Guest Editorial Introduction to the Special Section on Heterogeneous Communications Networks

HETEROGENEOUS communications networks, consisting of terrestrial mobile networks, satellite networks, IoT, WiFi, and etc., is a promising technique to meet the challenges in future mobile communications. Heterogeneous network resources are expected to cooperate with each other to support more efficient data transmissions and also provide more reliable services. However, current network architectures cannot efficiently exploit the benefit of heterogeneous wireless communication networks. Considering the deficiency in existing wireless networks nowadays, the most substantial amount of future system performance gains will be obtained by means of heterogeneous network infrastructure densification. Therefore, the heterogeneous communication networks should be deeply investigated to realize the full benefits of each of them.

We sincerely value the extensive efforts of the reviewers and the support from the editorial board.

The special section on "Heterogeneous Communications Networks" aims to bring together academic and industrial researchers to identify and discuss technical challenges and recent results related to heterogeneous communication networks. To summarize, we have received 32 papers and accepted 13 papers. The contributions of these papers are categorized as follows.

Leveraging the game theory, Xiong *et al.*, in "Reward Optimization for Content Providers With Mobile Data Subsidization: A Hierarchical Game Approach," propose a Stackelberg hierarchical game to model the interactions between mobile users and content providers in heterogeneous mobile networks with data subsidization, where an equilibrium program with equilibrium constraints is formulated to optimize the content providers' reward. Furthermore, in "Multi-Layer Radio Network Slicing for Heterogeneous Communication Systems," Hu *et al.* establish a three-layer Stackelberg game to tackle the joint power and frequency allocation at the infrastructure provider in a sliced heterogeneous radio access network. The proposed scheme can meet the various quality of service (QoS) requirements of heterogeneous users. Besides the game theory, reinforcement learning and deep learning have also emerged as attractive technologies in heterogeneous communication network designs. In "Traffic-Aware Rate Adaptation for Improving Time-Varying QoE Factors in Mobile Video Streaming," Xiao *et al.* formulate a centralized reinforcement learning based traffic-aware video bitrate adaptation scheme to improve the time-varying user viewing experience during mobile video transmission in heterogeneous networks. In "Deep Learning Based Radio Resource Management in NOMA Networks: User Association, Subchannel and Power Allocation," Zhang *et al.* design a deep learning based framework for radio resource management including user association, subchannel allocation, and power control in non-orthogonal multiple access aided heterogeneous networks. The developed framework is shown to offer energy and computation efficiency benefits. In "Deep Reinforcement Learning Based Resource Management for Multi-Access Edge Computing in Vehicular Networks," Peng *et al.* exploit a deep reinforcement learning based approach to jointly schedule the spectrum, computing, and storing resources in an edge computing aided vehicular network. This technique could support heterogeneous vehicular applications. From a stochastic geometry perspective, in "Performance Analysis of Heterogeneous Networks With Wireless Caching and Full Duplex Relaying," Chen *et al.* analyze the successful probability in a wireless caching enabled heterogeneous communication network. The proposed full duplex relaying abided caching model and the corresponding content hit-and-retrieve strategies aim to improve the system offloading performance. Li *et al.*, in "Achieving High Throughput for Heterogeneous Networks With Consecutive Caching and Adaptive Retrieval," devote their efforts on the throughput improvement in an information-centric networking (ICN) architecture based heterogeneous networks and developed an adaptive retrieval with consecutive caching scheme to bridge the gap between data transport and caching. This technique is shown to involve less data source node switch-over times and Interest packet overhead. In "Large-Scale User-Assisted Multi-Task Online Offloading for Latency Reduction in D2D-Enabled Heterogeneous Networks," Sun *et al.* establish a distributed optimization based task offloading framework where user-assisted computing, mobile edge computing, and cloud computing are jointly considered therein to reduce the computing latency in heterogeneous ultra-dense network. The resource management problem in virtualization and slicing enabled heterogeneous networks is explored by Cao *et al.* in "On Virtual Resource Allocation of Heterogeneous Networks in Virtualization Environment: A Service Oriented Perspective," where a service oriented scheme is proposed to allocate the sliced physical resources. This scheme considers the specificity of resource and

Digital Object Identifier 10.1109/TNSE.2020.3026566

2327-4697 © 2020 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission.
See https://www.ieee.org/publications/rights/index.html for more information.

QoS requirement in each virtual network service and thus achieves more efficient resource utilization. To maximize the value created by heterogeneous communication networks, Wu *et al.*, in "FlowTrace: Maximizing the Service Payoff of Heterogeneous Communications Networks," design a QoS guarantee scheme named FlowTrace to allocate the bandwidth online and optimize the service payoff of the network. This technique could reduce the computational burden of the centralized network controller. In "Abnormal Crowd Traffic Detection for Crowdsourced Indoor Positioning in Heterogeneous Communications Networks," Li *et al.* investigate the security risks in WiFi fingerprint-based positioning aided heterogeneous networks and proposed an abnormal crowd traffic detection approach to detect attackers based on their abnormal received signal strength sensing behaviors. It is expected this technique to begin a trend to identify malicious attackers using the location information and identity changing. More interestingly, the physical layer aspects of heterogeneous communication networks are investigated by Bai *et al.* in "A Precoding Compensation Scheme for Heterogeneous Communication Networks With CSI Feedback Delay," where a robust precoding compensation scheme is formulated to mitigate the interference among coordinated base stations under outdated channel state information feedback. Finally, in "Polymorphic Smart Network: An Open, Flexible and Universal Architecture for Future Heterogeneous Networks," Hu *et al.* design a novel network architecture called Polymorphic Smart Network by introducing the concept of structure definability to all layers of the network. This new design is expected to meet the business requirements of future heterogeneous networks.

We believe this special section is timely and important in enhancing and advancing research on heterogeneous communication networks. We hope that this special section will impact and contribute to diverse communities in academia and industry with interests in heterogeneous communication networks.

CHUNXIAO JIANG, *Guest Editor*
Tsinghua Space Center
Tsinghua University
Beijing 100084, China

ABDERRAHIM BENSLIMANE, *Guest Editor*
University of Avignon
84911 Avignon, France

MIANXIONG DONG, *Guest Editor*
Department of Sciences and Informatics
Muroran Institute of Technology
Muroran 050-0071, Japan

EKRAM HOSSAIN, *Guest Editor*
Department of Electrical and Computer Engineering
University of Manitoba
Winnipeg, MB R3T 5V6, Canada

Chunxiao Jiang (Senior Member, IEEE) is currently an Associate Professor with the School of Information Science and Technology, Tsinghua University, Beijing, China. His research interests include application of game theory, optimization, and statistical theories to communication, networking, and resource allocation problems, in particular space networks and heterogeneous networks.

Abderrahim Benslimane (Senior Member, IEEE) has been a Professor in computer science with Avignon University, Avignon, France, since 2001. His research interests are in development of communication protocols with the use of graph theory for mobile and wireless networks.

Mianxiong Dong (Senior Member, IEEE) became the youngest ever Professor with the Muroran Institute of Technology, Muroran, Japan, where he is currently the Vice-President. His research interests include wireless networks, cloud computing, and cyberphysical systems.

Ekram Hossain (Senior Member, IEEE) is currently a Professor and an Associate Head (Graduate Studies) with the Department of Electrical and Computer Engineering, University of Manitoba, Winnipeg, MB, Canada. His current research interests include design, analysis, and optimization beyond 5G cellular wireless networks.