ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

Analysis of the Current Situation, Evolution, and Policy of Direct-To-Handset Satellite

Chang Pei[1], Wang Wei[1], Zhao Yijun[2], Wang Yingkui[1], Lin Xinfa[1], Gan Wei[1]

[1]Marketing Department (Brand Development Department) of China United Network Communications Group Co, Ltd, Beijing, 100033, China
[2]Marketing Department of China Unicom Vsens Communication Co, Ltd, Beijing, 100033, China

Abstract: *In recent years, many domestic and foreign enterprises have conducted innovative research and application in the field of direct-to-handset satellite communication. They have made progress in satellite communication payload development, mobile terminal technology innovation, satellite constellation networking, and integrated network of satellite and terrestrial. Direct-to-handset satellite communication has become the main development direction of the next generation of communication technology. This article summarizes the current development status of direct-to-handset satellite communication, analyzes the evolution direction of future direct-to-handset satellite technology, summarizes the main policies promoting the development of direct-to-handset satellite communication in China, and provides personal suggestions for the development of direct-to-handset satellite communication in China.*

Keywords: *Direct-To-Handset Satellite; Satellite Communication; Policy Research*

1. Current Status of Mobile Direct-to-Satellite Communication

1.1 Classification and Characteristics of Satellite Communication

In 1963, the United States launched the world's first geostationary orbit communication satellite, achieving communication functions such as telephone, television, and fax[1]. Since then, satellite communication has rapidly developed and been widely applied due to its long communication distance, broad coverage, independence from geographical constraints, and flexible networking[2]. The technological evolution has spanned from analog satellite communication to digital satellite communication, narrowband satellite constellations, high-throughput satellites, and broadband satellite constellations[3].

Communication satellites can be categorized based on their orbital altitude into low Earth orbit (LEO) satellites, medium Earth orbit (MEO) satellites, and geostationary Earth orbit (GEO) satellites[4]. LEO satellites operate at an altitude of approximately 300 to 1500 kilometers above the Earth's surface, offering high signal strength and low transmission latency, but their fast orbital speed and small signal coverage require a greater number of satellites to cover the same area[1]. MEO satellites operate at an altitude of approximately 7000 to 25000 kilometers above the Earth's surface, with moderate signal strength, transmission latency, and coverage. GEO satellites operate at an altitude of approximately 35786 kilometers above the Earth's equator, matching the Earth's rotation speed, offering broad signal coverage but with weaker signal strength and higher transmission latency[5].

Satellite communication services can be divided into three major categories: fixed satellite services, broadcasting satellite services, and mobile satellite services. Fixed satellite services refer to wireless communication services between fixed Earth stations using satellite communication capabilities[5]; broadcasting satellite services refer to wireless communication services that use satellites to transmit or forward wireless signals for direct reception by terminals; mobile satellite services refer to wireless communication services between mobile terminals, between mobile terminals and satellites, and between satellites, such as mobile direct-to-satellite services[2].

As satellite technology continues to advance, the distinction between these categories becomes more pronounced. For instance, LEO satellites, despite their high deployment costs, are favored for their ability to provide global coverage with a constellation of fewer satellites compared to GEO systems. This is due to their proximity to Earth, which allows for reduced signal propagation delay,

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

crucial for real-time applications such as telephony and live broadcasting. Table 1 below illustrates the comparative orbital characteristics and applications of different types of communication satellites.

Table 1 Characteristics and Applications of Communication Satellites

Satellite Type	Altitude Above Earth's Surface (km)	Signal Strength	Transmission Latency (ms)	Coverage Area	Number of Satellites Required	Primary Applications
LEO	300-1500	High	1-10	Global	60-120	Real-time services, IoT, Broadband Internet
MEO	7000-25000	Moderate	100-200	Regional	6-12	Navigation, Positioning
GEO	35786	Low	240-270	Continental	3-5	Fixed services, Broadcasting, DTH TV

Note: The number of satellites required for global coverage is an approximation and can vary based on the specific system design and coverage requirements.

The evolution of satellite communication services has also been influenced by the advent of high-throughput satellites (HTS), which have significantly increased the capacity for data transmission. HTS satellites use spot beams and frequency reuse techniques to provide higher data rates and improved performance, particularly for broadband services. This technological leap has enabled satellite communication to compete more effectively with terrestrial networks in terms of speed and bandwidth, opening up new possibilities for rural broadband access, maritime and aeronautical communications, and even supporting disaster recovery efforts where terrestrial infrastructure is compromised.

In conclusion, the satellite communication industry is at a pivotal point where technological advancements are redefining its capabilities and applications. The shift from traditional broadbeam satellites to HTS and the exploration of new orbital slots for LEO and MEO constellations present both challenges and opportunities. As the industry moves towards a more integrated satellite-terrestrial network ecosystem, the focus is on optimizing these systems for efficiency, reliability, and affordability. The future will likely see a symbiotic relationship between satellite and terrestrial networks, leveraging the strengths of each to create a truly global and robust communication infrastructure.

1.2 Current Status of Broad Sense Mobile Direct-to-Satellite Communication

In 1998, Motorola designed and constructed the Iridium satellite system and released the commercial satellite phone Motorola 9500 series, which first realize real-time voice communication through specialized communication terminals similar to mobile phones[3]. In addition, the Inmarsat satellite communication system and Thuraya satellite communication system have also achieved mobile direct-to-satellite communication[6].

(1) Iridium Satellite Communication System

In November 1998, the Iridium satellite communication system, constructed by Motorola in the United States, officially became commercially available. Using handheld satellite telephones, it is possible to make calls from anywhere on Earth. Currently, the Iridium system consists of 66 operational satellites and some backup satellites operating in low Earth orbit[7], primarily providing mobile satellite services for the U.S. Department of Defense and global industries such as aviation, maritime, land mobile, and the Internet of Things, offering services including telephone, fax, data, and paging. It is one of the world's largest satellite communication service providers[8].

(2) Inmarsat Satellite Communication System

In 1982, the satellite communication system operated by Inmarsat began providing maritime communication services and subsequently provided aviation and land communication services in 1983 and 1989, respectively[9]. The system then consisted of 4 satellites operating in geostationary orbit. To date, the Inmarsat system has evolved to its fifth generation, composed of 11 satellites in different orbital positions, mainly providing communication services for maritime businesses and widely applied in global ship safety, government, aviation, disaster relief, and other areas[10].

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

(3) Thuraya Satellite Communication System

In October 2000, Thuraya Satellite Telecommunications Company in the United Arab Emirates launched the first mobile communication satellite in the Middle East, which was subsequently increased to 3 satellites[11]. The satellites operate in geostationary orbit, covering most areas of the Earth except for North and South America and Antarctica, providing voice, SMS, and data communication services[12].

The development of these satellite communication systems has significantly expanded the reach of mobile connectivity, particularly in remote and underserved regions where terrestrial networks are either non-existent or unreliable. The Iridium, Inmarsat, and Thuraya systems have played a crucial role in enabling communication in various sectors, from maritime and aviation to military and emergency services. Table 2 below provides a comparison of the key features of these three satellite communication systems.

Table 2 Comparison of Key Features of Iridium, Inmarsat, and Thuraya Satellite Communication Systems

Feature	Iridium System	Inmarsat System	Thuraya System
Number of Operational Satellites	66	11	3
Orbit Type	Low Earth Orbit (LEO)	Geostationary Orbit (GEO)	Geostationary Orbit (GEO)
Coverage	Global	Global except North and South America, Antarctica	Global except North and South America, Antarctica
Primary Services	Telephone, Fax, Data, Paging	Maritime, Aviation, Land, Safety, Government	Voice, SMS, Data
Year of Initial Operation	1998	1982	2000
Current Generation	-	5th Generation	-
Backup Satellites	Yes	Yes	Yes

Note: The number of operational satellites and backup satellites can fluctuate due to launches and decommissioning.

The Thuraya system, in particular, has been instrumental in providing communication services to the Middle East, Africa, Europe, and Asia. Its geostationary orbit allows for a static coverage area, which is beneficial for providing consistent services to users within its coverage area. The system's ability to offer direct mobile satellite services has been a game-changer for regions that lack robust terrestrial infrastructure, ensuring that communication is possible even in the most remote locations.

Looking ahead, the future of satellite communication systems is poised for further advancements. With the increasing demand for global connectivity and the proliferation of the Internet of Things (IoT),there is a growing need for more satellites and advanced systems capable of handling higher data rates. The next generation of satellite systems will likely incorporate advanced technologies such as quantum communication and software-defined satellites, which will enable even greater flexibility and resilience in satellite communications. As these systems continue to evolve, they will play a critical role in bridging the digital divide and ensuring that communication is accessible to all, regardless of location.

1.3 Current Status of Mobile Direct-to-Satellite Communication

In contrast to the broad sense of mobile direct-to-satellite, the current research on mobile direct-to-satellite communication integrates satellite communication functions into ordinary consumer mobile terminal devices, eliminating the need for specialized terminals for communication[13]. For example, in September 2023, Huawei released the Mate 60 Pro mobile phone based on China's TianTong satellite, integrating the satellite communication module into ordinary mobile phones through chip integration, antenna design, and heat dissipation design technologies, bringing users a more convenient experience[14]. Currently, China's mobile direct-to-satellite support includes the TianTong satellite communication system, and the Beidou system supports mobile direct-to-satellite text messaging functions. Additionally, internationally, the iPhone 14 series uses the Globalstar satellite system to send emergency messages, and the U.S. Starlink system is also constructing and implementing mobile direct-to-satellite communication functions[15].

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

(1) TianTong Satellite Communication System

In August 2016, the TianTong satellite communication system launched its first satellite. The system currently has 3 operational satellites, covering areas including China and its regions, the Middle East, Africa, and most of the Pacific and Indian Oceans, supporting voice, short messages, data, positioning, and IoT services[16]. The TianTong satellite communication system is an independently developed and constructed satellite communication system in China, with satellites operating in geostationary orbit and operated by China Telecom for civilian use[17]. Starting in September 2021, China Telecom and Huawei initiated a project to integrate satellite communication functions into mobile phones, optimizing the terminal side, network side, and service side of the project. In September 2023, Huawei successfully released the Mate 60 Pro mobile phone, which supports satellite calls based on the TianTong system, achieving direct-to-satellite calls via TianTong satellites[18].

(2) Beidou System

In 2000, China launched 2 Beidou geostationary orbit satellites; by the end of 2019, the Beidou system had 39 operational satellites in orbit. The Beidou system is an independently developed global satellite navigation system in China, primarily providing positioning, navigation[19], and timing services.Beidou-3 supports two-way short message services, providing services to China and its regions through 3 geostationary orbit satellites, supporting a maximum of 1000 Chinese characters per message, with uplink and downlink short message service capabilities of 12 million times/hour and 6 million times/hour, respectively. The system allocates 10% of civilian resources for public services, allowing users to send short messages of up to 19 Chinese characters at a time. In September 2022, Huawei's Mate 50 supported the function of sending short messages directly to Beidou satellites[20].

(3) Starlink System

SpaceX, a U.S. space exploration technology company, proposed the low Earth orbit internet constellation plan (Starlink) in 2014. As of March 2024, Starlink had launched 6077 satellites[21], providing high-speed internet services to over 2.3 million users worldwide. In January 2024, SpaceX launched the first 6 satellites capable of direct-to-device capabilities, planning to provide text services starting in 2024 and expanding to voice, data, and IoT services by 2025[22].

The integration of satellite communication into mobile devices represents a significant leap forward in the accessibility and convenience of global communication. This technology not only enhances connectivity in remote areas but also plays a critical role in emergency communication during natural disasters when terrestrial infrastructures are compromised. The following table provides a comparison of the capabilities and coverage of the TianTong, Beidou, and Starlink systems, highlighting their unique contributions to mobile direct-to-satellite communication. Table 3 is showing the information of the comparison in the following part.

Table 3 Comparison of Mobile Direct-to-Satellite Communication Systems

Feature	TianTong System	Beidou System	Starlink System
Type of Orbit	Geostationary	Geostationary	Low Earth Orbit
Number of Operational Satellites	3	39	6077
Coverage	China, Middle East, Africa, Pacific and Indian Oceans	Global	Global
Services Provided	Voice, SMS, Data, Positioning, IoT	Positioning, Navigation, Timing, Two-way SMS	High-speed Internet
Direct-to-Device Capabilities	Yes	Yes (SMS only)	Yes (text, planned voice, data, IoT)
Operator	China Telecom	China	SpaceX
Year of Initial Operation	2016	2000	2014

Note: The number of operational satellites and the extent of services may change over time due to additional launches and technological upgrades.

The Starlink system, in particular, has made significant strides in providing global internet coverage, especially in areas traditionally underserved by terrestrial broadband. With its large constellation of LEO satellites, Starlink is capable of offering high-speed internet services with lower latency compared to traditional GEO systems. This has significant implications for the future of global connectivity, as it

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

reduces the digital divide and provides a viable alternative for internet access in remote regions.

As mobile direct-to-satellite communication technology continues to evolve, it is expected to play an increasingly integral role in the global communication ecosystem. Future advancements may include improved integration of satellite technology into smartphones, enhanced security features for data transmission, and the development of more efficient power management systems to extend the battery life of mobile devices. Additionally, as the number of operational satellites increases, the potential for satellite constellations to provide seamless, global coverage will become more feasible, further solidifying the importance of mobile direct-to-satellite communication in the modern world.

2. Evolution of Mobile Direct-to-Satellite Technology

Currently, mobile direct-to-satellite has become an emerging field in satellite communication, with many domestic and international satellite operators and terminal manufacturers cooperating to promote rapid development of mobile direct-to-satellite in satellite deployment, terminal research and development, and application implementation. The industry, in solving the problems of long communication distances and low signal strength in mobile direct-to-satellite communication, has mainly evolved in three directions[23]: satellite adaptation to mobile phones, mobile phone adaptation to satellites, and the 3GPP NTN unified standard.

2.1 Satellite Adaptation to Mobile Phones

The evolution of satellite adaptation to mobile phones involves transforming ground communication stations into satellite communication payloads, with minimal changes to the mobile phone side[24]. The satellite side mainly uses large array multi-beam antennas to increase antenna gain, increases satellite transmission power to enhance signal strength, adopts lower wireless frequencies to improve transmission distance, uses low Earth orbit satellites to reduce transmission loss, and shares ground mobile communication frequencies , among other technical solutions[25]. This approach addresses the long-distance star-ground link transmission issues in mobile direct-to-satellite communication. The advantage of this scheme is that it does not require modifications to the existing mobile user terminals, but the downside is the high cost of satellite modification and constellation interconnection projects. A typical representative is the American ASTS company's plan. In April 2023,ASTS used the BlueWalker3 low Earth orbit satellite to achieve LTE 4G satellite voice calls with unmodified smartphones. Additionally, in March 2024, SpaceX used the Starlink V2.0 mini low Earth orbit test satellite and ordinary smartphones to demonstrate mobile direct-to-satellite internet functionality, achieving a peak downlink rate of 17 Mbps, with plans to achieve voice call functionality within the next two years[26].

2.2 Mobile Phone Adaptation to Satellites

The evolution of mobile phone adaptation to satellites involves modifying the mobile phone side to achieve mobile direct-to-satellite communication by integrating the communication modules from satellite communication terminals into ground mobile communication phones, adopting dual-mode technology, and focusing on overcoming technical challenges such as antenna miniaturization[28], power consumption control, and chip miniaturization. A typical representative is Huawei's Mate 60 Pro plan, which embeds a baseband processing chip adapted to the TianTong satellite and an internal antenna into the phone. The advantage is the rapid commercialization of mobile direct-to-satellite services, but the downside is that TianTong satellites belong to geostationary orbit satellites with very low ground signal strength, only capable of narrowband low-speed voice and SMS services to satellites[27].

2.3 3GPP NTN Unified Standard

The evolution of the 3GPP NTN unified standard is led by the 3GPP international standardization organization as a satellite-ground integrated technology system facing 6G, widely participated in by global mobile communication equipment manufacturers and operators, and has the ability to evolve continuously. It mainly has two branches: narrowband IoT NTN for IoT applications and broadband NR NTN. It is considered the main direction of mobile direct-to-satellite technology. In July 2022, the 3GPP 5G R17 standard divided the mobile direct-to-satellite plan into two modes: transparent forwarding and satellite regeneration. In terms of frequency, it introduced two dedicated frequency

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

bands, L-band n255 and S-band n256, supporting direct communication between mobile phones and low and high orbit satellites. The advantage is that a unified international standard is beneficial for industrial development and facilitates the development of global business. The downside is that the 3GPP NTN standard is still in the research stage and requires time to mature.

3. Policy Promotion of Mobile Direct-to-Satellite in China

With mobile direct-to-satellite communication becoming a hot topic in research and application, the Chinese government regulatory authorities have also strengthened business guidance, policy support, and standardized management in the field of satellite communication. In terms of equipment licensing management, in January 2023[29], the Ministry of Industry and Information Technology (MIIT) issued a notice to include satellite internet equipment in the current network access permission management in accordance with the "Telecommunications Regulations" and "Telecommunications Equipment Network Access Management Measures." In terms of satellite wireless frequency and orbital resource use, in May 2024, the MIIT awarded Tsinghua University the radio frequency usage permit and space radio station license for the Smart Sky Network No. 1 satellite, supporting Tsinghua University in conducting technology verification for medium Earth orbit broadband communication satellite technology. In terms of industry support and promotion, in December 2023, under the active promotion of the Chinese government, the 2023 World Radiocommunication Conference (WRC-23) established topics for the 2027 World Radiocommunication Conference on mobile direct-to-satellite and S-band non-terrestrial network frequency use to adapt to the international mobile communication development needs of 6G integrated satellite and terrestrial networks. In January 2024, the MIIT issued four new application guidelines for space business-related administrative permissions, including the "Satellite Radio Frequency Usage License Application Guide," "Space Radio Station (Station) Setup and Usage License Application Guide," "Satellite Communication Network Radio Frequency Usage License Application Guide," and "Satellite Earth Station Setup and Usage License (National Level Authority) Application Guide," further refining the process and improving permit efficiency. In terms of business guidance, in March 2024[30], the MIIT guided China Telecom to obtain approval from the International Telecommunication Union to obtain E.164 number (882) 52 and E.212 number (901) 09, respectively, as the user dialing number and network identification code for the TianTong satellite business, marking the first time a Chinese telecommunications enterprise has obtained international telecommunications numbering resources for satellite communication business[31].

4. Suggestions for the Development of Mobile Direct-to-Satellite Communication in China

4.1 Leveraging 5G Advantages to Drive Satellite Communication Development

In the development process of terrestrial mobile communication technology, Chinese communication industry participants, with strong national policy support and their own efforts, have evolved from following in the 3G era, paralleling in the 4G era, to taking a leading international position in the 5G era. They have built the world's largest 5G network, with network quality also at the international forefront, and have accumulated experience in equipment research and development, network construction and maintenance, and business operations. Looking at the entire communication industry chain, the successful experiences gained in the field of terrestrial mobile communication can be used to promote the rapid development of China's mobile direct-to-satellite field. Specifically, in terms of mobile direct-to-satellite policy, China can draw on the experience of strongly supporting the domestic TD-SCDMA standard in the 3G era, giving priority to the development of domestic communication satellite technology in terms of wireless frequency usage, satellite orbit usage, and commercial license issuance. In terms of mobile direct-to-satellite research and development, China can draw on the experience of supporting Huawei's success in terrestrial mobile communication development and strongly support private enterprises in the research and development of communication satellite fields. In terms of network construction, referring to the successful experience of co-construction and sharing in China's terrestrial mobile communication field, promote the co-construction and sharing of satellite communication networks by existing basic telecommunications operators, quickly gaining network advantages in the mobile direct-to-satellite field. In terms of customer operations, leverage the successful commercial experience of basic telecommunications operators among 1.4 billion people to conduct mobile direct-to-satellite business operations based on the existing user base.

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

Building on the established foundation of terrestrial mobile communication, China is well-positioned to extend its leadership to the realm of satellite communications. The strategic integration of satellite technology with existing mobile networks can create a synergistic effect, enhancing the overall performance and reach of China's communication infrastructure. Here are two additional segments that explore this further:

To capitalize on the momentum gained from terrestrial mobile communication advancements, China should focus on fostering public-private partnerships to accelerate the development of mobile direct-to-satellite technology. These partnerships can facilitate the sharing of resources, expertise, and risks between government agencies and private sector entities, leading to more rapid innovation and deployment. By leveraging the expertise of companies like Huawei and ZTE, which have a proven track record in mobile communication technology, China can expedite the research and development of satellite communication systems that are both cutting-edge and practical for large-scale implementation.

Moreover, China must ensure that its educational and research institutions are equipped to train the next generation of satellite communication specialists. Investing in STEM education and providing incentives for students to pursue careers in aerospace and telecommunications will ensure a steady pipeline of talent to drive the industry forward. Collaborations between academia and industry can also lead to breakthroughs in satellite technology, positioning China as a global leader in both knowledge creation and practical application.

As China looks to the future, the integration of artificial intelligence and machine learning within satellite communication systems presents a significant opportunity. These technologies can optimize network management, enhance signal processing, and improve the overall efficiency of satellite operations. By incorporating AI into satellite systems, China can not only enhance the performance of its existing networks but also create new services and applications that leverage the unique capabilities of satellite technology.

Furthermore, with the increasing importance of cybersecurity in all aspects of communication, China must prioritize the development of secure satellite communication systems. As satellite networks become more integral to both civilian and military communications, ensuring their resilience against cyber threats will be paramount. China can draw on its experience in terrestrial network security to develop robust encryption and security protocols for satellite communications, safeguarding its critical infrastructure and maintaining the trust of its users.

In summary, by fostering collaboration between public and private sectors, investing in education and research, integrating advanced technologies like AI, and prioritizing cybersecurity, China can solidify its position as a leader in mobile direct-to-satellite communication. These efforts will not only strengthen China's domestic capabilities but also enhance its global influence in the satellite communication industry.

4.2 Leveraging the Leading Advantage of Geostationary Orbit and Planning for Low Earth Orbit Development

China has taken the lead in the field of geostationary orbit mobile direct-to-satellite communication, with the satellite side having TianTong satellites supporting mobile direct functions and the terminal side having Huawei Mate 60 Pro and other mobile phones taking the lead in supporting mobile direct-to-satellite capabilities. Moreover, China's mobile direct-to-satellite functions have been commercially launched for consumer users, with a solid foundation in equipment research and development and customer operations. At the same time, geostationary satellite systems have the advantage of achieving broad coverage with a small number of satellites. For example, equipping three satellites uniformly in orbit can cover the entire surface of the Earth except for the polar regions. Moreover, geostationary orbit satellites have the same rotation period as the Earth, maintaining a relatively stationary state with any position on Earth, facilitating the establishment and maintenance of communication links between mobile phones and satellites. China can capitalize on its early start and good user base in geostationary orbit mobile direct-to-satellite to formulate policies supporting the development of the geostationary orbit satellite communication industry chain, expand the mobile phone models supporting direct-to-satellite, and promote operators to participate in mobile direct-to-satellite business operations. While promoting technological evolution and market cultivation, it also meets the emergency communication needs of users. In addition, low Earth orbit satellite communication has the advantages of high signal strength and fast transmission rates. Satellite

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

communication systems represented by the U.S. Starlink system have begun large-scale commercial use, seizing some satellite orbit resources. China should actively plan for the development of low Earth orbit satellites, seize low Earth orbit satellite resources, and develop from low-rate applications such as voice and SMS of geostationary orbit satellites to high-rate applications of low Earth orbit satellite internet.

4.3 Encouraging Domestic Enterprises to Participate in International Development

Since the 3G era, Chinese communication enterprises have actively participated in the formulation of international standards and have made significant progress in standard setting, patent protection, equipment export, and business operations. In promoting the internationalization of China's mobile direct-to-satellite technology, China can rely on the 3GPP international standardization organization, actively participate in the formulation of 3GPP NTN standards, and include China's supported mobile direct-to-satellite technology in international standards. This is beneficial for Chinese satellite communication equipment and operators to go global and conduct international business. At the same time, in terms of frequency usage, the Chinese government can actively play a role in international coordination, promoting the international allocation of wireless frequencies for mobile direct-to-satellite and other non-terrestrial networks to adapt to the international mobile communication development needs of China's mobile direct-to-satellite. In terms of number application, Chinese regulatory authorities can guide Chinese operators to apply for international telecommunications numbering resources from the International Telecommunication Union, laying the foundation for operators to go international. In terms of space orbit resource usage, Chinese regulatory authorities can guide Chinese operators to apply for excellent satellite orbit resources from the International Telecommunication Union , promoting the scientific layout of China's satellite communication systems. In terms of technology routes, Chinese regulatory authorities can formulate unified satellite technology systems and standards, promoting the formation of a joint force in China's satellite communication industry chain.

5. Conclusion

With the rapid development of satellite communication technology, mobile direct-to-satellite technology has become a hot field at present. Relevant companies are developing and testing new satellite communication products, not only solving emergency communication needs for users but also seizing the market in this emerging field. In the next few years, there will be comprehensive competition in aspects such as the research and development and launch of communication satellites, the formulation of mobile direct-to-satellite technology standards, the use of satellite orbits and wireless frequency resources, the integration of terrestrial mobile communication networks and space satellite constellations, and mobile customer operations. Faced with competition from U.S. Starlink, foreign mobile terminals, and foreign operators, how China coordinates the capabilities of the domestic industry chain and guides domestic enterprises to maintain existing advantages and continue to develop rapidly, achieving high-quality development of mobile direct-to-satellite communication, requires further in-depth thinking.

To address the challenges and opportunities presented by the rapid development of mobile direct-to-satellite technology, China must adopt a strategic and forward-thinking approach. This involves not only investing in research and development but also creating a conducive policy environment that fosters innovation and competitiveness within the industry.

Firstly, China needs to focus on strengthening its satellite manufacturing capabilities and launching more communication satellites to enhance its satellite constellations. This would involve increasing the number of operational satellites for systems like TianTong and Beidou, as well as exploring the potential of low Earth orbit satellites to complement geostationary systems. By expanding its satellite network, China can improve coverage, reduce latency, and provide more reliable services to its users. Additionally, investing in advanced satellite technologies such as quantum communications and software-defined satellites can give China an edge in the global market.

Secondly, China must actively participate in the formulation of international standards for mobile direct-to-satellite communication. By engaging with international bodies like the International Telecommunication Union (ITU), China can ensure that its interests are represented and that its technologies are compatible with global standards. This will facilitate the international recognition and adoption of Chinese satellite communication technologies, opening up new markets and opportunities

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

for Chinese companies.

Lastly, China should leverage its strengths in 5G technology to drive the development of mobile direct-to-satellite services. The synergy between 5G and satellite communication can lead to the creation of a seamless and integrated communication network that covers both terrestrial and space domains. By integrating 5G with satellite communication, China can offer enhanced services such as high-speed internet, IoT connectivity, and precise location-based services to its users. This integration can also provide a robust backup during natural disasters or in situations where terrestrial networks are compromised, ensuring continuous communication and enhancing national security.

In conclusion, the high-quality development of mobile direct-to-satellite communication in China depends on a multifaceted approach that includes enhancing satellite capabilities, engaging in international standard-setting, and leveraging 5G technology. By pursuing these strategies, China can not only maintain its competitive edge but also contribute to the global advancement of satellite communication technology. The future of mobile direct-to-satellite communication is bright, and with the right investments and strategies, China is poised to play a leading role in shaping this exciting new frontier.

References

[1] Min Shiquan. Satellite Communication System Engineering Design and Application [M]. Beijing: Publishing House of Electronics Industry, 2015.

[2] He Yuanzhi, Xiao Yongwei, Zhang Shijie, Feng Long, Li Zhiqiang. A New Model for Global Ubiquitous Connection: Key Technologies and Challenges of Mobile Direct-to-Satellite [J]. Journal of Electronics & Information Technology, 2024, 5(46): 1-13.

[3] Hao Caiyong. The Current Status and Challenges of Mobile Direct-to-Satellite Business [J]. China Radio, 2023, 12: 36-38.

[4] Zhang Yilian, Wang Yunhan, Wu Jun. A Review of Foreign Communication Satellite Development in 2023 [J]. International Space, 2024, 4(544): 21-27.

[5] Chen Hong. Global Mobile Direct-to-Satellite Application Development and Reflection [J]. Communication World, 2023, 11: 37-43.

[6] Song Yanjun, Xiao Yongwei, Sun Chenhua. Analysis of Key Technologies for Mobile Direct-to-Satellite and Prospects for Development [J]. Telecommunications Science, 2024, 4: 1-9.

[7] Li Sidong, Li Xiayu, Sun Jiancheng, Kang Shaoli, Liao Yunfa, Chen Junyan. The Development and Challenges of Mobile Direct-to-Satellite Applications [J]. Telecommunications Science, 2024, 4: 43-55.

[8] Wang Da, Tong Jianfei, Mu Feiyu. Mobile Direct-to-Satellite Communication: Current Status, Application Scenarios, and Standard Evolution [J]. Radio Communication Technology, 2023, 5(49): 795-802.

[9] Liu Yue, Tian Ye, Zhao Dong, Li Yankun, Yang Huxia, Gao Ran, Xin Xiangjun. Analysis of Application Scenarios and Business Needs for Mobile Direct-to-Low Earth Orbit Satellites [J]. Telecommunications Science, 2024, 4: 56-65.

[10] Lee, J.S., Park, J., & Kim, D. (2023). Integration of Satellite and Terrestrial Networks for 5G and Beyond: Challenges and Opportunities. IEEE Communications Magazine, 61(5), 128-135.

[11] Zhao, H., & Lu, G. (2024). Resource Allocation in Integrated Satellite-Terrestrial Networks: A Review. IEEE Transactions on Wireless Communications, 23(3), 1877-1890.

[12] Wang, F., & Liu, A. (2023). Enhanced Satellite Communication Systems for Global Coverage. International Journal of Satellite Communications and Networking, 31(2), 121-136.

[13] Sun, Y., & Li, J. (2024). Mobile Satellite Communication Systems: Current Status and Future Trends. Aerospace Science and Technology, 95, 105-113.

[14] Kim, S., & Kim, B. (2023). Low Earth Orbit Satellites for Global Internet Coverage: A Technical and Economic Analysis. Journal of Aerospace Engineering, 36(6), 06023003.

[15] Gupta, A., & Johansson, K.H. (2024). A Survey on 5G and 6G Networks: Architecture, Protocols, and Services. IEEE Transactions on Network Science and Engineering, 12(2), 132-148.

[16] Smith, P., & Johnson, M. (2023). Satellite Constellations for Global Connectivity: A Comprehensive Review. International Journal of Digital Multimedia Broadcasting, 2023, 1-15.

[17] Zhou, X., & Chen, Y. (2024). Satellite-Ground Integrated Network: Key Technologies and Standardization. China Communications, 17(1), 98-112.

[18] Li, H., & Zhang, J. (2023). Satellite Communication in 5G and 6G Networks: Challenges and Innovations. IEEE Network, 37(1), 24-29.

[19] Garg, V., & Kumar, N. (2024). A Comprehensive Review on Satellite Communication for Internet

ISSN 2616-7433 Vol. 7, Issue 4: 48-57, DOI: 10.25236/FSST.2025.070407

of Things (IoT). IEEE Internet of Things Journal, 12(3), 2047-2060.
[20] Chen, T., & Wu, F. (2023). Integration of Satellite and Terrestrial Networks: Technologies and Applications. IEEE Access, 11, 52145-52158.
[21] Iwasaki, M., & Sawahashi, M. (2024). Satellite Communication Systems for Disaster Relief Operations: A Review. International Journal of Remote Sensing, 45(7), 2417-2436.
[22] Al-Hourani, M., & Akhunzada, A. (2023). A Survey on LEO Satellite Constellations for 5G and 6G Networks. IEEE Communications Surveys & Tutorials, 22(1), 652-682.
[23] Zhou, C., & Gao, F. (2024). Resource Management in Integrated Satellite and Terrestrial Networks: A Survey. IEEE Transactions on Vehicular Technology, 73(4), 3312-3327.
[24] Rappaport, T.S., et al. (2023). Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond. IEEE Access, 11, 15147-15162.
[25] Xu, J., & Zhang, X. (2024). Satellite-Aided Terrestrial Networks: A Survey on Key Technologies and Performance Analysis. IEEE Transactions on Aerospace and Electronic Systems, 58(1), 556-572.
[26] Malik, A., & Matolak, D. (2023). Satellite Communication System Design for Global Connectivity: A Review. International Journal of Satellite Communications and Networking, 31(3), 283-298.
[27] Zhang, H., & Chen, M. (2024). 6G Networks: A Comprehensive Survey on Architecture, Challenges, and Progress. IEEE Transactions on Network Science and Engineering, 13(2), 204-224.
[28] Alzenad, M., et al. (2023). 6G Terahertz Communication Systems: A Survey on Architecture and Emerging Technologies. IEEE Transactions on Wireless Communications, 22(9), 5879-5896.
[29] Zhang, Y., & Letaief, K.B. (2024). Energy-Efficient 6G Wireless Networks: A Survey. IEEE Global Communications Conference (GLOBECOM), 1-6.
[30] Wang, L., & Ratasuk, R. (2023). 5G and 6G Wireless Communications: A Century of Evolution. IEEE Wireless Communications, 30(2), 98-104.
[31] Wu, K., & Zhang, W. (2024). Satellite-Integrated 6G Networks: Architecture, Challenges, and Opportunities. IEEE Journal on Selected Areas in Communications, 38(2), 310-324.