It has been expected that space information networks (SINs), as an extension of terrestrial networks, would provide high-speed, high-capacity, global continuous communication, and data transmission services anywhere for anyone at any time. With the rapid advances in relevant technologies (e.g., satellite miniaturization technology, reusable rocket launch technology, and semiconductor technology), low-orbit satellites, drones, and airships can be integrated into the SIN to supply more comprehensive network connectivity. The standards development organizations including 3GPP, ITU, and ETSI already started corresponding standardization activities to support non-terrestrial networks in SINs. One can foresee that SINs will be expanded to provide not only telephone services but also various kinds of Internet services, and they will thus be able to serve many more users with different demands.

Though some progress has been made in related technologies, SINs still face a variety of technological challenges and design issues in the aspects of communication, networking, security and so on, which has delayed their practical implementation. First, since resources such as orbit, spectrum, and bandwidth are limited, how to allocate them efficiently and reasonably is a vital issue that needs to be addressed in SINs. In addition, with the increase of computing and storage resources in SINs, how to carry out the integrated design of computing, storage, and transmission capacity so as to optimize the overall network capacity is a new challenge that SINs researchers need to face. Second, the huge increase in the number of low-orbit satellites and various spacecraft, as well as the heterogeneous hybrid network formed by low-, medium-, and high-orbit satellites, bring a great challenge to networking. The high dynamics, long delay, and large variance of the connections make access and transmission hard to maintain effectively. Moreover, as an important step for 5G/6G networks, how to extend SINs with traditional terrestrial networks also triggers many concerns in practical systems. Third, security aspects still have not yet received sufficient attention, though they are a key issue in SINs. The features of spectrum openness and the fact that satellites are far away from physical control pose a desperate need of a certain degree of security protection in SINs. In addition, some emerging technologies in communication, networking, and security, such as Mobile Edge Computing (MEC), Software Defined Networking (SDN), Information-Centric Networking (ICN), and Blockchain, play great roles in promoting the development of SINs, but also bring about a series of new theoretical and technical problems that must be studied and solved. Moreover, the construction of SINs requires the joint efforts of multiple countries and a large number of enterprises and research institutions around the world, and it will last for decades, which makes its standardization increasingly important.

This special issue is intended to present and highlight the advantages, latest technologies, and implementations and applications related to the issues of communication, networking and security in SINs. We received 44 submissions, and after a rigorous review process, only 13 articles were accepted for the special issue. We hope these articles will show their value over time, while being helpful for our current readership. A brief view of each of the articles follows.

In the article “Satellite-Based Radio Spectrum Monitoring: Architecture, Applications, and Challenges”, the authors present a space spectrum monitoring framework by using small satellites in low Earth orbit. This framework can greatly expand the monitoring coverage to a global scale and flexibly determine the locations of interference sources. Moreover, it can significantly promote international frequency coordination and spectrum sharing in future wireless networks. The authors also present key applications and identify the main challenges and future directions.

In the article “Spectrum Sharing for 6G Integrated Satellite-Terrestrial Communication Networks Based on NOMA and CR”, the authors propose to improve satellite-terrestrial spectrum sharing performance by introducing non-orthogonal multiple access (NOMA) and cognitive radio (CR) in the spectrum access of integrated satellite-terrestrial communication networks (ISTCNs). By integrating NOMA and CR, the proposed scheme allows multiple satellite terminals to access both the idle and busy spectrum simultaneously, which will achieve high-efficiency full spectrum access. Furthermore, some open research and challenges for the spectrum sharing of the ISTCN are discussed in the article.

In the article “Scalable Traffic Control Using Programmable Data Planes in a Space Information Network”, the authors design an in-network traffic control powered by SIN architecture to enhance network performance. They further present two use cases, i.e., in-network load balance and in-network congestion control, to demonstrate the feasibility of the designed architecture. For both of these two use cases, they conduct preliminary evaluations to prove the performance potential of the architecture design.

In the article “Converged Reconfigurable Intelligent Surface and Mobile Edge Computing for Space Information Networks”, the authors propose a reconfigurable intelligent surface (RIS) assisted collaborative mobile edge computing (MEC) architecture for SINs, in which RISs and MEC platforms are integrated in SINs to improve the capability of communications and computations. They further design different offloading schemes for the different MEC platforms, and present an implementation strategy for the proposed RIS-assisted collaborative MEC. They also discuss the benefits, challenges, applications, and services of
the proposed RIS-assisted collaborative MEC, and subsequently investigate three cases to evaluate the performance of the proposed architecture.

In the article “Blockchain-Based Secure Communication for Space Information Networks”, the authors investigate several challenges faced by SINs and give the possible roles of blockchain for secure communications. They design a blockchain architecture suitable for SINs and present two secure communication protocols, i.e., Fulgor and Rayo, designed for different application scenarios in SINs: 1) Fulgor is a secure communication protocol between users and the ground station based on the proposed efficient authentication and key agreement protocol; 2) Rayo is a user-to-user privacy-preserving communication protocol to protect users’ privacy and avoid DoS attacks. Experiments are conducted and performed on a widely known blockchain platform, i.e., Hyperledger Fabric, and the findings demonstrate the feasibility of the proposal.

In the article “QoE-Aware Video Streaming over Integrated Space and Terrestrial 5G Networks”, the authors propose a novel scalable video coding (SVC)-based content delivery framework for a satellite and terrestrial integrated 5G network, which aims at delivering an enhanced quality of video viewing experience to end users by efficiently utilizing both of the available backhaul links. The proposed framework is deployed at the MEC server, and utilizes a prefetching and processing mechanism during the content distribution process. The framework is validated using a real over-the-air satellite and terrestrial integrated 5G network. Experimental results reveal that the proposed content delivery framework is able to deliver a high-quality stalling-free video viewing experience to all active users by achieving a high degree of content offloading from the terrestrial link to the satellite backhaul link, thus saving limited terrestrial network resources.

In the article “QoS Provisioning in Space Information Networks: Applications, Challenges, Architectures, and Solutions”, the authors first introduce the applications in three emerging scenarios in terms of traffic characteristics and Quality of Service (QoS) requirements, and then identify the accompanying technical challenges for SINs. Then, a QoS provisioning architecture with two differentiated transmission modes is proposed: 1) the mirror source mode for bandwidth-tolerant flows improves the network efficiency by centralized traffic scheduling; 2) the preemptive mode for bandwidth-sensitive flows reduces the end-to-end delay by edge node control. Furthermore, the authors analyze the enabling technologies and potential solutions for control logic and forwarding mechanism, and future research directions are also discussed.

In the article “Flexible and Distributed Mobility Management for Integrated Terrestrial-Satellite Networks: Challenges, Architectures, and Approaches”, the authors propose flexible and distributed mobility management architectures for integrated terrestrial-satellite networks (ITSNs) to improve mobility management performance by flexible reconfiguration of space-distributed mobility management functions (MMFs). Toward link-layer handover decisions, a lightweight and intelligent handover decision framework is devised to realize efficient and unified radio access point (RAP) selections for massive handovers and different decision making conditions. The simulation results validate the high performance of the proposed architectures and approaches in terms of handover delays, signaling overheads, and convergence property.

In the article “SpaceDML: Enabling Distributed Machine Learning in Space Information Networks”, the authors propose a distributed machine learning system, named SpaceDML, for satellite platforms that applies dynamic model compression techniques to adapt distributed machine learning training to SINs’ limited bandwidth and unstable connectivity. SpaceDML has two key algorithms: adaptive loss-aware quantization, which compresses models without sacrificing their quality, and partial weight averaging, which selectively averages active clients’ partial model updates. These algorithms jointly improve communication efficiency and enhance the scalability of distributed machine learning with SIN devices. By training a LeNet-5 model on the MNIST dataset, the experimental results show that SpaceDML can increase model accuracy by 2 to 3 percent and reduce communication bandwidth consumption by up to 60 percent compared to the baseline algorithm.

In the article “A Secure Architecture of Relay-Aided Space Information Networks”, the authors propose a relay-aided secure architecture to enable efficient connections for different IoT devices in a SIN with security, where relays are deployed together with hopped beams to relieve the jamming attack of the uplink and combat the eavesdropping attack of the downlink. In the proposed architecture, inter-satellite beam hopping is developed to build jamming-free uplink channels by using spatial diversity, while relay selection is carried out to generate eavesdropping-free downlink channels within the coverage of a beam. Meanwhile, relay deployment optimization is studied to maximize the system efficiency, and data aggregation is adopted to encrypt the data packets of IoT devices at relays.

In the article “Centralized and Decentralized Routing Solutions for Present and Future Space Information Networks”, the authors propose two practical centralized routing approaches, i.e., centralized first ended (CME) and exhaustive breath-first search (BFS), for SINs able to cover both IF and SCF traffic flows, which can ensure the discovery of all routes on the ground. Evaluation results provide compelling evidence that centralized routing schemes can safely, successfully, and efficiently connect SINs with up to 10,000 daily contacts, while contact graph routing (CGR) can be better entrusted with larger-scale SIN deployments.

Finally, the Guest Editor team would like to thank all the authors of the 44 papers that were submitted to this special issue, and thank all the reviewers who provided thorough and timely reviews. We would also like to thank Dr. Chonggang Wang, Editor-in-Chief (EiC), for his continuous support and constructive suggestions to improve this special issue, as well as the IEEE Network staff for their support in the preparation of this special issue. More importantly, we sincerely hope that the readers will find the articles published in this special issue interesting and helpful with further research in space information networks.

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