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Space-air-ground integrated networks for future IoT: Architecture, management, service and performance

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Guest Editorial:

With the emerging applications of ubiquitous Internet of Things (IoT), autonomous driving, and virtual reality (VR)/augmented reality (AR), future networks are expected to enable ultra-reliable and low-latency communications (URLLC), and support massive simultaneous access with extremely high data rates (~ 10Gbps). Terrestrial networks, e.g., the well-deployed 4G or the emerging 5G cellular networks, are unable to fully satisfy the Quality of Services (QoS) due to their limitations, such as the inflexibility of fixed ground infrastructure, coverage holes, and rigid resource feeding manner, etc. Space networks (e.g., low Earth orbit (LEO) satellites) and aerial networks (e.g., unmanned aerial vehicles (UAVs)) can be leveraged to extend the scope of the terrestrial networks and constitute the space-air-ground integrated networks (SAGIN) ingeniously. Particularly, in SAGIN, in addition to the terrestrial networks, the satellites can provide ubiquitous wireless coverage cost-effectively, and the on-demand deployment of aerial networks can enhance the network flexibility and adaptability to various and dynamic environments, collectively ensuring the network QoS in supporting IoT services.

Despite the promising merits of SAGIN, technical and in-depth researches for SAGIN are urgently required. On the one hand, the heterogeneous network resources that have distinct features in terms of spectrum usage, access technology, transmission performance, and mobility characteristic, can render the operation and management of network intricate, which challenges the crucial construction of network architecture, resource management, and protocol design. On the other hand, to fully unleash the potential of SAGIN, the novel service provision, new computing-communication integrated paradigms, and performance modeling and analysis in SAGIN, need further investigation.

This special issue aims to bring together state-of-the-art research contributions that push forward the technological developments related to SAGIN enabled IoT, which will focus on the SAGIN network architecture design and implementation, resource management and orchestration, software-defined SAGIN, edge computing/ intelligence, IoT services, performance analysis and evaluation, and other promising technologies in SAGIN enabled IoT.

The response to our call for this special issue was significant, as we received in total 22 submissions from around the world. During the review process, each article was assigned to and reviewed by at least three experts in the field, with a rigorous multi-round review process. Thanks to the great support from the Editor-in-Chief, Prof. Xuemin (Sherman) Shen, and the dedicated work of numerous reviewers, we were able to accept 9 high-quality articles covering various topics in SAGIN. In what follows, we will introduce these articles with highlighting their contributions.

In this first article "A Distributed Matching Game for Exploring Resource Allocation in Satellite Networks", Mi et al. proposed a novel one-to-one matching model under

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bilateral preferences in order to satisfy the QoS requirements with limited resources, and then devised the Task-Oriented Gale-Shapley (T-O GS) algorithm and Adjacent Time Slot Matching (ATSM) algorithm to achieve the stable matching dynamically.

In the article "Cooperative Content offloading Scheme in Air-Ocean Integrated Networks", Zhou et al. proposed a Q-learning and game based unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs) cooperation content offloading scheme in the air-ocean integrated networks (AOINs), which can significantly improve the use efficiency of UAV and increase the utility of USV compared with the traditional schemes.

In the article "Joint Association and Power Optimization for Multi-UAV Assisted Cooperative Transmission in Marine IoT Networks", Lyu et al. proposed a multi-UAV assisted cooperative transmission to maximize the total throughput under the constrained of outage probability, transmit power and available channels, where they analyzed the achievable transmission reliability of the USV-OBS link, and the USV-UAV association and the transmit power control are jointly optimized to maximize the total transmission throughput for environment monitoring in marine IoT systems.

In the article "Downlink Aware Data Scheduling with Delay Guarantees in Resource-Limited LEO Satellite Networks", Wan et al. proposed a downlink aware data scheduling algorithm based on a decomposition strategy of rolling horizon mechanism, which can improve the network profit with guaranteeing the transmission delay.

In the article "A Double-layer Collaborative Apportionment Method for Personalized and Balanced Routing", Wei et al. proposed a double-layer collaborative apportionment method, named 2 L-CoV, for personalized and balanced routing in transportation system, which can guide traffic flow speed, and plan the routing with considering the driving preferences under the assistance of space-air-ground integrated networks.

In the article "An ACO-based Cross-layer Routing Algorithm in Space-Air-Ground Integrated Networks", Zheng et al. proposed a novel ACO-based cross-layer routing algorithm for Space-air-ground integrated networks, which takes the link quality and end-to-end packed delay in the physical layer as driving factors to search for the optimal routing path.

In the article "Trust based Task Offloading Scheme in UAV-enhanced Edge Computing Network", Ouyang et al. proposed a trust based intelligent task offloading scheme in the UAV-enhanced edge network, which can effectively reduce both the task loss rate of the network and the total energy consumption of the IoT devices.

In the article "Resource Management of GEO Relays for Real-Time Remote Sensing", Xu et al. proposed a real-time resource management approach for GEO relaying, aiming at maximizing the network throughput and reducing the transmission delay.

In the article "An efficient three-factor remote user authentication protocol based on BPV-FourQ for Internet of Drones", Zhang et al. proposed a lightweight multi-factor authentication and key agreement (AKA) protocol for Internet of Drones (IoD), which can realize the real multi-factor security using smart card, biometric and password, and achieve perfect forward secrecy and anonymity of users.

We would like to express our sincere gratitude to all the authors for submitting their papers and to the reviewers for their valuable comments and suggestions that significantly enhanced the quality of these articles. We are also grateful to Prof. Shen, the Editor-in-Chief of Peer-to-Peer Networking and Applications, for his great support throughout the whole review and publication process of this special issue, and, of course, to all the editorial staff for their great helps. We hope that this special issue could be a useful reference for researchers, scientists, engineers, and academics in the field of IoT networks.

Feng Lyu received the PhD degree from the Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, China, in 2018, and the BS degree in software engineering from Central South University, Changsha, China, in 2013. During respective Sept. 2018-Dec. 2019 and Oct. 2016-Oct. 2017, he worked as a postdoctoral fellow and was a visiting PhD student in BBCR Group, Department of Electrical and Computer Engineering, University of Waterloo, Canada. He is currently a professor with the School of Computer Science and Engineering, Central South University, Changsha, China. His research interests include vehicular networks, beyond 5G networks, big data measurement and application design, and could/edge computing. He is the recipient of the best paper award of IEEE ICC 2019, and Norbert Wiener Review Award 2020 of IEEE/CAA Journal of Automatica Sinica. He currently serves as associate editor for IEEE Systems Journal, leading guest editor for Peer-to-Peer Networking and Applications, and guest editor for China Communications, and served as TPC members for many international conferences. He is a member of the IEEE Computer Society, Communication Society, and Vehicular Technology Society.

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