

GTI

5G Air-to-Ground (ATG)

Communication

Technology

White Paper 1.0



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Preface

Aviation internet is a key infrastructure for advancing the digital transformation of the civil aviation industry and enhancing passengers' in-flight experience. It holds strategic significance in building the new industry ecosystem of "Smart Aviation." 5G Air-to-Ground (5G-ATG) communication, as an important technical path for achieving aviation broadband access, offers a reliable technical foundation for optimizing cabin service quality and improving operational efficiency in civil aviation, leveraging its advantages of low latency, high bandwidth, and cost-effectiveness.

China Mobile actively plays an industrial leadership role by accelerating the maturation and industrial implementation of 5G-ATG technology. Adhering to the core concepts of network-terminal coordination, air-ground coordination, and intelligent coordination, China Mobile has systematically established an end-to-end 5G-ATG technology system covering terminals, networks, and platforms. This system addresses key challenges of ultra-high-speed and ultra-high-altitude coverage as well as air-ground interference. Simultaneously, as the rapporteur of the 3GPP ATG project, China Mobile is leading technical standard formulation for 5G ATG system, fostering industrial development and maturity. Recently, China Mobile has deployed the industry's first 5G-ATG trial network by using 4.9GHz along western air routes. Multiple key technology verifications have been completed, laying a solid foundation for subsequent large-scale commercial use.

This white paper systematically outlines China Mobile's 5G-ATG development vision and technical roadmap, providing reference and guidance for the industry in areas such as air-ground communication technology development, technology adoption planning, and product solution design. China Mobile is committed to collaborating with all industry partners to tackle challenges together, jointly promote the large-scale commercialization of 5G-ATG, empower the construction of smart aviation, and drive the high-quality development of aviation internet.

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1. Aviation Internet Overview

Aviation internet refers to a suite of technologies enabling high-speed and stable internet access for civil aviation aircraft, significantly enhancing passengers' in-flight experience. By leveraging aviation internet, airlines can achieve value enhancement across three dimensions. 1. Enhanced competitiveness: By delivering internet access services with an experience close to ground usage, aviation internet significantly improves passengers' travel experience. 2. Commercial expansion: Airlines can collaborate with content service providers to achieve precise value-added service push and customized advertising, increasing ancillary revenue. 3. Operational efficiency: Real-time data exchange enables continuous monitoring of aircraft health, optimized flight scheduling, and improved maintenance planning.

There are two mainstream technical approaches for aviation internet: satellite-based airborne communication and ground-based Air-to-Ground (ATG) communication, as shown in Figure 1. Satellite-based airborne communication uses high-orbit or low-orbit satellites as relays to establish communication links between the aircraft and ground gateway stations. Passenger or crew data is transmitted to the satellite and then forwarded to the internet via the gateways. In contrast, ground-based ATG communication achieves direct communication between the aircraft and the ground network through ATG base stations deployed along flight routes. In this case, the airborne antenna, typically installed on the aircraft belly, receives mobile cellular signals and converts them into Wi-Fi signals to achieve network coverage inside the cabin.

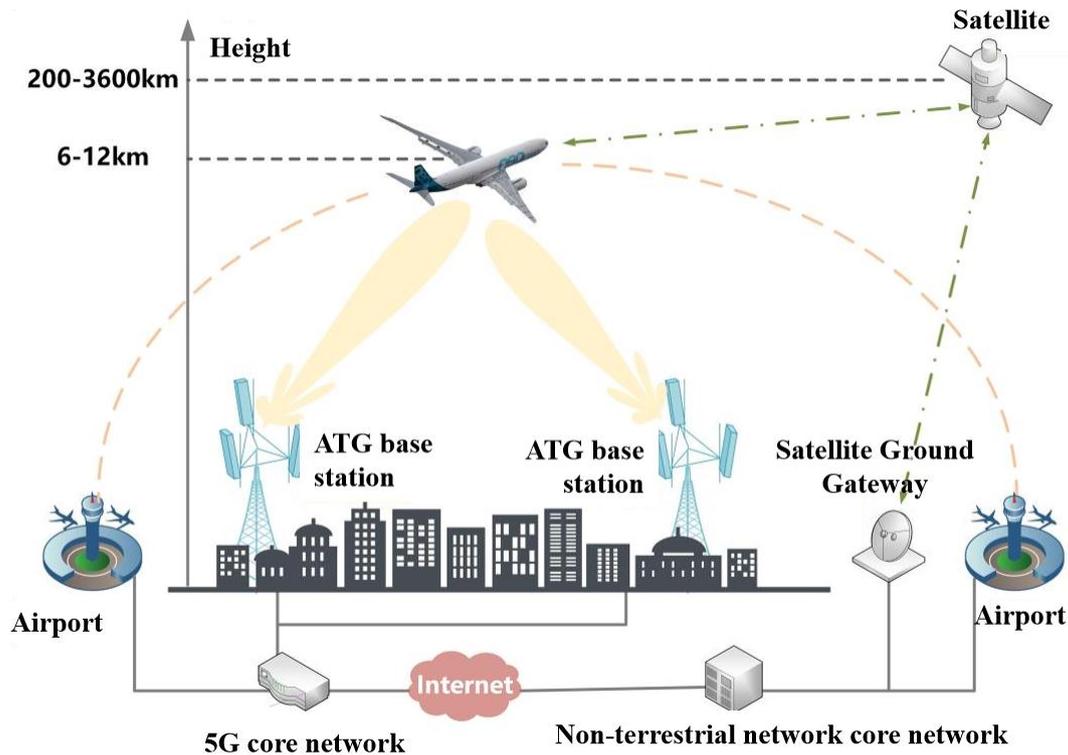


Figure 1 Mainstream Technical Approaches for Aviation Internet

Globally, North America and Europe pioneered the aircraft connectivity market with ATG+Satellite hybrid networking. In Europe, Ku-band Geostationary Earth Orbit (GEO) satellites were initially used to provide connectivity services, but the bandwidth per aircraft was small and performance was poor. Coupled with severe fragmentation of European airspace, the networking method gradually evolved into a coexistence of satellite and ATG, driven by policy and air traffic control demands. In 2015, Deutsche Telekom, Inmarsat, Thales, and others jointly developed the European Aviation Network (EAN), deploying a total of 400 4G-ATG base stations to achieve coverage across Europe, while simultaneously using satellites for intercontinental coverage. Currently, with the continuous maturation of 5G technology, the EAN is now advancing toward a 5G-ATG upgrade, transitioning from NSA to SA. In North America, Gogo, an American company, deployed 425 3G-ATG base stations in 2008 to cover the entire United States and the Great Lakes region, while using satellites for coverage outside North America. In recent years, Gogo has continuously refined its networking strategy, successively introducing Gogo 4G-ATG and Gogo 5G-ATG evolution plans. In July 2025, Gogo successfully completed the first call test based on 5G-ATG, with commercial service expected in 2026.

In China, due to policy constraints and scarce satellite resources, aviation internet

started relatively late. Initially, it primarily relied on GEO satellites from Inmarsat. With the deployment of high-throughput satellite systems such as ChinaSat and APT 6D, as of 2024, approximately 200 aircraft in China offered connectivity services, primarily on wide-body aircraft due to cost-performance considerations.

2. Development Trends of Aviation Internet

2.1. Market Prospect Analysis

The penetration rate of aviation internet exceeds 80% in the US and 50% in Europe, with the global market size reaching tens of billions of US dollars. In contrast, China's aviation sector has long been an internet service blind spot, with a coverage rate of less than 6%. In 2024, the global civil aviation passengers reached 4.893 billion, representing a 10.2% year-on-year increase. As the world's second-largest civil aviation market, China handled 730 million in 2024, representing a 17.9% year-on-year increase. With the widespread adoption of mobile internet, people have become accustomed to being real-time online, making the "information island" experience during flights increasingly unacceptable. Research shows that over 60% of passengers are willing to pay for in-flight internet, indicating strong commercial potential.

Typical aviation internet applications are divided into front-cabin (ToB) services and rear-cabin (ToC) services, as shown in Figure 2. Now the focus is primarily on serving rear-cabin services. In the future, with policy and regulatory approval, services can be further extended to the front cabin. The diverse and distinct requirements of front-cabin services and rear-cabin services impose higher demands on network performance, driving the evolution of aviation internet services towards broadband, real-time, and low-cost connectivity, specifically:

- ✧ **Broadband:** Meeting the high-bandwidth requirements of services, such as short videos, high-definition movies in rear-cabin applications; as well as data services such as web browsing, instant messaging, and social media access; and real-time cloud redundant storage for partial black box data in front cabin applications.
- ✧ **Real-time:** Meeting the low-latency requirements of services, such as online gaming, AR/VR in rear-cabin applications, as well as emergency support services like remote medical consultation and emergency communication; and synchronization of flight data such as weather and airspace dynamics in front

cabin applications.

- ✧ **Low-cost:** Pricing should be competitive with terrestrial mobile data, regardless of charging model (per flight, per data volume, etc.).



Figure 2 Typical Application Scenarios of Aviation Internet Services

2.2. Technical Solution Analysis

In terms of 5G-ATG, benefiting from the comprehensive coverage of the terrestrial network, ATG technology development has inherent technical and industrial advantages. Compared with satellite communication, its distance to the aircraft is closer, propagation loss is smaller, and performance is excellent. Targeted optimization for the civil aviation flight environment can guarantee an experience equivalent to that on the ground. Meanwhile, developing ATG communication can fully leverage the existing 5G industry chain foundation, resulting in stronger end-to-end autonomous controllability. A comparison between 5G-ATG and satellite-based airborne communication is shown in Table 1 below.

Table 1 Comparison of Advantages and Disadvantages between 5G-ATG and Satellite-Based Airborne Communication

Comparison Item	5G-ATG	Satellite-Based Airborne Communication	
		Ku/Ka High Throughput Satellite	LEO Satellite Constellation

Technical Level	Communication Altitude	6-12 km	About 36,000 km	200-2000 km
	Per-Aircraft Bandwidth	420 Mbps	About 150 Mbps	About 200 Mbps
	Air Interface Delay	20 ms	540 ms	<99 ms
	National Coverage	1500 Stations	1 Satellite	Simultaneously in orbit ≥ 100 satellites (basic connection only)
	System Capacity	15750 Gbps	100 Gbps	2000 Gbps
	Coverage Range	Land Routes	Global Routes	Global Routes
Operational Level	Construction Cost	About 750 million yuan	About 2 billion yuan	About 6.6 billion yuan
	Network Lifespan	>15 years	About 15 years	3-5 years
	Per-Aircraft Modification Cost	<1.5 million yuan	About 4.5 million yuan	About 4.5 million yuan
	Data Traffic Fee	Slightly higher than terrestrial use	300 yuan/GB	180,000 yuan/aircraft/month
Industrial Level	Domestic Base Station/Satellite Equipment Maturity	Mature, supporting independent production	Gradually maturing	Gradually maturing

	Domestic Airborne Equipment Maturity	Mature, supporting independent production	Gradually maturing	Gradually maturing
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Given China’s vast landmass and over 80% domestic route share, 5G-ATG presents a highly practical near-term solution. For the mid- to long- term (in the next 5-10 years), integration with satellite-based communication in terms of equipment and capabilities will achieve global connectivity and complementary advantages. This white paper (version 1.0) focuses only on the near term, providing a detailed analysis around the technology, standards, and industry aspects of 5G-ATG, with satellite integration to be addressed in future versions.

2.3. Industry Chain Analysis

With the emergence of market demand, and the increasing maturity of 5G-ATG technology, related industries are actively engaging. The 5G-ATG ecosystem comprises upstream, midstream, and downstream segments, as shown in Figure 3. The upstream includes ground equipment, airborne equipment, and avionics system providers and provides software and hardware equipment. The midstream includes ATG network operators and professional service providers with integration capabilities and provides network operation and services. The downstream includes airlines and content service providers and provides applications for 5G-ATG.

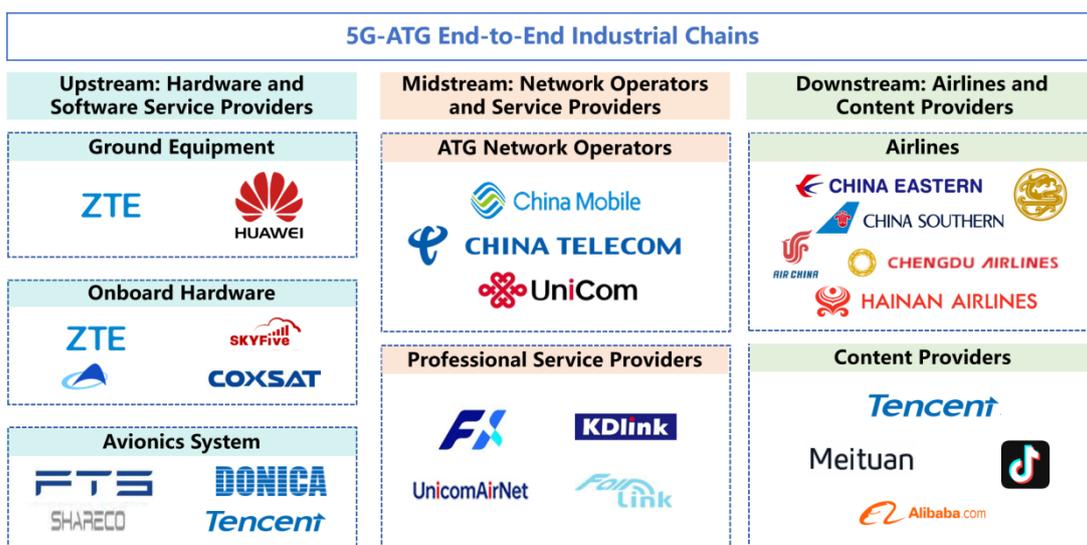


Figure 3 Domestic 5G-ATG End-to-End Industry Chain Map

In the upstream, ZTE, with its sustained investment in the ATG field, has relatively

mature supply capabilities for 5G-ATG base stations and airborne CPEs. Huawei and Airborne & Terrestrial Connectivity have also completed laboratory joint debugging tests. Donica possesses relatively mature airborne cabin products and solutions. In the midstream, China Mobile has completed the construction of the world's first 5G-ATG trial network based on the Chengdu-Dunhuang-Turpan commercial route, and completed multiple flight tests. The network performance has been fully optimized, possessing pre-commercial capability. China Telecom and others are also actively promoting 5G-ATG. In the downstream, Chengdu Airlines has jointly completed the modification of the C909 aircraft model with COMAC, which has passed airworthiness certification, and has completed multiple flights relying on the 5G-ATG trial network built by China Mobile. Tencent is actively deploying in aviation internet, committed to creating premium digital cabin services.

3. 5G-ATG Network Architecture and Key Technologies

Although 5G-ATG reuses the terrestrial network, due to special operating environment of the civil aviation aircraft, there are certain differences in network architecture, challenges, and solutions compared to traditional terrestrial networks. In this regard, China Mobile actively collaborates with the industry to conduct technical research, building an integrated system spanning terminals, the network, and platform, and promoting the mature application of 5G-ATG.

3.1. End-to-End Network Architecture

The 5G-ATG system enables direct aircraft-to-ground communication via specialized 5G-ATG base stations along flight routes, providing high-speed connectivity services for civil airliners and meeting passengers' network needs for entertainment, social interaction, shopping, emergency situations, and other scenarios during the flight. The overall end-to-end system architecture of the 5G-ATG system is shown in Figure 4.

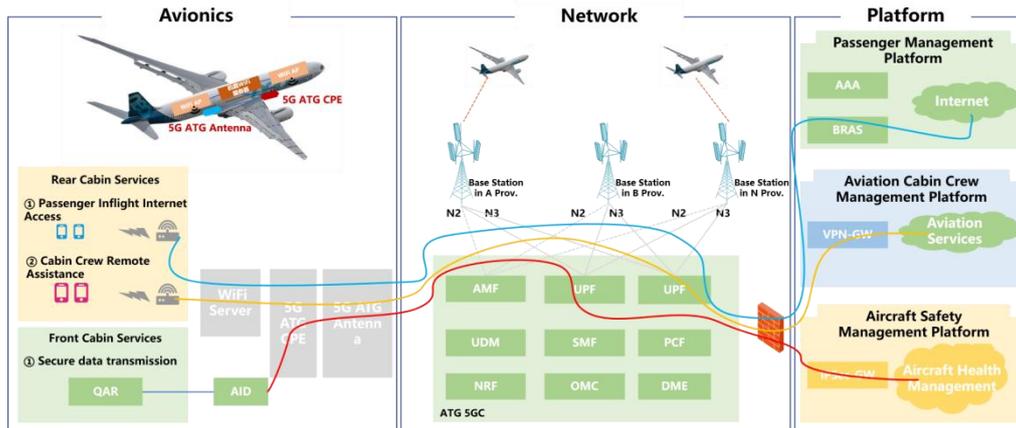


Figure 4 5G-ATG End-to-End System Architecture

The 5G-ATG end-to-end system consists of three major parts: the network system, the airborne system, and the platform system. The components of each part are as follows:

(1) Network System: Consists of the access network and the core network. The access network primarily comprises 5G-ATG base stations, deployed along flight routes to provide aerial coverage. The core network mainly includes network functions such as AMF and UPF, which can be constructed by using a 5G private network or by reusing parts of the public network. 5G-ATG base stations connect to the AMF and UPF via the SPN/PTN+IP bearer network. A firewall is deployed at the core network user plane egress for isolation and protection of data exchanged with external platforms.

(2) Airborne System: Includes the airborne 5G CPE, airborne antenna, airborne WiFi server, and APs. Among these, the airborne CPE is a terminal-side device with 5G communication capability. It connects internally to the airborne WiFi server and externally to the airborne antenna, serving as a bridge connecting the external 5G network with the internal cabin WiFi. The AP is used for WiFi signal coverage in the cabin. Passengers' portable devices access internet services after completing authentication by connecting to the cabin WiFi.

(3) Platform System: Mainly includes three categories: the passenger operation management platform, the aviation crew management platform, and the aircraft safety management platform. Among these, the passenger operation management platform is managed and maintained by the operator. The AAA platform is used for passenger login authentication within the cabin, the BRAS platform is used for service traffic statistics and access control, and it connects externally to the internet. The aviation crew management platform and the aircraft safety management platform are managed and maintained by the airline, transmitting crew remote data and aircraft health data. These two have high security requirements and require security isolation.

3.2. Five Major Technical Challenges

The initial design of mobile communication networks primarily focused on meeting the needs of moving terrestrial users, such as pedestrian movement, travel by car, and using high-speed rail. However, with the continuous development of services, application scenarios have gradually extended from the ground to low-altitude and high-altitude, and network coverage has progressively expanded from two-dimensional to three-dimensional, facing more severe problems. Specifically, 5G-ATG networks face the following five technical challenges:

(1) Speed (high mobility): In terrestrial mobile communication scenarios, car speeds are about 120 km/h, high-speed train speeds are about 300-350 km/h, while civil aviation aircraft cruise speeds are generally in the range 800-1200 km/h, which is 6.67-10 times as fast as that of cars and 2.28-4 times as fast as that of high-speed rail. In the 4.9 GHz band, a cruise speed of 800-1200 km/h will cause a one-way Doppler frequency shift of 3630-5444 Hz, severely affecting aircraft access success rate. Ordinary terminals generally do not have uplink frequency offset correction capability. The 5G-ATG system needs to overcome a frequency offset of nearly 11 kHz, which far exceeds the correction capability of existing reference signals, posing severe challenges to access success rate and service quality assurance.

(2) Coverage (wide area): 700 MHz 5G terrestrial base stations have a coverage radius of about 1 km, and the 4.9 GHz band is about 300-500 m. In contrast, to meet the coverage requirements of deserts and offshore areas, and to minimize frequent handovers as much as possible, 5G-ATG base stations need to support a maximum coverage of 300 km, which is 300-1000 times greater than the coverage capability of conventional 5G terrestrial base stations, leading to two issues: First, path loss increases by nearly 50-60 dB compared to terrestrial two-dimensional coverage. Second, propagation delay increases significantly to about 1 ms under a 300 km coverage radius. In response, adjustments are needed for airborne terminal transmit power, public-network slot structure, access methods, and timing relationships.

(3) Altitude (high cruise): The vertical coverage height of terrestrial and low-altitude networks is below 0.6 km, which can be effectively realized by adjusting the tilt angle of conventional antennas; whereas civil aviation aircraft cruise at altitudes of 6-12 km. The vertical beam scanning angle of traditional AAUs (for example, those operating at 4.9 GHz) is limited (maximum 24°), leading to difficulties in covering the

area directly above the base station, creating coverage holes, and posing a risk of communication link interruption when aircraft fly directly over the base station.

(4) Interference (complex environment): On one hand, it is necessary to consider the compatibility with systems outside IMT, such as radio astronomy and radio altimeters. On the other hand, it is also necessary to consider the impact of 5G-ATG on terrestrial public networks, such as co-channel interference and cross-slot interference to low-altitude communication, and Integrated Sensing and Communications (ISAC) within IMT.

(5) Evaluation (3D dynamics): Traditional 5G terrestrial networks use single-point cell edge rates as the core metrics for evaluating service requirement satisfaction, whereas 5G-ATG networks exhibit significant three-dimensional dynamic characteristics in distance, altitude, and azimuth. Traditional evaluation metrics cannot represent the service requirement satisfaction of airborne terminals on the full three-dimensional link, making simulation evaluation challenging. Specifically manifested in the following: First, the motion of civil aviation aircraft is highly time-varying, propagation loss and antenna gain dynamically shift, and link quality fluctuates non-linearly. Second, terminal distribution within a cell is extremely sparse, but the service rate requirement per aircraft far exceeds the average of terrestrial users. Third, 5G-ATG networks cover three-dimensional airspace, while single-point rate metrics reflect only edge performance in the two-dimensional plane, unable to quantify high-altitude weak coverage areas.

3.3. 5G-ATG Technology System

3.3.1. End-to-End Technology System

To address the five major challenges, China Mobile has developed an integrated 5G ATG Communication Technology System (1.0), based on a 5G-ATG end-to-end network architecture. This system spans five layers: terminal, access, network, platform, and security. Guided by the core principles of Network-Terminal Coordination, Air-Ground Coordination, and Intelligent Coordination, it overcomes coverage and interference issues in high-speed, high-altitude environments. The solution enables high-quality connectivity to support diverse in-cabin service applications in civil aviation, as illustrated in Figure 5.

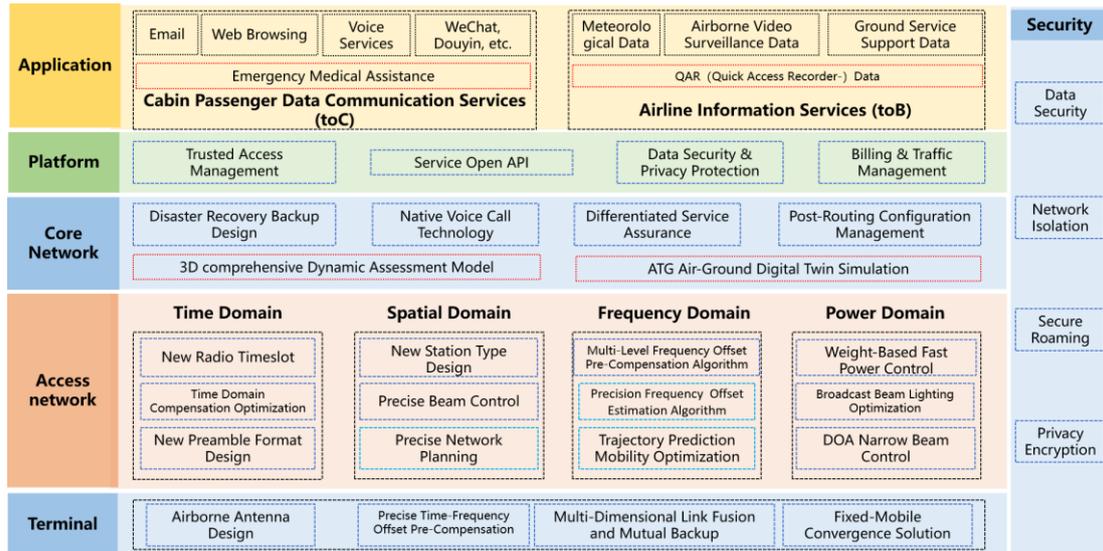


Figure 5 5G ATG Communication Technology System (1.0)

The terminal layer ensures the stability of high-speed access through innovative time-frequency offset compensation algorithms, and improves transceiver gain and suppresses ground interference by redesigning the airborne antenna. The access layer adopts new station types to extend AAU vertical scanning capability on the hardware side, and designs new air interface slot structures to adapt to wide coverage and introduces ATG interference suppression schemes on the software side. The network layer designs a coordinated networking architecture for the radio and core networks based on route distribution, enabling high-reliability, low-cost coverage. The security layer combines network isolation and privacy encryption strategies to ensure absolute end-to-end data security. The innovations above are condensed into new algorithms, new air interface, new station types, new technologies, and new methods, detailed as follows.

3.3.2. New Algorithms, Overcoming Ultra-High Doppler Frequency Offset

To overcome the nearly 11 kHz ultra-large Doppler frequency offset caused by the high-speed movement of civil aviation aircraft, a multi-stage pre-compensation technique is designed to gradually suppress the Doppler frequency offset while ensuring high-precision, low-complexity system performance. Specifically, the airborne CPE calculates the uplink and downlink Doppler frequency shifts based on its position, terminal speed, and the base station's approximate location respectively. Referring to

the calculation results, the CPE performs frequency domain pre-compensation before uplink transmission and downlink reception. During the downlink synchronization process, a coarse frequency offset estimation of ± 6.29 kHz is performed via SSB. After access, TRS is used for frequency offset tracking and compensation. During uplink transmission, the downlink frequency offset estimate is inverted for uplink frequency offset pre-compensation. Simultaneously, the base station side still performs further frequency offset compensation based on conventional frequency offset estimation algorithms. The residual Doppler frequency offset after compensation is 0.01 ppm at most, within the range of existing reference signal estimation compensation, as shown in Figure 6.

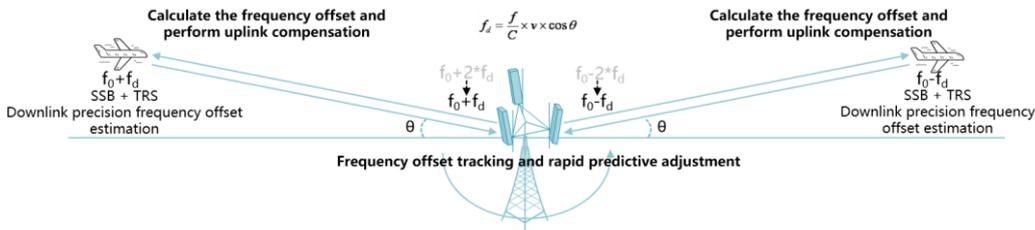


Figure 6 5G-ATG Ultra-High Doppler Frequency Offset Compensation

3.3.3. New Air Interface, Breaking Through Ultra-Wide Area Coverage Boundaries

Civil aviation aircraft fly at high speeds. To reduce frequent handovers and lower deployment costs, while considering the coverage of eastern coastal routes in China, 5G-ATG base stations are designed to support an extreme coverage radius of up to 300 km. However, the 4.9 GHz band slot configuration for existing networks uses a 2.5 ms dual-periodicity (7D3U) frame structure with a special slot configuration of 10:2:2, and the Guard Period (GP) is only 2 symbols, supporting a maximum coverage radius of about 10 km. Furthermore, the coverage capability of existing 3GPP PRACH formats also cannot support 300 km coverage.

To address the above issues, a redesigned 20 ms long-periodicity frame structure and optimized PRACH access mechanism have been implemented to achieve 300 km coverage and ensure reliable access. First, the round-trip delay for a 300 km link is 2 ms, requiring that the GP for uplink/downlink switching be at least 2 ms. Given that in-flight traffic is predominantly downlink-heavy with minimal uplink demand, a typical uplink-to-downlink slot ratio of 1:5 is adopted. To minimize resource overhead from

frequent uplink-downlink switching, a 20 ms single-periodicity frame structure is used. Second, the existing 3GPP-defined PRACH formats support a maximum coverage radius of only 102 km. To extend the coverage radius, time-domain pre-compensation technologies are adopted to ensure stable random access under ultra-large cell conditions.

3.3.4. New Station Type, Achieving Ultra-High Altitude Continuous Coverage

To resolve the issue of limited vertical beam scanning angles in traditional AAUs (which result in coverage holes directly above base stations), a new type of AAU with an ultra-wide vertical scanning range has been developed. Currently, two solutions are available: First, panel segmentation design. The antenna array panel of existing AAUs is improved by dividing it into different panels. For example, use Panel A to cover the 2°-40° area, and use Panel B to cover the top 40°-90° overhead area. Flexible panel design meets the requirement for ultra-high altitude continuous coverage and solves the coverage hole issues in existing AAUs. Second, ultra-wide-angle AAU design. For instance, the industry's existing 128TR ISAC AAU uses 768 antenna elements to increase the vertical scanning capability from the traditional 24° to 60°, significantly improving continuous coverage in the ultra-high altitude area above the base station. As shown in Figure 7 below:

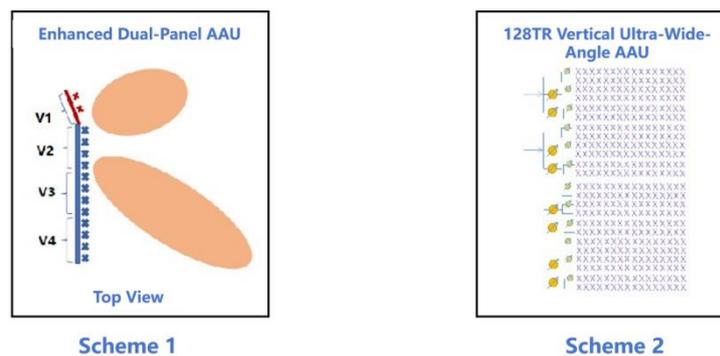


Figure 7 New 5G-ATG AAU Station Type

3.3.5. New Technologies, Optimizing Ultra-Complex ATG Interference

With the ATG coverage extending from two-dimensional planes to three-dimensional

space and incorporating new slot configurations, the potential interference, both uplink and downlink, within and outside the IMT system, increases significantly. Traditional interference control methods include physical isolation (requiring 5G-ATG base stations to maintain minimum physical distance from sensitive systems), frequency offset scheduling (using dynamic or static frequency offsets between the 5G-ATG network and low-altitude or terrestrial base stations), and slot silencing (ensuring that 5G-ATG uplink slots do not transmit data during G slots for ISAC). These methods can solve or avoid some interference issues but some interference issues remain. For example, in tourist hotspot cities or densely routed eastern regions, physical isolation requirements may not be feasible. Moreover, with the growth of low-altitude economy and increasing drone operations (whose flight routes are unpredictable), physical isolation becomes impractical. The long-duration wide-area radiation from main lobes or side lobes of ATG base stations toward the air easily interferes with drone flights.

To address this, optimization methods that can further reduce ATG interference need to be adopted. As shown in Figure 8 below, a dynamic interference optimization scheme based on flight path tracking is designed, combining the characteristics of the ATG scenario. Under this scheme, all ATG base stations, except those within a predefined range around airports, are initially in lights off (silent) state. When an aircraft flies along its scheduled route, the ATG base stations along the route undergo state transitions from lights off to lights on to lights off one by one based on the aircraft's real-time position. In lights off state, RF transmission is turned off and broadcast beams are not transmitted, minimizing interference. In lights on state, RF transmission resumes and broadcast beams are transmitted, enabling normal access and uplink/downlink services. This scheme reduces the interference from constantly transmitted broadcast beams on ground communication stations, low-altitude RF terminals (including flying drones), and ISAC stations and also mitigates co-channel interference among ATG base stations covering altitudes above 3 km, improving handover accuracy. For ATG base stations deployed in locations that cannot meet physical isolation conditions, the dynamic lights on and lights off mechanism converts long-duration interference into instantaneous interference. Combined with the randomness of ground services and airborne services, the overall interference is significantly reduced.

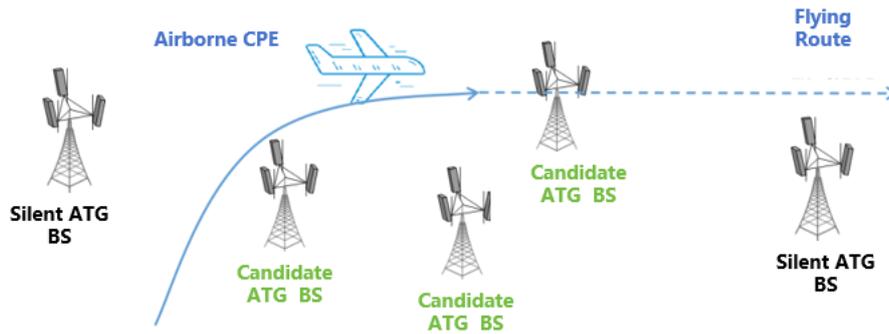


Figure 8 Optimization Scheme Based on Flight Path Tracking

3.3.6. New Methods, Enhancing Three-Dimensional Evaluation Accuracy

The differences between 5G-ATG and traditional terrestrial networks lie in four aspects: extremely large cell radius, very high terminal position, very few concurrent users, and a simplified propagation model. The conventional method of using single-point cell edge rates to evaluate service requirement satisfaction is no longer applicable.

To address this, an innovative three-dimensional full-domain evaluation model has been proposed for 5G-ATG scenarios. This model integrates the antenna patterns of 5G-ATG base stations and airborne CPEs to evaluate the entire three-dimensional airspace link conditions of civil aviation aircraft from far to near and from high to low. It enables accurate evaluation of uplink and downlink rates and quickly identify coverage blind spots to guide network planning. This model breaks through the convention of traditional terrestrial networks using the single-point metrics, expanding the rate evaluation capability to line distributions at different projection distances, then to surface distributions at different flight altitudes, and is compatible with the future evolution to volume distributions under different azimuth directions, ultimately forming a three-dimensional full-domain ATG link budgeting capability, as shown in Figure 9 below.

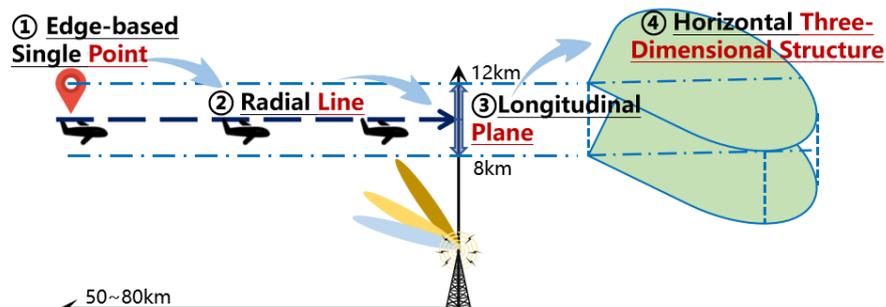


Figure 9 5G-ATG Three-Dimensional Full-Domain Evaluation Model

4. 5G ATG Communication Standardization Progress

With the rapid advancement of 5G-ATG technology, its standardization framework is progressively maturing. In terms of international communication standards, 3GPP Release 18 (Rel-18) was frozen and released on June 18, 2024, defining relevant enhancement technologies supporting 5G-ATG, making it the first standard version that supports 5G-ATG.

China Mobile serves as the rapporteur for the 3GPP ATG communication project, leading the development of 5G NR ATG Rel-18 and Rel-19 related technical research and standardization work, defining a series of enhancement features that can meet the connectivity needs of civil aviation aircraft. Specifically, 3GPP Rel-18 focuses on FR1 single-carrier single-stream data transmission scenarios and was frozen and released in June 2024. 3GPP Rel-19 focuses on enhanced scenarios such as FR1 carrier aggregation and dual-stream data transmission. The key requirements and technical enhancements defined in 3GPP R18 for 5G-ATG are as follows:

- **Frequency bands:** 5G-ATG reuses the existing terrestrial 5G FR1 bands. Based on operator requirements, the following bands are specified as available for ATG deployment: n1, n3, n34, n39, n41, n78, and n79.
- **Antenna types:** In addition to omnidirectional antennas, the standard now permits the use of array antennas at airborne terminals. This enhances signal directivity, and improves uplink and downlink coverage and link performance. Relevant RF indicators and test methods are also defined in the standard.
- **Enhancement technologies:** To address the challenges of ultra-long base station coverage (up to 300 km) and ultra-high terminal mobility (up to 1,200 km/h), 3GPP has introduced several enhancements to terrestrial 5G technologies. These include SIB22 broadcast messages, improved time-frequency domain pre-compensation based on terminal location and coarse base station position, TDD special slot configuration and symbol-level Timing Advance (TA) reporting, location-based conditional handover, and updated measurement metrics for array antennas.

5. 5G ATG Route Trial Progress

In China, China Mobile and China Telecom are actively driving the development of 5G-ATG related technologies and the industrial ecosystem. China Mobile, in collaboration with communication equipment suppliers, avionics manufacturers, and other industry partners, has completed the development of end-to-end 5G-ATG equipment and obtained TC/SB airworthiness certification based on the COMAC C909 aircraft platform. In January 2025, China Mobile has been granted exclusive authorization to conduct 5G-ATG technology trials. This permits China Mobile to use the 4840-4900MHz frequency band to perform technical performance evaluations and frequency compatibility tests with other radio services.

Leveraging this authorization, China Mobile has completed a 5G-ATG trial network covering the Chengdu-Dunhuang-Turpan western route, spanning four provinces: Sichuan, Qinghai, Gansu, and Xinjiang. After multiple rounds of route coverage optimization, the network has achieved near-optimal performance. In terms of coverage, the average RSRP is -107dBm and SINR is about 9.8dB. The comparison before and after optimization is shown in Figure 10 below. During actual flight tests, the network delivered uplink and downlink peak rates of 73 Mbps and 353 Mbps respectively, with an average latency of 129 ms and a 100% handover success rate throughout the journey.

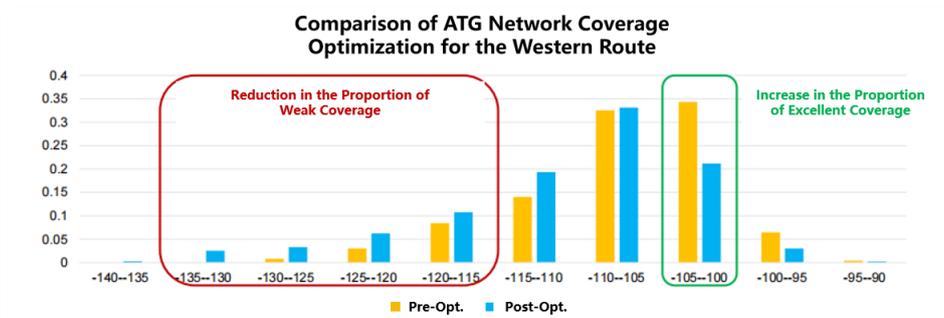


Figure 10 Comparison of China Mobile's 5G-ATG Trial Network Coverage Before and After Optimization

From February 2025 to July 2025, China Mobile conducted four flight tests and invited customers including COMAC, Chengdu Airlines, China Southern Airlines, and Airbus to participate in the tests. The tests received high praise. Demonstrated services included popular services such as WeChat instant messaging, 4K HD live streaming, multi-party video conferencing, and online games (such as Honor of Kings). Users reported a smooth and consistent experience throughout the flight, with perceived

performance closely matching that of terrestrial 5G networks.

6. Summary and Outlook

This white paper provides a comprehensive analysis of the intrinsic demands and evolution trends in aviation internet development. It addresses the key challenges in ATG communication, with a focus on China Mobile's breakthroughs in end-to-end technology systems, core research, and trial verification. It also summarizes the latest progress in standardization and industry ecosystem development. China Mobile adheres to a “dual-track” strategic approach, advancing both ATG and satellite-based airborne communication, fully leverages the technical and cost advantages of 5G-ATG, and accelerates the commercial deployment of ATG in the Chinese airline market. In the medium to long term, China Mobile will simultaneously build satellite-based airborne communication capabilities, aiming to establish a globally competitive aviation internet service platform.

Looking ahead, ATG communication will become an important component of the 6G Space-Air-Ground Integrated Network (SAGIN). ATG technologies will achieve progressive integration with terrestrial cellular networks and satellite internet in terms of technology, standards, and equipment forms, building a coordinated hybrid terrestrial and satellite-based network architecture. This will realize the beautiful vision of ubiquitous on-demand connectivity anytime, anywhere, across the three-dimensional global space.

Finally, 5G-ATG is a platform industry spanning multiple fields such as communications, aviation, and manufacturing, requiring all parties in the industry chain to collaborate and seek win-win development. In this regard, China Mobile is committed to working with industry partners to continuously improve the technical standards and airworthiness certification system, jointly explore sustainable business models and innovative application scenarios, and promote the high-quality development of the aviation internet industry.