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CURRENT STATUS AND DEVELOPMENT TRENDS OF SATELLITE IOT

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Abstract: Satellite-based Internet of Things (IoT) refers to the technology that uses satellite networks to achieve global connectivity and data transmission for IoT devices.With the advancement of satellite communication technology and the trends towards miniaturization and cost reduction, satellite-based IoT is gradually becoming an effective solution for communication issues in remote areas, oceans, and airspace, where traditional terrestrial networks are difficult to cover. This article discusses the current development status of satellite-based IoT, analyzes its application modes, technical indicators, and future development trends, and delves into the opportunities and challenges in the development of satellite-based IoT, providing a reference for its future development.

Keywords: Internet of things; Satellite communication; Space based network; Application mode; Technical specifications

1 INTRODUCTION

The Internet of Things (IoT), as a network that addresses the interconnectivity between objects and between people and objects, has, since its inception, formed a relatively complete technical system and delved into various fields such as smart transportation, precision agriculture, public safety, environmental protection, and logistics tracking[1]. According to market intelligence firm ABI Research, the satellite IoT market is expected to exceed $4 billion by 2030[2], indicating significant growth potential.

The development of the Internet of Things (IoT) is largely constrained by advancements in communication infrastructure. Currently, the two main communication methods are terrestrial communication networks and satellite communication networks[3]. Terrestrial communication networks, due to limitations imposed by space and environmental factors, cannot achieve global network coverage. In contrast, satellite communication networks, with their consistent and seamless coverage, can effectively address the blind spots of terrestrial networks. At present, satellite networks serve as a supplement, extension, relay, and backup to terrestrial networks. The integration of satellite IoT and ground-based IoT to form an “air-ground-space” IoT can fully leverage the communication and data transmission capabilities of satellites, achieving seamless integration between “ground” and “space” and realizing the vision of an integrated air-ground-space network.

In summary, compared with terrestrial IoT, satellite IoT relies on satellite networks to connect various IoT devices, enabling global and seamless data transmission[4]. This technology holds extensive application potential across numerous real-world scenarios. As the global development of integrated air-ground-space networks progresses, an increasing number of organizations are actively deploying satellite IoT, and its practical uses are becoming increasingly promising with substantial room for growth.

2 THE CURRENT STATUS OF SATELLITE IOT DEVELOPMENT

Satellite IoT leverages satellite networks to connect ground devices, facilitating global data transmission and communication. This technology offers notable advantages in remote regions or oceanic areas where traditional communication infrastructure struggles to provide coverage. Overall, satellite IoT has demonstrated significant potential and value in various fields. As technology continues to advance and costs further decrease, the application scope of satellite IoT will become even broader, having a profound impact on socioeconomic development. Currently, multiple satellite communication systems have conducted tests and applications in data acquisition, location tracking, and short message transmission. Typical systems include ARGOS, Orbcomm, Inmarsat-LoRaWAN, Iridium SBD, and SpaceX. In China, typical systems include BeiDou Navigation Satellite System, “TianTong-1” satellite mobile communication system, and “TianQi” constellation. Besides these already applied systems, many startups are actively researching and deploying satellite IoT, with one of the most innovative being Hubble Network’s Bluetooth direct-to-satellite test, which has opened a new chapter in the field of satellite IoT.

The ARGOS system is a global ocean observation test project launched by the United States, France, and other countries. This system uses satellites to monitor environmental parameters and track instruments, enabling wide-area connectivity for hydrological and meteorological monitoring devices. The ARGOS system can accurately collect temperature and salinity profile information from the upper layers of the ocean, allowing researchers to gain a clear understanding of ocean changes and improve the accuracy of weather and ocean forecasts. This serves to counteract deteriorating climatic and oceanic catastrophes and minimize impacts on human civilization. ARGOS has widespread applications in the domains of conservation of diversity, water resources management, and oceanic and meteorological observation[5].

The Orbcomm system is a worldwide commercial low-Earth orbit (LEO) satellite-based communications system designed especially for two-way short data communication[6]. Users may use the system for a number of applications, including data collection, real-time observation, location tracking, and short messaging. With great versatility, the Orbcomm system has been used in applications including logistics and transport, oil and gas field surveillance, environmental surveillance, and fire alarm systems.

The Inmarsat-LoRaWAN IoT system, jointly developed by Inmarsat and Actility—a maker of low-power wide-area network devices—achieves worldwide satellite-ground network connection. Based on Actility's platform, the system combines LoRaWAN ground network connection and Inmarsat's satellite communication capability to provide users from a wide range of industries with economical global IoT solutions[7]. Additionally, it enables the provision of IoT data to the cloud applications for analysis and processing to achieve in-depth data value extraction, innovative revenue model construction, and multi-dimensional decision-making support.

Inmarsat provides numerous terminal services in its satellite-ground-based network worldwide, and the Inmarsat D+ is a typical instance of such[8]. As it is extremely integrated in its nature, the terminal eases the installation and startup process to enable the advantage of deployment. The Inmarsat D+ supports position reporting and two-way SMS communication, accommodating messages up to 30 characters in length, and functions seamlessly across the globe. It effectively caters to the communication and positioning requirements of maritime zones and remote locations where connectivity becomes challenging otherwise.

Iridium Short Burst Data (SBD) provides a simple but significant satellite network data transport ability, enabling the transport of short data messages between systems hosted in the field and centralized host systems[9]. The major components of the system design consist of the Field Application (FA), the Iridium Subscriber Unit (ISU), the Iridium satellite network, the Iridium Gateway Subsystem (GSS), the Internet network, and the Vendor Application (VA). A diagram of the system configuration follows below Figure 1.

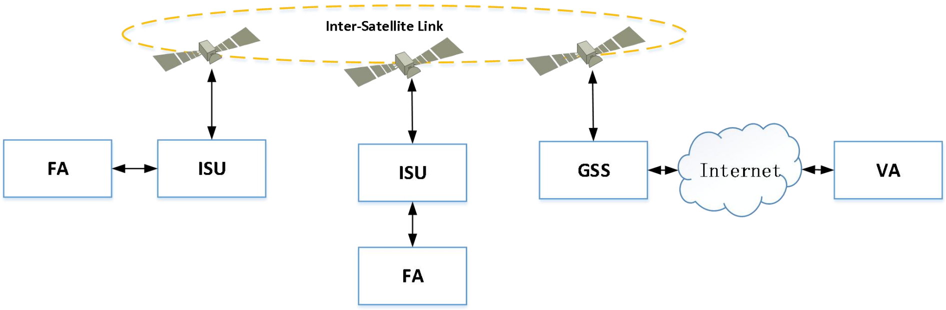

Figure 1 SBD Architecture

The system provides two modes of operation, each of them capable of user payload transmissions of 2000 bytes:

In one of these modes, the Field Application data from the FA to the Iridium Subscriber Unit (ISU) and then on to the application service center;

The second mode provides direct transmission via satellites in a way that one FA can relay information from one ISU terminal to another ISU-connected FA terminal.

SpaceX’s Direct-to-Cell (DTC) technology represents a groundbreaking satellite communication solution, leveraging the Starlink network to deliver connectivity directly to smartphones[10]. This innovation allows users to send text messages, make phone calls, and access the internet in any location with unobstructed sky visibility—eliminating reliance on traditional terrestrial infrastructure. A notable advantage of DTC lies in its compatibility: it operates seamlessly with existing LTE-enabled phones, requiring no hardware modifications, firmware updates, or specialized apps.The service will launch with text messaging capabilities in 2024, followed by voice calls and data services in 2025. That same year, DTC will introduce phased support for Internet of Things (IoT) devices, utilizing standard LTE protocols to ensure broad interoperability. Its coverage will span diverse environments, including landmasses, inland water bodies, and coastal regions, effectively bridging connectivity gaps in areas underserved by conventional networks.

The BeiDou Navigation Satellite System, a China-developed and China-operated global satellite navigation system[11], provides high-precision and stable positioning, navigation, and timing services and serves as a robust basis for massive applications of the Internet of Things (IoT). The combination of BeiDou and IoT relies on the positioning and communication capabilities of BeiDou to achieve precise location tracking and data communication of IoT devices. With the installation of the BeiDou system on IoT devices, the devices can achieve more accurate positioning and more efficient data communication, significantly broadening the depth and width of the applications of the IoT. In various fields such as smart cities, intelligent transportation, logistics tracking, and environmental monitoring, the combination of BeiDou and IoT is playing a significant role.

The TianTong-1 satellite mobile communication system, as an important component of China’s space information infrastructure, provides all-weather, round-the-clock, and stable and reliable mobile communication services to users in

China and its surrounding regions, as well as parts of the Pacific and Indian Oceans. It supports voice, short message, and data services[12]. The TianTong IoT service achieves high-concurrency short message transmission capabilities by simplifying communication protocols, providing users with bidirectional, small-data-volume transmission services. This meets the data interaction needs between user application platforms and remote IoT devices, enabling data collection and remote control. The architecture is shown in Figure 2. Additionally, China Telecom has developed its own IoT terminals, achieving a closed industrial loop, and can provide high-quality services around the clock in areas such as remote monitoring, environmental monitoring, emergency communication, and agricultural management.

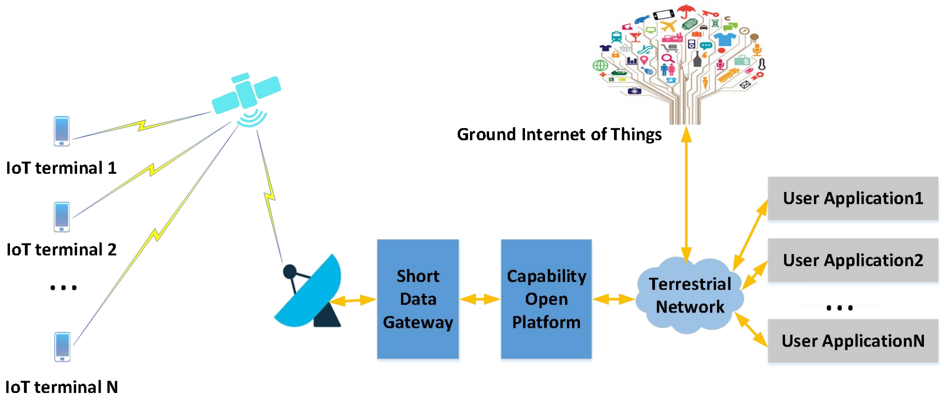

Figure 2 Tiantong IoT Architecture

The Tianqi Constellation is China’s first narrowband IoT communication system providing low-orbit satellite data services. It consists of three segments: the user segment, the terrestrial segment, and the space segment[13], enabling real-time coverage on a global scale. Currently, the Tianqi Constellation has been applied in various fields and is offering data services, continuously giving rise to new services and business models, providing all-weather data collection and communication services to users across multiple industries.

In 2024, Hubble Network successfully launched two satellites equipped with 3.5 mm Bluetooth chips via SpaceX’s Transporter-10 mission[14]. These satellites successfully received and transmitted Bluetooth signals from a distance of 600 km above the Earth during subsequent tests, breaking the world record for Bluetooth connection range. This achievement has paved a new way for the development of satellite IoT. Using this technology, any off-the-shelf Bluetooth device can be connected to this satellite network through simple software updates, without the need for additional cellular devices, enabling global coverage. Based on this innovation, we may see Bluetooth direct-to-satellite connections in various fields of satellite IoT in the future.

3 APPLICATION SCENARIOS

With the gradual maturation of technology, standards, and industry ecosystems, the global satellite IoT market is experiencing robust growth. According to several IoT analytics institutions, this market is poised to enter a phase of explosive expansion.Berg Insight’s latest research report on satellite IoT indicates that the number of global satellite IoT subscribers exceeded 4.5 million in 2022 and is projected to surge to 23.9million by 2027, representing a compound annual growth rate (CAGR) of 39.6%[15]. Meanwhile, Counterpoint’s recent global IoT market forecast report highlights that worldwide satellite IoT connections are expected to grow from 3.6 million in 2020 to 41 million by 2030, achieving a CAGR of 28%[16].

Driven by consumer-end smartphone direct-to-satellite services, China’s satellite IoT market is poised for a leap forward starting in 2024. According to predictions by Taibo Think Tank, the market size is expected to achieve a compound annual growth rate (CAGR) exceeding 40% between 2024 and 2028. Satellite IoT services targeting government and enterprise sectors are also projected to maintain rapid growth[17]. By 2028, China’s satellite IoT market size is anticipated to approach 10 billion RMB. Detailed data is illustrated in the following figure 3.

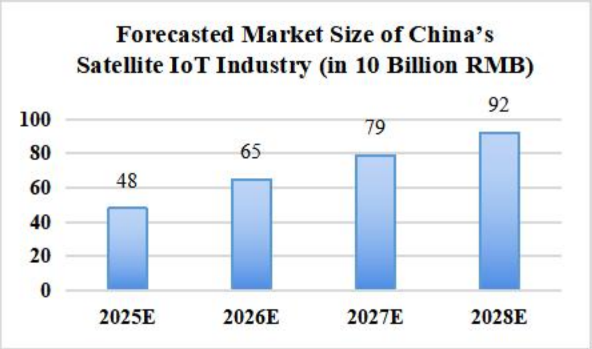

Figure 3 China Satellite IoT Market Forecast

The satellite IoT market is entering a phase of rapid development, driven by its characteristics of extensive coverage and diverse application scenarios.These features enable satellite IoT to conduct long-term environmental monitoring in remote and inaccessible areas—such as regions requiring hydrological and water quality assessments, atmospheric environment tracking, and land desertification surveillance—while achieving real-time collection, processing, and distribution of various types of environmental data essential for human needs. As a result, vast remote areas previously limited by traditional communication infrastructure can now also access information services[18].

In terms of natural disaster early warning, satellite IoT has the capability for 24/7 unattended data processing. It can transmit real-time information about various disasters such as earthquakes, landslides, and extreme weather conditions even when ground networks are down, continuously providing accurate situational updates to the rear for decision-making.

In the monitoring of oil and gas pipelines, especially those located in uninhabited areas, satellite IoT systems enable relevant organizations to promptly obtain the status and trends of pipeline resources, achieving effective control over data information. Beyond the scenarios mentioned above, satellite IoT is widely applied across various sectors of human society, with some of the most representative application scenarios illustrated in the following figure 4.

Figure 4 Application Scenarios of Satellite IOT

4 TECHNICAL INDICATORS

Currently, commercial satellite IoT systems at home and abroad mostly adopt proprietary standards defined by satellite providers rather than open and universal standards, leading to differences in performance evaluation. Therefore, this paper attempts to study and analyze the common working modes of satellite IoT and provide an overview. Based on the research on satellite IoT working modes, this paper presents basic universal technical indicators for satellite IoT by incorporating factors such as coverage, service performance, and practical applications.

As a wide-area multi-dimensional application system, satellite IoT should support multiple working modes according to actual needs. Generally speaking, the following are several common working modes:

1.In Long Listening Mode,terminal devices continuously listen for downlink messages from the network without requiring caching. In this mode, terminal devices can receive downlink messages in real time without significant delay and support high concurrency. However, due to the continuous listening of terminal devices, power consumption is relatively high.

2.In Low Power Mode,terminal devices periodically enter a sleep state to reduce power consumption and wake up when needed for data transmission. In this operational mode, the network stores downlink information and delivers it to terminal devices solely when they send uplink data.

3.In Acknowledgment Mode, terminal devices await a confirmation from the network after transmitting uplink data to help ensure successful data transfer. This mode employs the acknowledgment mechanism to enhance the transmissions' dependability and minimize data loss: the devices will retransmit the data automatically if there is no acknowledgment. The need to wait for acknowledgments will also create extra delays in data transmissions.

4.In Unacknowledged Mode, the terminal devices never await a network acknowledgment upon transmitting data in the network direction and proceed to transmit new data immediately. This mode provides better data transport in the sense that delay time for confirmation is eliminated but at the expense of decreased transmission reliability and the possibility of data loss owing to the absence of an acknowledgment protocol.

5.In Multi-Band Handover Mode, terminal devices possess the ability to change between various frequency bands to suit diverse communication environments and requirements. This mode enhances the reliability of the communications and raises the coverage, and therefore, it is highly suitable for complicated and dynamic geo environments. It, however, contributes complexity and cost to the terminal devices since it requires more complex frequency management and handover algorithms to be able to work effectively.

The combination of the above working modes enables the basic operations of satellite IoT. Based on the study of these working modes and the current status of practical applications, this paper summarizes the basic universal technical indicators for satellite IoT, as shown in Table 1. These indicators provide a reference for the design, development, and application of satellite IoT systems, helping to improve system performance and reliability.

Table 1 Universal Technical Indicators

Serial Number	Indicator Name
1	Packet Loss Rate
2	Symbol Error Rate
3	Latency
4	Jitter
5	Communication Elevation Angle
6	Equivalent Isotropic Radiated Power
7	Communication Rate
8	Bandwidth Occupation
9	Gain over Temperature Ratio
10	Signal-to-Noise Ratio
11	Concurrent Processing Capability
12	Maximum Single-Message Capacity
13	Throughput
14	Availability
15	Single Satellite Capacity
16	System Capacity
17	Lost Segment Retransmission Success Rate
18	Terminal Device Power Consumption
19	Service Provision Area
20	Minimum Received Signal Strength Indicator
21	Maximum Transmit Power
22	Maximum Communication Distance
23	Supported Frequency Bands
24	Maximum Supported Length for Long Messages
25	Long Message Segmentation Success Rate
26	Long Message Reassembly Success Rate
27	Path Loss
28	Orbital Altitude
29	Polarization Mode
30	Communication system
31	Operating Temperature and Humidity
32	Connection Success Rate
33	Mobility Support
34	Inter-Satellite Link
35	Service Security Encryption Strength
36	Service Environmental Sustainability

5 DEVELOPMENT TRENDS

Satellite Internet of Things (SatIoT) serves as a crucial complement and extension to terrestrial IoT[19]. Distinguished by its global ubiquitous coverage capabilities and resilience against meteorological disturbances, SatIoT effectively addresses the inherent limitations of ground-based IoT systems, particularly their vulnerability to geographical constraints and disaster susceptibility. Currently, integrating satellite communication systems with terrestrial counterparts to form space-terrestrial integrated IoT has emerged as the hottest research direction in the aerospace information industry. The following sections focus on discussing its development trends.

5.1 The Commercialization of SatIoT

Pursued by commercialization, the SatIoT market is advancing in the dual directions of technological deepening and application development. The latter manifests in continuous innovation in the underlying technologies—efficient coding and decoding, intelligent routing software, dynamic resource sharing, and space-based processing of massive amounts of data—albeit all of them augment the reception, transit, and analysis abilities of aerospace data. Meanwhile, application development expresses itself in SatIoT's deep cross-industrial penetration from traditional industries such as defense, meteorology, and land surveying into new domains such as the smart city, precision agriculture, ecology protection, and emergency relief[20]. This transition frees more market potential, further driving market growth and enhancing its social impact.

5.2 Data Valorization in Space-Terrestrial IoT Integration

Data valorization comprises the conversion of raw data to real-world value and economic benefit by serial processes, including data cleaning, data integration, data analysis, and data interpretation. Space-terrestrial data valorization entails the conversion of raw data from satellites and ground sensors to useful data and economic benefits by the same analysis processes. Examples of the data include feature data, communication signals, location data, and others from whence useful information for applications like environmental observation, disaster warning, traffic control, and planning in agriculture are accessible through the use of sophisticated data analysis processes (e.g., machine learning and artificial intelligence). The goal of space-terrestrial data valorization is to provide data-driven support for government decision-making, corporate operations, and scientific research, thereby fostering the sustainable development of the social economy.

5.3 Bluetooth Direct Connection to SatIoT Has Emerged as a Hot Topic

Building on Hubble Network's pioneering work in Bluetooth direct satellite connection, numerous enterprises and research institutions worldwide have initiated studies into this technology. Recent findings reveal that certain entities have submitted materials to the International Telecommunication Union (ITU) for utilizing the 2.4 GHz Bluetooth frequency band in direct satellite connectivity, aiming to establish a Bluetooth backup communication network that operates without relying on terrestrial networks and SIM cards—an initiative poised to effectively safeguard public lives and properties. Given the massive market penetration of Bluetooth devices and ongoing technological development trends, more enterprises, research organizations, and universities are expected to enter the field of Bluetooth direct satellite connection. This novel technology opens up new possibilities in the communications domain, potentially ushering in a brand-new era of connectivity.

5.4 Evolving Towards the 6G Era

The evolution towards the 6G era represents the next significant stage in the advancement of communication technologies. Although 6G technology remains in the research and conceptual phase, its goals and vision have gradually taken shape. A key enabler for achieving 6G objectives is space-terrestrial integration technology, which involves integrating terrestrial communication networks with non-terrestrial systems such as satellites, high-altitude balloons, and unmanned aerial vehicles (UAVs) to form a seamlessly covered, highly collaborative integrated communication network. This technology will also be used to overcome territorial limitations and realize world-class communications services—particularly in remote areas, over the ocean, in airspaces, and in other areas where traditional ground-based network services have previously been limited. Below is the 6G theoretical space-terrestrial integration concept diagram. With the development of 6G, the Satellite Internet of Things (IoT) will be a more developed technology with extended applications and improved capability. Future IoT will not be a mere addition of ground-based networks but a homogeneous space-terrestrial system that will deliver unprecedented convenience and innovation to human civilization, see Figure 5.

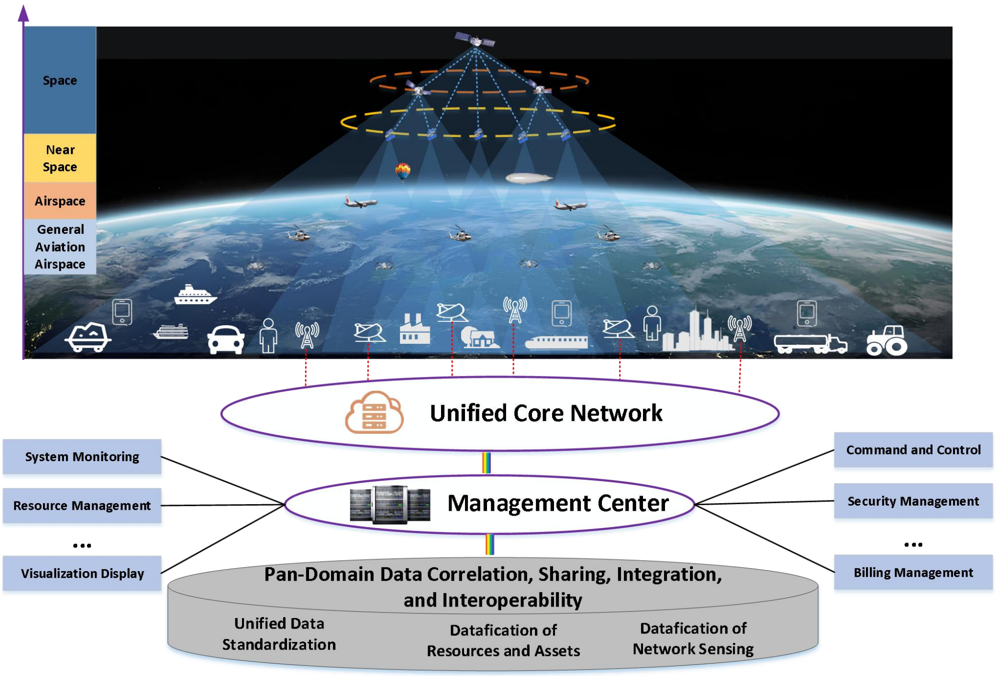

Figure 5 6G Space-Ground Integration Concept

6 CONCLUSION

As a communication paradigm of worldwide seamless coverage, the satellite Internet of Things (IoT) faces new opportunities and arduous challenges of the era. With the booming satellite market and prosperous development, numerous countries and areas have provided policy support and financial incentivization to SatIoT, thus hastening the development of related industries. Such market development quickened new opportunities in technology, business, cross-industrial cooperation, and so on. Under the framework of space-terrestrial interaction, such opportunities have enormous potential and immense developmental space. With such an opportunity, however, the development of SatIoT should face severe challenges—control of spectrum resources, security, environmental protection, regulation and standardization, and cost and benefit analysis, to name just a few. Such challenges have long been constraints to the extensive applications of Satellite IoT. Thus, follow-up related research needs to continue research and innovation in order to overcome such challenges and promote the rational development of Satellite IoT.

COMPETING INTERESTS

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REFERENCES

[1] Chen Y, Ma X, Wu C. The concept, technical architecture, applications and impacts of satellite internet: A systematic literature review. Heliyon, 2024, 10(13). DOI: https://doi.org/10.1016/j.heliyon.2024.e33793.

[2] ABI Research Satellite IoT Market Soars to US$4 Billion by 2030. Driven by Growth in Key Verticals and Strategic Partnerships. 2024. https://www.abiresearch.com/press/satellite-iot-market-soars-to-us4-billion-by-2030-driven-by-growth-in-key-verticals-and-strategic-partnerships.

[3] Adiprabowo T, Ramdani D, Daud P, et al. Satellite Technology for Internet of Things: An Overview. IOTA Journal, 2025, 5(1): 58-68.

[4] Zhong N, Wang Y, Xiong R, et al. CASIT: Collective intelligent agent system for internet of things. IEEE Internet of Things Journal, 2024, 11(11): 19646-19656. DOI: 10.1109/JIOT.2024.3366906.

[5] Morris T, Scanderbeg M, West-Mack D, et al. Best practices for Core Argo floats-part 1: getting started and data considerations. Frontiers in Marine Science, 2024, 11: 1358042.

[6] Lagunas, Eva, Symeon Chatzinotas, Björn Ottersten. Low-Earth orbit satellite constellations for global communication network connectivity. Nature Reviews Electrical Engineering, 2024, 10(1): 656-665.

[7] Damuddara Gedara C, Danyal Khattak M, Asad Ullah M, et al. Direct-to-Satellite Connectivity for IoT: Overview and Potential of Reduced Capability (RedCap). 2023 IEEE World Forum on Internet of Things: The Blue Planet: A Marriage of Sea and Space, WF-IoT. IEEE, 2024, 1-8. DOI: 10.1109/WF-IoT58464.2023.10539387.

[8] Caldentey Jiménez Miguel. Monitorización, control y gestión de terminales Inmarsat C y D+. Diss. 2021. https://riunet.upv.es/handle/10251/162308.

[9] Shutao Z. Satellite Internet of Things Research Report. arxiv preprint arxiv:2407.17696, 2024. DOI: https://doi.org/10.48550/arXiv.2407.17696.

[10] Tuzi D, Delamotte T, Knopp A. Performance Assessment of Sparse Satellite Swarms for 6G Direct-to-Cell Connectivity. 2024 IEEE 25th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Lucca, Italy, 2024, 616-620. DOI: 10.1109/SPAWC60668.2024.10694119.

[11] Li Rui, Zheng Shuaiyong, Wang Ershen, et al. Advances in BeiDou Navigation Satellite System (BDS) and satellite navigation augmentation technologies. Satellite Navigation, 2020, 12(1): 1-23.

[12] Zheng, Jun, Wang Ru, Li Qiang, et al. Research on key technologies of satellite mobile communication system. 2022 IEEE 5th International Conference on Electronics and Communication Engineering (ICECE), Xi'an, China, 2022, 34-38. DOI: 10.1109/ICECE56287.2022.10048610.

[13] Qi, Yanhui, Meng Weican, Zeng Chao. Influence of Co-frequency interference on transmission performance in satellite communication. 2023 8th International Conference on Communication, Image and Signal Processing (CCISP), Chengdu, China, 2023, 1-5. DOI: 10.1109/CCISP59915.2023.10355854.

[14] Despres T, Dutta P, Ratnasamy S. Make Way for Ducklings: Centering Data Files in Sensor Networks. Proceedings of the 26th International Workshop on Mobile Computing Systems and Applications. 2025, 97-102. DOI: https://doi.org/10.1145/3708468.3711883.

[15] Satnews. Sweden’s Berg Insight’s 2027 forecast — satellite IoT subscribers to reach 23.9 million. 2023. Satnews. https://news.satnews.com/2023/08/30/swedens-berg-insights-2027-forecast-satellite-iot-subscribers-to-reach-23-9-million.

[16] Counterpoint. Standardization Pushes Satellite IOT Connection Growth. Counterpoint. 2024. https://www.counterpointresearch.com/insight/standardization-pushes-satellite-iot-connection-growth.

[17] Taibo Intelligence Unit. China Satellite IoT Market Research Report (2024). 2024. https://tiu.taibo.cn/p/490/.

[18] Chen Yingying, Zhang Minghu, Li Xin, et al. Satellite-enabled internet of remote things network transmits field data from the most remote areas of the xizang plateau. Sensors, 2022, 22(10): 3713.

[19] Shi, Jianfeng, Chen Xinyang, Zhang Yujie, et al. Joint optimization of task offloading and resource allocation in satellite-assisted IoT networks. IEEE Internet of Things Journal, 2024, 11(21): 34337-34348. DOI: 10.1109/JIOT.2024.3398055.

[20] Chippalkatti, Vinod S, Rajshekhar C Biradar. Review of satellite based Internet of Things and applications. Turkish Journal of Computer and Mathematics Education, 2021, 12(12): 758-766. DOI: https://doi.org/10.17762/turcomat.v12i12.7463.