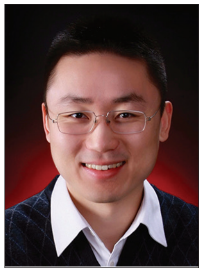
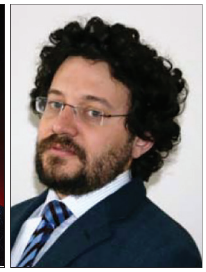
Space Information Networks



Lin Bai



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With the growing demand for real-time communications anywhere for anyone, satellite communications are widely expended using different platforms on geostationary Earth orbit (GEO) satellites and medium/low Earth orbit (M/LEO) satellites. However, suffering from scarce frequency/orbit resources and limitation of satellite platform capacity, there is a demand for the development of new space network infrastructures to supplement and extend the satellite communication systems. The space information networks are integrated networks based on various space platforms including GEO, M/LEO satellites, and airships on high altitude platform stations (HAPSs) to support real-time communications, massive data transmission and processing, and systematized information services. In the last decade, many Internet giants have proposed various space information network development projects aimed at providing Internet access anywhere and at any place for everyone globally. Compared to terrestrial networks, space information networks have broader application areas and wider coverage, which may expand human activities to space, high seas, and even outer space. Due to the unique features (i.e., high altitude, wide coverage, and line-of-sight transmission) of space information networks, they are expected to play a key role in the applications of communications, remote sensing, air traffic control, aviation/maritime communications, Internet of Things (IoT), and aerospace measurement. Particularly, space information networks become more significant and indispensable to construct Internet infrastructures in remote areas of the globe and provide emergency communication services in case of natural disasters (hurricanes, earthquakes, floods, etc.). However, the extension of space-time coverage leads to numerous theoretical and technical challenges with respect to the development of space information networks given the restricted spectrum, energy, and orbit resources. In order to thoroughly discover the fundamental issues of SIN and their applications, the basic theories and key technologies for space information networks need to be explored.

This Special Issue aims to reflect the recent theoretical foundations and original technical contributions on space information networks. This collection consists of eight articles that cover a wide range of research topics on space information networks, including the basic information network architecture, antenna and beamforming design for satellite systems, resource allocation and multiple user access schemes, and the network layer design for integrated space-air-ground systems.

In the first article, "Effects of Solar Scintillation on Deep Space Communications: Challenges and Prediction Techniques" by Guanjun Xu and Zhaohui Song, the state of the art of solar scintillation research is reviewed. It proposes a more applicable and accurate solar scintillation prediction model to overcome the problems of the existing solar scintillation models. The bit error rate (BER) performance of the proposed channel and link models is further analyzed. The authors also shed light on future research on the key techniques of solar scintillation analysis and mitigation in deep space communications during superior solar conjunctions, which is a promising research direction for space information networks.

In the second article, "Multiple User Transmission in Space Information Networks: Architecture and Key Techniques" by Xuejun Zhang, Lina Zhu, Tian Li, Yongxiang Xia, and Weihua Zhuang, a general architecture and key techniques for multiple user transmission in space information networks are investigated. The authors present advantages and applications of multiple antennas, and various multiple user access especially non-orthogonal approaches and cooperative transmission methods in satellite and satellite-terrestrial communication systems. They provide a brief but typical architecture of the multi-user system in future space information networks.

In the third article, "Application of Time Modulated Array in Satellite Communication" by Chong He, Qun Chen, Anjie Cao, Jingfeng Chen, and Ronghong Jin, an overview of the time modulated array (TMA) and its possible applications in satellite communication systems is introduced. Further, the authors propose an effective user detection and tracking method that can be used in satellite, based on which adaptive beamforming schemes are used to enhance the performance of the TMA.

In the fourth article, "IoT Applications and Services in Space Information Networks" by Manlio Bacco, Luca

Boero, Pietro Cassará, Marco Colucci, Alberto Gotta, Mario Marchese, and Fabio Patrone, horizontal solutions are analyzed to allow interworking among different protocol stacks and services by acting as relay entities, which can be vertically implemented over different network segments. The authors also propose a protocol stack for machine-to-machine (M2M)/IoT communications based on the oneM2M standard. At the end of the article, the performance of the most diffused application protocols, Constrained Application Protocol (CoAP) and Message Queuing Telemetry Transport (MQTT), are compared to shed light on their efficiency and differences.

In the fifth article, "Bidirectional Mission Offloading for Agile Space-Air-Ground Integrated Networks" by Sheng Zhou, Guangchao Wang, Shan Zhang, Zhisheng Niu, and Xuemin (Sherman) Shen, the concept and key role of network reconfiguration in a space-air-ground information network are introduced. A bidirectional mission offloading approach is proposed by using network functions virtualization (NFV) and service function chaining (SFC). The article also presents a case study to validate the performance gain brought by bidirectional mission offloading.

In the sixth article, "Compressed Robust Transmission for Remote Sensing Services in Space Information Networks" by Hancheng Lu, Yongqiang Gui, Xiaoda Jiang, Feng Wu, and Chang Wen Chen, compressive sensing and robust transmission based SoftCast are investigated for downlink image/video-based remote sensing services under resource-limited, time-varying, and heterogeneous space environments. Specifically, an efficient ComCast scheme is proposed and implemented by integrating compressive sensing and robust transmission into one framework, based on which resource allocation is addressed to minimize system distortion caused by both CS and transmission. Simulation results are provided to demonstrate the advantages of ComCast over the existing CS-based scheme, which contribute to the application of ComCast for remote sensing image/video transmission in space information networks.

In the seventh article, "Broadband LEO Satellite Communications: Architectures and Key Technologies" by Yongtao Su, Yaoqi Liu, Yiqing Zhou, Jinhong Yuan, Huan Cao, and Jinglin Shi, a comprehensive overview of key issues in broadband LEO satellite communication systems is provided, including the network architecture, the satellite constellation, coverage models, interference coordination schemes, and global resource management. The article also solves some open issues in LEO satellite communication systems such as optimal routing strategies, coordination of multiple constellations, and adaptive frequency and bandwidth usage for minimizing the interference. The work provides a technically meaningful reference in the design of broadband LEO satellite communications that support stable, convenient, and low-cost broadband access services for anyone at any time and any place.

In the eighth article, "Ultra-Dense LEO: Integration of Satellite Access Networks with 5G and Beyond" by Boya Di, Lingyang Song, Yonghui Li, and H. Vincent Poor, a network architecture for the dense LEO-satellite access network is introduced where the terrestrial and satellite communications are integrated to offer more reliable and flexible access. Several key techniques for the dense LEO-satellite access network, such as interference management, diversity technique, and cognitive radio schemes, are proposed to achieve seamless and high data rate wireless links for devices with different QoS requirements. Furthermore, the authors discuss several applications and future research directions in both the physical layer and network layer, which shed light on further integration of heterogeneous satellite systems and the extension to other space information networks.

In the end, we would like to thank all the authors for submitting their research work to this Special Issue, and also for the contribution of many experts in the field who have participated in the review process. We hope the articles in this issue will be good references for future research in space information networks.

Biographies

Lin Bai [SM'17] received his Ph.D. degree in advanced telecommunications from the School of Engineering, Swansea University, United Kingdom, in 2010. Since 2011, he has been with Beihang University, Beijing, China, as an associate professor. He is now with the School of Cyber Science and Technology as assistant dean. His research interests mainly focus on signal processing of wireless communications and UAV communications. He serves as an Editor of *IEEE Wireless Communications Letters* and the *Journal of Communications and Information Networks*.

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Quan Yu [SM'15] received his Ph.D. degree in fiber optics from the University of Limoges in 1992. Since 1992, he joined the faculty of the Institute of China Electronic System Engineering Corporation. He is currently a principal research scientist at Peng Cheng Laboratory.His main areas of research interest are the architecture of wireless networks, optimization of protocols, and cognitive radios. He is an Academician of the Chinese Academy of Engineering (CAE) and the founding Editor-in-Chief of the *Journal of Communications and Information Networks*.

Wei Zhang [F'15] received his Ph.D. from the Chinese University of Hong Kong in 2005. He is a professor at the University of New South Wales, Sydney, Australia. His current research interests include 5G communications, mmWave communications, and space information networks. He is the Editor-in-Chief of *IEEE Wireless Communications Letters* and the *Journal of Communications and Information Networks*. He is a member of the Board of Governors of IEEE Communications Society.