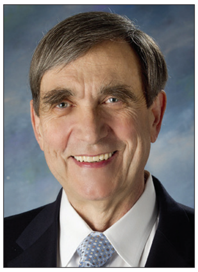
Space and Terrestrial Integrated Networks: Emerging Research Advances, Prospects, and Challenges



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Currently, many aerial platforms, satellite systems, and space and terrestrial integrated networks (STINs) have been developed, while some of them are still under construction. The basic idea of STIN is to simply connect heterogeneous devices, systems, and networks via the Internet, thus providing much more effective services than traditional infrastructures. Through effective acquisition, coordination, transmission, and aggregation of multi-dimensional information, the resource planning, task distribution, and action management of STIN can be realized. The goal is to provide all kinds of users a real-time and reliable communication infrastructure by conducting efficient collaboration. However, there are still many open issues that need to be solved. For example, signal distortion and fading in the network connections in the atmosphere often occur. Therefore, the design of STIN typically needs to take into account signal distortion and fading, multiple access interference, large latency, and so on. At present, the development of STIN has reached a crossroad. Radio resource management, transparent handover, network management, wireless communication, and other promising technologies (e.g., long-term evolution, software-defined networking [SDN], and device-to-device communication [D2D]) are critical research trends for such hybrid satellite-aerial-terrestrial networks.

In response to the Call for Papers, we received 23 submissions. After a careful review process, 10 outstanding papers were selected for this Special Issue. The issue opens with an article on an identifier framework in STIN networks, "SI-STIN: A Smart Identifier Framework for Space and Terrestrial Integrated Network," authored by Su *et al.* A novel heterogeneous wireless network architecture named the smart identifier for space and terrestrial integrated network (SI-STIN) is designed to coordinate heterogeneous communication networks and platforms to provide more effective services, which seriously hinder the further development of networks. Based on the smart identifier network (SINET), SI-STIN aims to solve the problem of the heterogeneous convergence of the integrated network layer, break through the triple binding of the traditional network layer design, and ultimately achieve high efficiency for resource integration and interconnection. Experimental analysis verifies that SI-STIN improves the performance in regard to network security and transmission efficiency, and thus has great potential to satisfy various network demands. The second article, "Heterogeneous Space and Terrestrial Integrated Networks for IoT: Architecture and Challenge," by Lai *et al.*, targets the problem of integrating communication protocols, the routing problem, and resource allocation in the large-scale and heterogeneous network architecture. Therefore, this article proposes a potential H-STIN architecture based on the development trends of the Internet of Things (IoT), mobile networks, and satellite networks. Since a terrestrial network (TN) has adequate computation resource and routing architecture, the backbone network is given to support an entire network, and the autonomous system (AS) is adopted to achieve regional self-optimization. The self-organization satellite-terrestrial integrated system (SSTIS) is composed of the perception layer, the cognition layer, and the intelligence layer. It integrates IoT, SDN, and network functions virtualization (NFV) technologies to achieve self-monitoring, crisis forecasting, and optimal control.

The article "Software Defined Space-Terrestrial Integrated Networks: Architecture, Challenges, and Solutions" by Han *et al.* reveals that STIN is still confronted with some fundamental challenges including time-varying network topology, high satellite mobility, large end-to-end delay, scalability, and so on. In this article, the authors present a composite architecture that integrates space and terrestrial network components for providing anytime anywhere communications by utilizing the SDN paradigm and mobile edge computing, which not only facilitates the network management and increases network flexibility, but also provides improved quality of service (QoS) for global multimedia services. In the fourth article, "A Cross-Domain SDN Architecture for Multi-Layered Space-Terrestrial Integrated Network," Liu *et al.* begin with a brief review of the deployment problem of multi-layered STIN to manage the diverse physical devices. A cross-domain SDN architecture, which divides the MLSTIN into satellite, aerial, and terrestrial domains, is proposed in this article. The design and implementation details of this architecture and then some challenges and open issues are discussed. Moreover, illustrative results validate that the proposed architecture can significantly improve the efficiencies of configuration updating and decision making in MLSTIN.

In their article on the space-based wireless network, "Security Analysis on a Space-Based Wireless Network," He *et al.* use the satellite's internal communications security as an example to illustrate the space network security threats. First, a summary of the security requirements of space-based wireless networks and three typical attack approaches for satellite platforms based on MIL-STD-1553B bus are described. Subsequently, the authors present some attack simulation results and suggest some protective mechanisms. The sixth article, "Secure Emergent Data Protection Scheme for a Space-Terrestrial Integrated Network," by Shen *et al.*, presents a novel secure emergency data protection scheme for such users in a STIN. The novel scheme is composed of three phases: emergency data transmission, group block-design-based key agreement, and secure satellite information acquisition. The performance analysis shows that the novel scheme is secure and efficient.

The seventh article, "Modeling Space-Terrestrial Integrated Networks with Smart Collaborative Theory" by Song *et al.*, proposes a modeling scheme named generalized logical sphere (GLS) for space-terrestrial networks based on smart collaborative theory. First, the coverage range, transmission mechanism, and practice guidelines of integration evolutions are fully investigated via three phases to guarantee comprehensive combinations. Then the specific approach as well as the advanced characteristics of GLS (i.e. load balancing, hierarchical shielding, cognitive healing, and smart routing) are analyzed and discussed. In the eighth article, "Virtualized QoS-Driven Spectrum Allocation in Space-Terrestrial Integrated Networks" by Lin *et al.*, the authors design a new STIN architecture supporting virtualization technology to manage spectrum resource in STIN to satisfy various QoS requirements from heterogeneous devices. Then a dynamic virtualized QoS-driven spectrum allocation algorithm(VQSA) is proposed to improve the QoS from different devices in STIN. VQSA classifies heterogeneous devices into virtual cells according to their QoS correlation and determines the corresponding remote radio units (RRUs) and satellite for providing services. Spectrum resources in multiple base stations and satellite are rationally assigned in a virtual cell to serve heterogeneous devices with different QoS requirements.

In the ninth article, "A Tensor-Based Big-Data-Driven Routing Recommendation Approach for Heterogeneous Networks" by Liu *et al.*, the authors theorize that the diverse factors of the heterogeneous network, such as bandwidth, delay, and communication protocol, bring great challenges to routing recommendation. Therefore, a tensor-based big-data-driven routing recommendation framework including the edge plane, fog plane, cloud plane, and application plane is proposed. In the framework, a tensor-based, holistic, hierarchical approach is introduced to generate efficient routing paths using tensor decomposition methods. Additionally, a tensor matching method including the controlling tensor, seed tensor, and orchestration tensor is employed to realize the routing recommendation.In the last article, "Satellite Mobile Edge Computing: Improving QoS of High-Speed Satellite-Terrestrial Networks Using Edge Computing Techniques" by Zhang *et al.*, the authors focus on the great innovations of satellite mobile edge computing (SMEC), in which a user equipment (UE) without a proximal MEC server can also offload tasks to other domain MEC server via satellite links. In this article, a dynamic network virtualization technique to integrate the network resources and a cooperative computation offloading (CCO) method are proposed to achieve parallel computation in satellite-terrestrial networks (STNs).

In closing, we would like to thank all the authors who submitted their research work to this Special Issue. We would also like to acknowledge the contribution of many experts in the STINs field who have participated in the review process and provided helpful suggestions to the authors to improve their articles. We would in particular like to thank Dr. Mohsen Guizani, the Editor-in-Chief, for his support and very helpful suggestions and comments during the delicate stages of concluding the Special Issue.

Biographies

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