Ubiquitous IoT with Integrated Space, Air, Ground, and Ocean Networks

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Global connections to everyone and anything are becoming increasingly important as Internet of Things (IoT) applications and services spread throughout our society. Such needs cannot be met by terrestrial networks alone. Hence the idea of combining space, air, ground, and water communication infrastructures has emerged. The integrated platform that emerges from this process should not simply be a mashup of several networks and domains. It is extremely difficult to manage heterogeneity and hybridity's full potential at the world's largest geographical scale ever.

Recent advancements in networking, computation, and artificial intelligence provide us a realistic chance to overcome those obstacles. By unifying high-level behaviors, SDN/NFV-based network virtualization improves the effectiveness and efficiency of coordination of heterogeneity and hybridity. Simultaneously, deep machine learning offers new structural models for accumulating information about specified networks and applying authorized experience, and current microelectronics production enables substantial increases in processing capacity per unit area of chips at a lower cost.

The purpose of this special issue is to encourage astute colleagues to offer cutting-edge knowledge and technological perspectives on ubiquitous IoT with integrated space, air, ground, and ocean networks. Our Call for Papers received worldwide responses with a large number of high-quality submissions. Due to the limited space, we selected only 10 papers that are best aligned with this feature topic and able to outline the main research directions and future works.

The article "Cooperative Drone Communications for Space-Air-Ground Integrated Networks" studies energy-and-spectrum-limited communication among cooperative drones for space-air-ground-integrated networks. The article "Unlocking Unlicensed Band Potential to Enable URLLC in Cloud Robotics for Ubiquitous IoT" investigates the challenges for Ubiquitous IoT (UIoT) operating in the unlicensed band and also discusses enabling technologies to facilitate URLLC in the unlicensed band for ubiquitous cloud robotics applications. Future UIoT service requests will probably be irregular and span across different geographic regions. The article "Intelligent Resource Management at the Edge for Ubiquitous IoT: An SDN Based Federated Learning Approach" presents an SDN-assisted Federated Learning framework to provide secure and trustworthy service delivery and ensure seamless communication to users. Emergency scenarios confront many unprecedented ser-

vice requirements and challenge the ubiquitous connectivity of integrated networks. The article "UAV-based Wide-area Internet of Things: An Integrated Deployment Architecture" presents an unmanned aerial vehicle-based wide-area IoT deployment framework to effectively deal with wireless information interactions in emergency scenarios. Federating learning is a valuable machine learning paradigm and utilized in several articles. To develop a lightweight training framework, the article "On Smart IoT Remote Sensing over Integrated Terrestrial-Aerial-Space Networks: An Asynchronous Federated Learning Approach" presents an asynchronously updated federated learning model for the edge nodes for data exchange efficiency and privacy. The article "Federated Imitation Learning: A Cross-Domain Knowledge Sharing Framework for Traffic Scheduling in 6G Ubiquitous IoT" presents a cross-domain knowledge-sharing framework to allocate the heterogeneous IoT resources for efficient traffic scheduling in 6G UIoT networks. Considering the scarcity of available spectrum resources, the article "Blockchain-Based Dynamic Spectrum Sharing for 6G UIoT Networks" proposes integrating hybrid blockchain technology into a 6G cloud to enable dynamic spectrum sharing between UIoT devices. The article "Key Technologies in 6G SAGS IoT: Shape Adaptive Antenna and Radar Communication Integration" mainly demonstrates the effects of the proposed shape-adaptive antennae and the performance of its application in radar-communication integration systems and the use of micro-Doppler to identify UAVs. The article "Integrating Sensing and Communications for Ubiquitous IoT: Applications, Trends, and Challenges" lists the achievable gains by integrating sensing and communications (ISAC) and discusses some major solutions to the integration to highlight the essential role of ISAC in the IoT era. Service coordination is a crucial technology to guarantee quality and continuity of services in space-air-ground networks. The article "Service Coordination in Space-Air-Ground Integrated Network" presents a service coordination approach to reduce service delays and low costs.

This Feature Topic seeks to promote the dissemination of high-quality research, including novel concepts, methods, theories, frameworks, and practices for addressing the complex problems associated with ubiquitous IoT with integrated space, air, ground, and ocean networks. Additionally, innovative solutions were proposed that combine industry views and cutting-edge academic models with real-time data. As the research is still in its infancy, we hope that this Feature

Topic will serve as a helpful resource while encouraging additional *IEEE Network* users to contribute their efforts in this field.

Finally, we would like to express our gratitude to all the authors for their generous submissions and all the reviewers for their timely and professional reviews. We also acknowledge the support from the Editor-in-Chief of *IEEE Network* and the help from the publication staff for their efforts in the publication process.

BIOGRAPHIES

TIANYANG BAI received the B.E from Harbin Institute of Technology, Harbin, China, in 2007, and the M.S.E. and Ph.D. degrees from The University of Texas at Austin, Austin, Texas, USA, in 2013 and 2016, respectively, all in electrical engineering. Since July 2016, he has been with Wireless R&D at Qualcomm Technologies, Inc., where he is a staff system engineer working on millimeter wave (mmWave) communication technologies in 5G standards. He has published several highly cited journal papers on performance analysis of mmWave cellular networks. He has 53 issued and many pending U.S. patents in the field of wireless communications. He is a recipient of the 2014 Qualcomm Roberto Padovani Awards.

JALEL BEN-OTHMAN received his B.Sc. and M.Sc. degrees, both in computer science, from the University of Pierre et Marie Curie, Paris 6, France in 1992, and 1994, respectively. He received his Ph.D. degree from the University of Versailles, France, in 1998. He is currently a full professor at the University of Paris 13 since 2011, and a member of the L2S lab at CentraleSupélec. His research interests are in the area of wireless ad hoc and sensor networks, VANETs, IoT, performance evaluation and security in wireless networks in general. He was the recipient of the IEEE ComSoc Communication Software Technical Committee Recognition Award in 2016, the IEEE Computer Society Meritorious Service Award in 2016, and he is a Golden Core Member of the IEEE Computer Society, AHSN Exceptional Service and Contribution Award in 2018 and the VEHCOM Fabio Neri award in 2018. He has served as a Steering Committee member for *IEEE Transaction on Mobile Computing*. He is currently as a senior editor for *IEEE communication Letters*, an Editorial Board member for several journals (*IEEE Network*, *IEEE IoT Journal*, JCN, IJCS, SPY, and *Sensors*, among others). He has also served as TPC Co-Chair for IEEE Globecom and ICC conferences and other conferences as, including WCNC, IWCMC, VTC, ComComAp, ICNC, WCSP, Q2SWinet, P2MNET, and WLN, among others. He was the chair of the IEEE Ad Hoc and Sensor Networks Technical Committee January 2016-2018, and he was previously the Vice Chair and Secretary for this committee. He was an IEEE ComSoc distinguished lecturer from 2015 to 2018, and he is currently an IEEE VTS distinguished lecturer, completing several tours around the world. He has been member of IEEE Technical Services Board since 2016.

SHUAI HAN (S'11–M'12–SM'17) is currently a full professor in the Department of Electronics and Communication Engineering, Harbin Institute of Technology. His research interests include wireless communications security, satellite communications and the global navigation satellite system. Over his academic career, his students and he have contributed in various fields in wireless networks and wireless positioning. His IEEE ICC2017 paper on wireless security was a candidate for best paper. His WiCON2017 paper on Full Duplex Decode-and-Forward Cooperative Relay System was the best paper. As PI, he has four national grants and more than 20 industrial grants on wireless networks and positioning. He has also participated in major projects on the national level in China. He was an associate editor of *IEEE China Communications*, *Journal of Communications and Information Networks*, and *Journal of Telemetry, Tracking and Command*, and he has served as a guest editor for many IEEE magazines and journals. He has served as a co-chair for technical symposia of international conferences including IEEE GC 2021, IEEE GC 2019, ICC 2018, IEEE VTC Fall 2016. He has also served as the TPC Chair for international conferences, including the AICON2019 and MLICOM2018. He is a senior member of IEEE, Vice Chair of the IEEE Harbin ComSoc Chapter, and Vice Chair of IEEE Harbin VTS Chapter.

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BO RONG is a research scientist with the Communications Research Centre, Canada. He has authored or co-authored over 100 technical papers in major journals and conferences on the topic of wireless networking and communications. Many of these publications have theoretical and practical significance to the research community and industry. His research interests include space-air-ground integrated networks (SAGINs), deep machine learning, intelligent RRM in 5G/6G, smart IoT, etc. He is a member of the IEEE Communications Society and the IEEE Broadcasting Society. He serves as an associate editor for *IEEE Network*, as well as a guest editor of special issues in *IEEE Communications Magazine*, *IEEE Wireless Communications Magazine*, and *IEEE Internet of Things Journal*.