framework for Optimizing the Operation of Future Networks” by Claudio Fiandrino et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900601**](https://doi.org/10.1109/MCOM.001.1900601)

The article proposes a general machine learning-based framework that leverages AI and ML tools to efficiently manage and optimize the performance of highly dynamic wireless networks. The proposed framework is modular and can instantiate and orchestrate multiple ML pipelines across different network segments for achieving different objectives. Machine intelligence is enabled into new as well as existing network functions, while reuse of existing control mechanisms with minimal or no modifications is succeeded. The authors use ML to forecast future traffic demands and characterize traffic features, advancing more intelligent decisions in critical network control mechanisms, such as load balancing, routing and scheduling. Their focus is on deep learning algorithms, while they additionally discuss the integration of their proposed solution in the 5G architecture. The proposed framework is validated, considering the proactive routing mechanism, and is shown to significantly reduce packet delay.

**Article 3 (pp 26-31), “Assisting for Intelligent Wireless Networks with Traffic Prediction: Exploring and Exploiting Predictive Causality in Wireless Traffic” by Juan Wen et al**

**DOI:** [**https://doi.org/10.1109/MCOM.001.1900211**](https://doi.org/10.1109/MCOM.001.1900211)

In a similar line of work to the above, the article endeavors to improve traffic prediction accuracy by exploiting predictable causality which arises between occurrences of special events and triggered traffic variations. Traditional temporal and spatial correlation based prediction techniques mainly predict the regular component in traffic, constituting them ineffective for large-scale varying traffic. Therefore, in order to tackle this limitation, the authors propose a novel framework of Correlation and Causality based Prediction (Coca-Predict) that integrates correlation and causality-based prediction to exploit their complementary strengths, predicting regular component and variation tendency, hence maximizing the prediction accuracy. Experimental results based on the realistic dataset demonstrate that Coca-Predict provides a significant improvement on prediction accuracy over the state-of-the-art techniques by exploiting traffic causality.

**Article 4 (pp 32-38): “Network Slicing Meets Artificial Intelligence: An AI-based Framework for Slice Management” by Dario Bega et al**

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The article highlights network slicing as an emerging paradigm in mobile networks in order to meet the highly stringent and diverse user requirements for service provisioning. Network slicing leverages Network Function Virtualization (NFV) to enable the instantiation of multiple virtual networks, i.e. slices, over the same physical network infrastructure. Optimizing managing functions and resource usage under network slicing is a challenging task that necessitates efficient decision making at all network levels, in some cases even in real-time. In light of the aforementioned, a general framework for AI-based network slice management is outlined, introducing AI into three different key functions of the system, namely (a) admission control of new slices, (b) radio resource scheduling of slice traffic, and (c) resource allocation to slices in the network core. Practical deep learning architectures are provided for three case studies, illustrating the high typical gain that could be achieved from integrating AI in network slicing. The authors conclude that AI has great potential to optimize next generation mobile network performance, assuming that present AI architecture limitations are properly addressed.

**Article 5 (pp39-45): “Explainable Artificial Intelligence (XAI) for 6G: Improving Trust between Human and Machine” by Weisi Guo.**

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This article highlights one of the most important open challenges to be addressed in AI/ML based architectures: building and quantifying trust between human end-users and enabling AI algorithms. Specifically, the author proposes adoption of Explainable AI that can quantify uncertainty in wireless networks and explain decisions taken in a way humans could understand in order to address the lack of transparency and trust challenge introduced by Deep Neural Networks (DNN). The author outlines core concepts of XAI for future wireless systems including public and legal motivations in AI, definitions of explainability, performance of deep learning techniques in the PHY and MAC layers vs explainability trade off, XAI algorithms and technical methods to improve explainability in deep learning, including symbolic representation, feature visualization techniques, local and global machine learning model reduction, and physics informed design. Finally, open research areas are highlighted.

**Article 6 (pp46-51): “Federated Learning for Wireless Communications: Motivation, Opportunities and Challenges” by Solmaz Niknam et al**

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This article highlights privacy preservation and communication limitations as another great challenge that needs to be adequately addressed by AI empowered wireless network architectures. The adoption of federated machine learning in the context of 5G networks and beyond is proposed, satisfying decentralization, privacy preservation, scalability, and efficiency requirements, taking into consideration energy, bandwidth, delay and data privacy concerns in wireless communications. After introducing federated learning, the authors discuss several possible applications in 5G networks, including edge computing and caching, spectrum management, and 5G core network functions. The authors also discuss open critical challenges concerning applications of federated learning and related considerations, including security and privacy, algorithm convergence under communication and computation limitations and wireless setting, referring mostly to wireless channel conditions/quality. To demonstrate the applicability of federated learning to content popularity prediction in a cache-enabled network for augmented reality (AR) applications, simulations were performed and the results indicate that federated learning could approach the performance of a centralized scheme.

**Article 7 (pp 52-57): “Machine Learning for End-to-end Congestion Control” by Ticao Zhang et al**

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As future networks are becoming more and more complex, conventional rule-based congestion control approaches tend to become inefficient. Therefore, ML techniques are embraced to design effective congestion control algorithms. This is the problem addressed in this article. A selected review of the recent advances on ML-based end-to-end congestion control is provided and open problems that need to be further investigated from both networking and ML perspectives are discussed, also offering insights on potential future research directions.

**Article 8 (pp 58-64): “Endogenous Security Defense against Deductive Attack: When Artificial Intelligence Meets Active Defense for Online Service” by Zan Zhou et al**

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This last article falls within the realm of security, exploiting AI to improve the endogenous security and the defense mechanisms of the active defense systems themselves. Specifically, existing static defense measures adopted for online service systems can be fragile and costly. To this respect, learning-enhanced active defense (LAD) is considered to be a promising technology. However, the security of the defense mechanism itself is neglected, focusing on fortifying the protected target. Thus, developing new defense technologies with self-protection capability is of outmost importance. The authors, after classifying LAD technologies and discussing their merits and shortcomings while analyzing relevant threats, propose a new endogenous security defense mechanism named Learning-enhanced Spatio-temporal Strategy Mutation (LSSM). This mechanism innovatively designs bidimensional strategy mutation against threats from deductive attacks, and thus ensures the endogenous security of the defense mechanism itself. The experimental results highlight the performance of the proposed mechanism.