



## Editorial

## Theory and Key Technologies in Space Internet Networking

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The rapid evolution of satellite constellation projects (e.g., SpaceX) and the standardization of 3rd Generation Partnership Project (3GPP) non-terrestrial networks (NTNs) have positioned satellite Internet networking (SIN) as a cornerstone of future communication systems. The demand for ubiquitous connectivity, resilient infrastructures, and intelligent network services has never been greater, driven by applications ranging from global broadband access to emergency response and space–air–ground integration. To meet these demands, advances are required not only in constellation design and communication technologies but also in computing, artificial intelligence (AI), and system resilience. Against this backdrop, this special issue assembles 14 contributions—including Views & Comments, Reviews, and Research Articles—that collectively examine the intelligence, adaptability, and strategic deployment of SIN, offering critical insights to inform the forthcoming sixth-generation (6G) satellite–Internet revolution.

We begin with the Views & Comments papers, which highlight visionary ideas and emerging technological directions in current SINS. A central theme is the convergence of AI and computing with space–ground integrated networks. In “Space–ground fluid AI for 6G edge intelligence,” Qian Chen et al. propose fluid AI as a way to dynamically support learning, inference, and model downloading in highly mobile and heterogeneous SIN environments. This work points toward a future in which satellites play a direct role in distributed edge intelligence. In a complementary direction, Yaoqi Liu et al. present “Computing over space: Status, challenges, and opportunities” which considers the feasibility of deploying high-performance computing in orbit. Through a discussion of commercial off-the-shelf devices, thermal control, and reliability challenges, the authors underline the importance of computational

infrastructures to match the increasing data-processing demands of next-generation SINS. Building on these foundations, Linling Kuang et al. introduce “Space computing power networks: Fundamentals and techniques,” offering an architectural vision that integrates communication and computation resources into a unified network. Their approach emphasizes task-oriented communication solutions and robust optimization, which will be critical to handling uncertainty in dynamic space environments. Viewed together, these three contributions paint a picture of SIN as not only a communication infrastructure but also a global computational fabric.

Beyond computing and AI, another cluster of Views & Comments looks at the evolution of satellite communication (SatCom) and its role in mobile services. In “Evolution of satellite communication systems toward 5G/6G for 2030 and beyond,” Afang Yuan et al. provide a roadmap that traces SatCom’s progression in international standards and outlines its integration into fifth-generation (5G)/6G architectures. This is followed by Wenjin Wang et al.’s “Toward mobile satellite Internet: The fundamental limitation of wireless transmission and enabling technologies,” which recognizes the physical limitations of wireless links while exploring breakthroughs in antenna technologies, mobility management, and multi-satellite cooperative transmission. Together, these works present a coherent outlook: SatCom is maturing from supportive infrastructure into a vital enabler of seamless global connectivity. Finally, the perspective widens to include societal needs. In “Key challenges and research directions for space–air–ground integrated emergency communication networks,” Bo Xu et al. show how space–air–ground integrated network technologies can address urgent communication requirements in disaster scenarios through rapid deployment, environmental modeling, and dynamic resource allocation. These contributions emphasize that SIN is not only about data rate and capacity but also about resilience and serving humanity in its most critical moments.

The Review papers provide structured insights into the current state of the art and future directions. In “Non-terrestrial networking for 6G: Evolution, opportunities, and future directions,” Feng Wang et al. survey NTN networking technologies with an emphasis on access management, service delivery, handover, and beamforming. Their analysis identifies unresolved problems such as efficient beam tracking and service continuity, laying out open research directions. Complementing this high-level view, Nuo Chen et al. provide “Network-layer perspectives on satellite–terrestrial inte-

grated networks in 6G: A comprehensive review.” They explore network-layer mechanisms, including topology maintenance, routing, and orchestration, and examine supporting tools such as frameworks, platforms, and datasets. Taken together, these reviews connect strategic evolution with detailed technical foundations, offering a bridge between vision and implementation.

The Research Articles deliver in-depth studies and novel technical solutions, with environmental robustness as a recurring theme. In “Effects of space environment on satellite mega-constellations: From nodes and links to network performance,” Min Sheng et al. quantify how radiation, solar activity, and orbital parameters degrade satellite and network performance. By linking physical space environment effects with system-level throughput, their study offers valuable guidance for resilient constellation design. Regarding constellation design, Yijing Sun et al. investigate “On an ultra-dense LEO-satellite-based computing network constellation design.” Their results demonstrate how a carefully designed constellation can improve coverage and computational capability while reducing the number of satellites, highlighting the trade-offs in next-generation network planning.

A second group of articles emphasizes adaptive learning algorithms and efficient resource utilization. In “SatFed: A resource-efficient LEO-satellite-assisted heterogeneous federated learning framework,” Yuxin Zhang et al. propose mechanisms such as freshness-based model prioritization and multigraph modeling to ensure fairness and robustness under limited bandwidth. Similarly, in “Dynamic time-difference QoS guarantee in satellite–terrestrial integrated networks: An online learning-based resource scheduling scheme,” Xiaohan Qin et al. introduce an online-learning-based resource-scheduling scheme that balances prediction accuracy with adaptability, ensuring quality of service under uncertain conditions. These works illustrate how machine learning tech-

niques can be tightly coupled with network design to achieve resilient and efficient operation.

Finally, there are research contributions pointing toward intelligent and collaborative satellite systems. In “Learning-based matching game for task scheduling and resource collaboration in intent-driven task-oriented networks,” Jiaorui Huang et al. propose a framework that uses context-aware learning to address uncertainties in dynamic task arrivals, enabling a new paradigm of intent-driven networking. Extending this vision, Guangteng Fan et al. present “Internet of satellites (IoS) for intelligent satellite cluster: Applications, methods, and challenges.” They envision satellite clusters functioning as a cooperative network, advancing autonomy, intelligence, and service customization. These works underscore the transformation of satellites from passive relays into proactive, intelligent agents in future networks.

In summary, this special issue demonstrates how SIN is evolving from a communication backbone into an intelligent, adaptive, and resilient infrastructure. From pioneering ideas on fluid AI and space computing to systematic reviews of NTN and satellite–terrestrial integrated network (STIN) technologies, and then to research articles addressing environmental challenges, adaptive algorithms, and intelligent clustering, the collected works reveal a technology landscape that is both rapidly advancing and deeply interconnected. Looking ahead, SIN can be envisioned as the backbone of a globally connected society: enabling real-time collaboration across Earth and space, ensuring resilient communication in times of crisis, and powering new services that seamlessly fuse connectivity with intelligence. We hope this collection both informs and inspires researchers and practitioners to further expand the boundaries of SIN and to shape its role as a foundational pillar of the 6G era and beyond.