Unleashing New Value with New 5G Technology

June 2023

Preface

Over the past four years since the commercial launch of 5G, global construction of 5G networks has steadily accelerated, the 5G industry chain has continued to improve, and personal business development and industry applications have entered a new phase. 5G is becoming a key driver behind the digital upgrade of people's lives, the intelligent upgrade of industries, and the intelligent development of society.

The development of technologies is an ongoing process. 5G has now been introduced to a wide array of industries to create value through its applications. 5G has also undergone technological iterations and upgrades since its launch, pushing it to evolve towards more functions, better performance, smaller carbon footprint, and higher intelligence in order to adapt to changing markets, solve real-world problems, and bring higher personal, economic, and social value.

This report dives into five megatrends in evolution from 5G to 6G, namely: superior performance,

high energy efficiency and lightweight equipment, network intelligence, integrated communication, sensing and computing, and space-air-terrestrial integration. The report also covers nine representative new technologies, and analyzes, in detail, 5G's new value as a new driving force for the in-depth and intelligent development of economy and society, which is helping to expand the boundaries of intelligent lifestyles for individual users, extensively incorporate intelligence within industries, and realize universal intelligence in society, in addition to requirements for business model innovation in order to realize this new value. Through this report, we hope to build consensus on 5G technology innovation and value creation, develop and strengthen the 5G industry, and stimulate 5G-enabled economic and social transformation.

China Mobile Intelligence, GSM Association (GSMA) Intelligence, and Global TD-LTE Initiative (GTI) jointly authored and published this report.

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1. Global 5G Development Enters a New Phase

Following the global commercial launch of 5G in 2019, 5G has experienced rapid development, making significant progress in areas like network deployment, spectrum allocation, terminal development, and service applications.

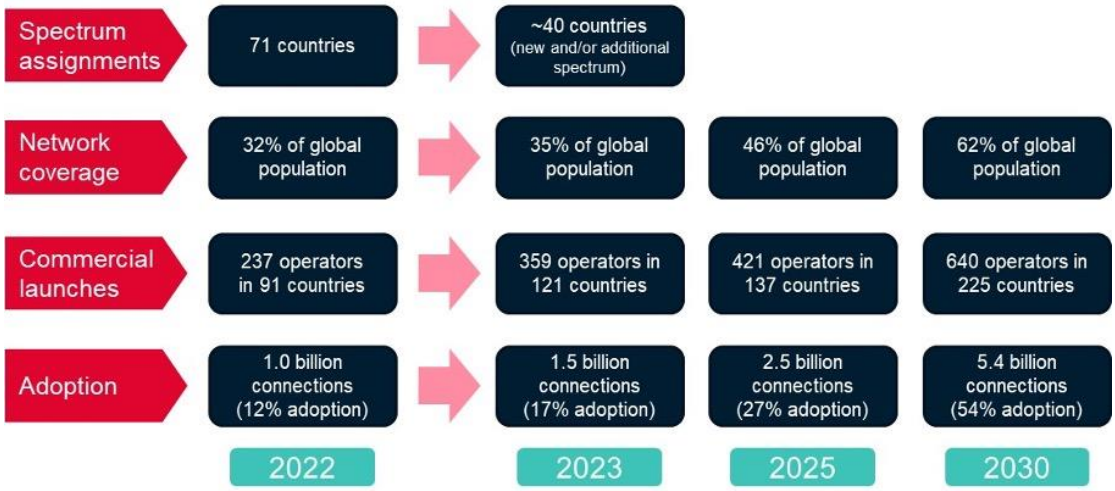

Figure 1 Global 5G developments at a glance

1.1. 5G Network Commercialization Is Rapidly Advancing

5G network coverage is gradually increasing. According to a GSMA Intelligence analysis, 5G networks had covered 32% of the world's population by the end of 2022. China by then had the world's largest scale of commercial 5G networks, with 2.312 million

5G base stations[1]. 5G networks have become a key area of investment, with global mobile operators set to invest US$1.5 trillion in mobile capital expenditure (CAPEX) between 2023 and 2030, of which approximately 90% will be allocated to 5G networks. Thanks to constant investment, the global population covered by 5G networks is expected to increase to 46% by 2025 and 62% by 2030.

5G commercial reach continues to expand. According to GSMA Intelligence, 237 operators had launched 5G services (including fixed wireless access, or FWA for short) in 91 countries by the end of 2022. 2023 will see the launch of new 5G services in about 30 countries, and by the end of 2025, 5G services are expected to cover 137 countries worldwide.

1.2. 5G Mid-band Spectrum Is a Step Ahead

The 5G spectrum is critical to enabling 5G services. According to a GSMA Intelligence analysis, 71 countries had identified their 5G spectrum by the end of 2022, with most countries issuing mid-band

1 Statistical Bulletin of the Communications Industry in 2022: Website of the Ministry of Industry and Information Technology of China

spectrum, followed by low-band and millimeter wave (allocated in 20 countries). In 2023, nearly 40 countries are expected to allocate new spectrum for 5G. World Radiocommunication Conference 2023 (WRC-23) is committed to helping the industry deliver affordable 5G services and bridge the digital divide, and will continue 5G spectrum planning to create space for future network demands.

1.3. The 5G Terminal Industry Is Booming

Global Mobile Suppliers Association (GSA) data shows that by the end of 2022, 224 manufacturers worldwide have announced about 1,800 models of 5G terminals (including available and upcoming models), of which about 900 were 5G handsets. Nearly 80% of these 5G terminals are already commercially available, representing a 67% increase in the number of commercial 5G terminals compared to 2021. In high-income countries, 5G handsets account for over 50% of smartphone sales. In addition to 5G handsets, FWA and enterprise terminals (e.g. modules, industrial or enterprise routers, gateways, or modems) are also showing signs of growth. For example, reportedly,

there were already 277 types of FWA customer-premises equipment (CPE) by the end of March 2023, 177 of which are already commercially available.

1.4. 5G Application Promotion Is Effective

1.4.1 Significant Increase in the Number of 5G Connections

In 2022, the number of 5G connections reached a significant milestone. According to GSMA Intelligence statistics, the number of 5G connections worldwide surpassed 1 billion, accounting for 12% of all mobile connections. By the end of 2022, China had developed 600 million 5G users, accounting for more than half of the world's 5G users and leading globally by a wide margin. By 2023, the number of global 5G connections will increase from 1 billion to 1.5 billion, and will reach 2.5 billion by the end of 2025, accounting for 27% of total mobile connections. In addition, the number of 5G FWA and 5G Internet of Things (IoT) connections continues to grow.

1.4.2 5G Personal, Home, and Industry Applications Accelerate

5G applications can fall into the categories of

personal, home FWA, and industry applications, all three of which have seen significant progress in recent years.

In the personal application market, user satisfaction regarding 5G network experience is high, and 5G is shown to positively impact traffic and average revenue per user (ARPU). According to a survey by GSMA Intelligence in 8 countries (China, France, Germany, Italy, Japan, South Korea, the United States, and the United Kingdom) in 2022, 70% of 5G users were satisfied with their network experience, with 5G users in China and the US being the most satisfied users. Active 5G usage has led to a significant increase in 5G traffic. A 2021 study of 20 leading 5G markets showed that 5G smartphone users consume 2.7 times more traffic than 4G users. 5G traffic growth has led to a rebound in mobile ARPU, as shown in the chart below. Research from GSMA Intelligence shows that as a result of 5G service rollouts, six of the eight countries analyzed have seen a reversal in the declining ARPU trend. Leading 5G countries in Asia Pacific (e.g. China, Japan,

South Korea, and Australia) have seen the most remarkable improvements in ARPU since the launch of 5G.

Figure 2 Mobile ARPU trend before and after the launch of 5G services

In the fixed broadband market, 5G makes FWA more competitive, significantly narrowing the speed gap with other high-speed technologies such as fiber access. By the end of 2022, 95 operators had launched 5G FWA services in 48 countries. By 2025, 5G FWA will account for more than 10% of total fixed broadband connections in countries such as Austria, Australia, Germany, and the United States.

For industry applications, 5G supports digital transformation in manufacturing, mining, transportation, healthcare, energy, and other industries. According to a GSMA Intelligence analysis, 16 leading operators reached 24% service revenue from

outside of traditional telecoms in 2021, representing an average growth of 14% year-on-year, compared to only 3% in traditional telecoms revenue. China is positioned as a global leader in 5G industry applications. According to the Chinese Ministry of Industry and Information Technology (MIIT), China has built over 16,000 5G virtual private networks for industry applications alone, and over 50,000 5G application cases, while 5G applications cover 52 of 97 major national economic categories[2].

2 China has built more than 16,000 5G virtual private networks for industries: Communication World (China), 2023.5.24

2. 5G Technology Evolution Achieves Breakthroughs

In recent years, personal digital applications have evolved to cloudization, HD, and virtualization, and industries have transformed to digitalization and intelligence, placing higher demands on 5G network performance, cost, and service experience. At the same time, technologies like Big Data, IoT, and artificial intelligence (AI) have combined with communications technologies to make 5G networks better and more efficient than ever. Following the first version of 5G (3GPP Rel-15), the second version (Rel-16) optimized basic performance and improved the capability of eMBB-uRLLC-mMTC, and proposed intelligent cost reduction and efficiency technologies. Rel-17 introduced industry capability customization, expanded air-space-terrestrial coverage, and improved network intelligence. Starting from Rel-18, 5G-Advanced (5G-A) proposed "advanced network, advanced intelligence system, advanced energy efficient industry". On the path towards 6G evolution, 5G technology standards are being

continuously upgraded and evolving in five major directions: excellent performance, energy efficient and lightweight, network intelligence, integrated communication, sensing and computing, and air-space-terrestrial integration.

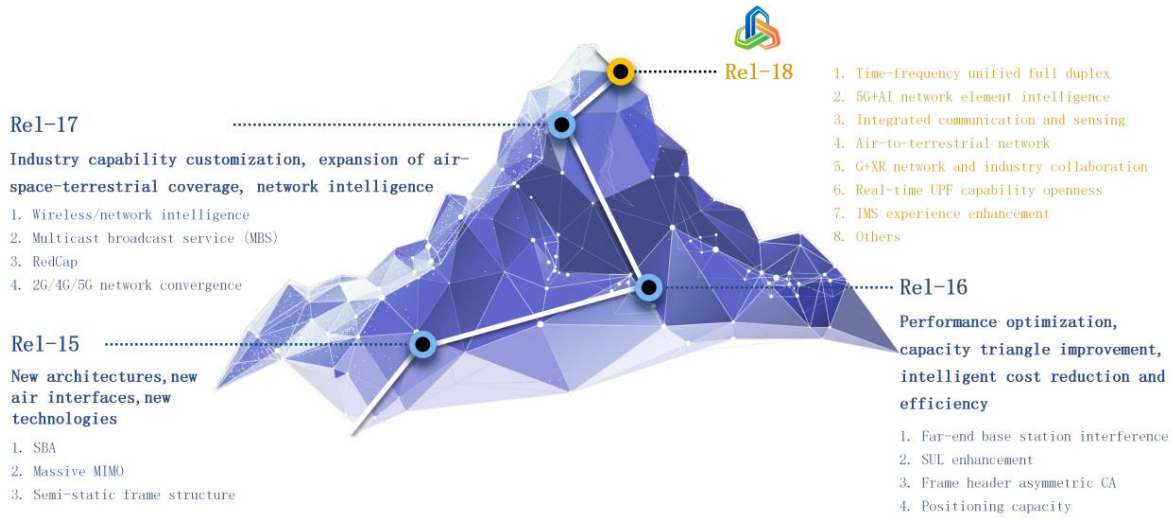

Figure 3 5G technology standards evolution path

2.1. Trend 1: Excellent Performance

5G delivers superior network performance by introducing faster data throughput technology, X-Layer technology, full-duplex technology, deterministic technology, and sea coverage technology.

Faster data throughput: With the introduction of carrier aggregation (CA) and uplink enhancement technologies in Rel-16 and Rel-17, the single-user peak rate can theoretically reach 3.2 Gbps downlink

and 500 Mbps uplink, which is ten times higher than that of 4G. With the subsequent introduction of large-scale antenna and millimeter wave technologies in Rel-18, the single-user peak rate can theoretically approach the target of 10 Gbps downlink and 1 Gbps uplink, meaning the rate can further increase by more than three times.

Real-time performance improvement: 5G introduces X-Layer technology to achieve the cross-layer optimization of service-aware network state and network-aware service information, to meet the needs of immersive virtual-real integration services, such as XR, and meet the large-bandwidth real-time indexes of instantaneous frame-level 100-megabit rate and 20 milliseconds latency required for 4K and 60fps services.

Deterministic capability enhancement: 5G achieves simultaneous uplink and downlink transmission on TDD spectrum, zero waiting latency, and high-precision time synchronization through the application of full duplex and unified division duplex (UDD) integration and time sensitive

networking (TSN) internalization to deliver the low latency and high uplink required by industrial Internet. 5G deterministic technology meets the requirements of low latency and high uplink for industrial Internet by combining air interface capability grading and precise network beat scheduling, all supplemented by collaborated and efficient service scheduling to save network resources. 5G deterministic technology realizes deterministic capabilities for 5G industrial Internet, namely a 20 ms latency and 99.99% reliability.

Coverage distance enhancement: 5G enhances cell coverage and capacity through beam-level power control of broadcast channels, suppression of co-channel interference in coverage overlapping areas, and AAU/RRU combined deployment in order to achieve ultra-long coverage, ultra-high capacity, and real-time backhaul in special scenarios such as those involving sea, high-speed rail, and grassland. Meanwhile, new ship-borne, high-gain antennas and ship-borne coverage enhancement equipment have been introduced to boost offshore sea coverage and create

a multi-frequency three-dimensional 5G network that can meet various demands for coastal and distant sea information.

Transmission efficiency improvement: NR-based 5G multicast and broadcast service (MBS) includes both broadcast and multicast, using cellular networking to deliver services to its subscribers in a resource-efficient manner. It maximizes and dynamically and flexibly reuses unicast designs to provide more efficient transmission capabilities and wider coverage.

2.2. Trend 2: Energy Efficient and Lightweight

5G networks enable large-scale antenna arrays, large bandwidth, and high-speed transmission while increasing energy consumption. This is making green operations and high energy efficiency an important direction for 5G development. In addition, in order to achieve the ultimate performance and meet varying needs, 5G network structure is relatively complex compared to that of 4G. When it comes to the overall network architecture, convergence and simplicity are the trend.

In terms of terminals, RedCap is a lightweight 5G technology that can provide high-speed service carrying capacity for 5G and reduce the complexity of 5G terminals in areas like bandwidth and antenna quantity. Compared to 5G NR terminals, RedCap terminals are about 60% less complex, which translate to cost advantages.

In terms of base stations, intelligent and simplified base stations can effectively reduce costs by overlaying network capabilities and customizing service capabilities on demand, on the basis of public network base stations to better match the needs of industry customers for customized capabilities and controllable costs.

In terms of the core network, it can accurately predict and evaluate the traffic volume and load of network elements through deep learning technology to effectively adapt computing power to traffic, which reduces the energy needed by network elements by more than 20%. The customized core network can tailor the functions of network elements on demand to save system resources, and can also customize the

functions of network elements to adapt to the differentiated and personalized needs of vertical industries.

2.3. Trend 3: Network Intelligence

The operators' vision for network intelligence is to shift from intelligent network operations and maintenance for reducing operational expenditures (OPEXs) to intelligent network service development and traffic management, and ultimately to native AI support.

To make this vision a reality, intelligent analysis and decision-making capabilities must be introduced in the areas of precise service identification, service experience modeling, precise management of network resources, and service quality assessments so as to deliver "one policy for one site" in terms of resource allocation and parameter adjustment. This will precisely match service needs, improve the service experience, and stimulate traffic growth.

2.4. Trend 4: Integrated Sensing, Communication, and Computing

Sensing applications such as smart manufacturing, smart energy, smart transportation, smart low altitude space system, smart cities, and smart networks require communications networks to possess more capabilities, such as end-to-end integrated design, high-precision sensing, and diversified sensing. Through network-supported sensing and integrated sensing and communication (ISAC), a network that integrates multiple capabilities can be formed.

Network-supported sensing: Air interfaces are flexibly multiplexed for integrated sensing and communication. During this process, communication signals and sensing reference signals are transmitted in time division multiplexing combined with frequency division multiplexing mode. Network-supported sensing offers higher sensing and measurement performances than conventional radars and also achieves high-precision sensing. Horizontal positioning accuracy can be achieved to a less than

one-meter level to assist autonomous driving and road supervision, or a less than 5-meter level to support drone supervision. The localized architecture is flexible, agile, and able to meet the requirement of 100 ms for V2X.

Integrated sensing and communication: Achieves intelligent connection and management of large-scale items based on the combination IoT capabilities such as seamless coverage, multi-sensor integration passive IoT features such as low power consumption, maintenance-free, easy-to-deployment. This is part of the minimalistic connection and ultra-low power consumption development direction of IoT. The new standard of passive IoT which integrated with cellular networks, supports seamless coverage of and multi-user host access, improves communicaiton distance from dozen meters to 100 meters based on the technologies such as self-interference suppression, error correction coding. In addition, the conflict resolution algorithm is designed to improve the random access efficiency of passive IoT tags to improve the inventory speed to about 200 tags per

second, and ultimately achieve inventory, positioning, and sensing and other capabilities based on massive tags and cellular networks, while reducing network complexity and costs.

Computing power development: as the core element of digital economy productivity, computing power is displaying a development trend of two "ultra", one "diversified", and one "converged". This refers to, ultra-focused central computing power, which forms super large-scale computing power clusters; ultra-distributed edge computing power, which is extended to the sites to meet real-time business needs; diversified computing power kernel, which create collaboration between general and heterogeneous computing power to improve computing efficiency at lower energy consumption; and deeply converged computing power, through which networks can connect to, sense, and carry computing power to transform computing network infrastructure and make it informationized. The new infrastructure integrates data sensing, connection, computing, storage, and analysis to provide increasingly rich computing

network services.

2.5. Trend 5: Air-Space-Terrestrial Integration

In recent years, low Earth orbit (LEO) satellite Internet deployment has been booming, making air-terrestrial integration a key evolution direction of information infrastructure

The integration of space-air-terrestrial combines cellular networks and space networks that include things like satellites, high-altitude platforms, and drones, to build an air-space-terrestrial integrated network that covers entire globe. This 3D network provides ubiquitous connectivity at low costs. This means, broadband and mobile communications are available for users anywhere, and human-machine-thing connection requirements can be met with security and reliability anytime.

2.6. Typical new 5G technologies

A series of new 5G technologies are emerging and trending towards 6G. Among them are RedCap, new passive IoT, ISAC, deterministic network, 5G MBS,

network element (NE) intelligence, X-Layer, 5G new calling data channel, and air-space-terrestrial communications. These nine technologies can be applied across various scenarios and have bright development prospects. This report takes these technologies as representative new 5G technologies to analyze their application prospects and the potential economic and social values they can generate.

Table 1 Typical new 5G technologies

Technologies	Features	Specifications	Applications
RedCap	Compared with 5G eMBB, the complexity and costs of 5G terminals are reduced by tailoring aspects of terminals such as bandwidth and the number of antennas.	Provides high-rate service bearing capacities: For 64QAM, FDD uplink rate 90 Mbps, FDD downlink rate 170 Mbps, and TDD uplink rate 17 Mbps, TDD downlink 122 Mbps	Video security, IoV, wearable devices, electric power, petrochemical, industry, etc.
New passive IoT	Low-costs, low-power consumption, easy-to-deploy, and maintenance-free	System: more-than-100-meter receiving distance for tag data, meter-level positioning with low costs, more-than-300 inventoried tags per second. Tags: multi-sensor integration, environment data self-collection, and microwatt -level power consumption.	Manufacturing, logistics, healthcare, grain storage, animal husbandry, energy, petrochemical, transportation, parks, government, etc.

ISAC	Communications network achieves ISAC.	Road horizontal positioning accuracy within 1 meter, and the latency of positioning within 100 ms; low-altitude sensing accuracy within 5 meters	IoV, autonomous driving, drone supervision, etc.
Deterministic networks	Addressing deterministic communications, encompassing low latency, bounded jitter, high-precision time synchronization, and high reliability	Provides communications performances, such as 6 ms end-to-end latency with 99.99% reliability and 100 us jitter, and high-precision time synchronization accuracy of 1 us	Industrial Internet, cloud XR, IoV, etc.
5G MBS	More efficient transmission capabilities for voice, video, and data and wider coverage	Effectively relieves network congestion and ensures service quality. In MCS emergency communications, the end-to-end intercom latency <300 ms.	Emergency broadcasting, disaster rescue, live streaming, massive IoT, etc.
NE intelligence	Intelligentize networks and services through the combination of networks, network elements and AI	Improves user experience, network operations efficiency, and O&M efficiency.	Live streaming, IoV, energy saving, cloud games, video conferencing, etc.
X-Layer	Provides XR applications with large bandwidth and low latency, ensuring an immersive experience that combines virtual and reality	Strong interaction with 4K and 60 fps. Instantaneous frame-level rate of VR game about 150 Mbps, MTP latency <75 ms and transmission latency of target network about 20 ms	VR games, cloud videos, etc.
5G new calling data channel	Combination of calling, multimedia processing, and AI brings a new "intelligent and interactive" call experience	Voice call latency ≤220 ms video call latency ≤250 ms, voice transcription latency <1.5s, Chinese-English translation latency <2s, and marking success rate >99%.	Calling subtitles, intelligent translation, fun calling, intelligent interactive menus, remote assistance, etc.

Air-space-terrestrial communication	Builds an air-space-terrestrial integrated network that covers the whole world with satellite-to-cell services and satellite-terrestrial integrated communications.	Cell-to-HEO satellites: Transmission rate from 1 to 2 Kbps and air interface latency is 540 ms. Cell-to-LEO satellites: The DL rate is from 2 to 10 Mbps, the UL rate from 0.4 to 2 Mbps, and air interface latency from 13 to 42 ms.	HEO: SMS messages, two-way voice intercom, NB-IoT. LEO: short message, voice call, broadband data, etc.

3. 5G technology innovation brings new value

New 5G technologies take endogenous intelligence as the development concept from which to lay an intelligent foundation for economic and social development. This will facilitate the deep integration and symbiosis of 5G and AI, and further expand the intelligence of personal life, industries and society across multiple dimensions. These expansions in different sectors are expected to improve consumer service experience and provide better care for more groups, improve production and operations efficiency and promote high-quality economic development, and support low-carbon development and improve the well-being of people's lives.

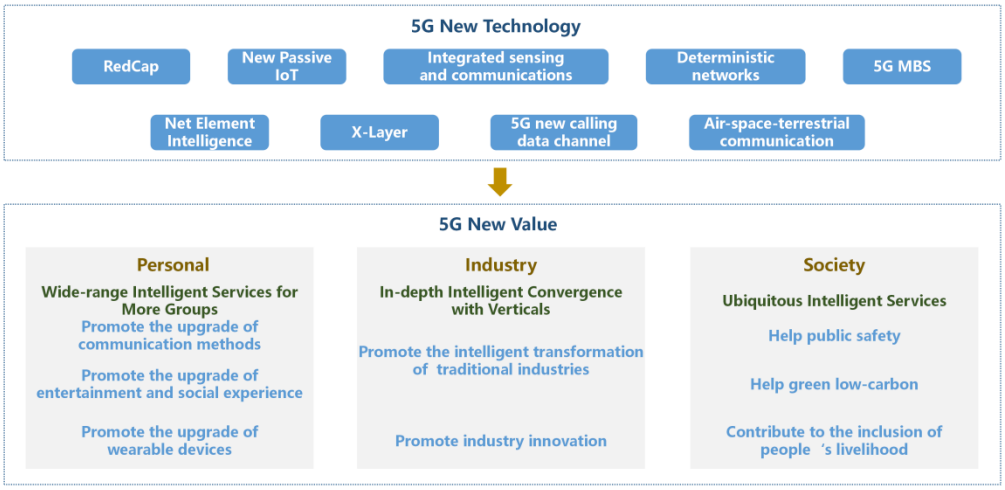

Figure 4 New 5G technology brings new value

3.1. Personal: Wide-range Intelligent Services for More Groups

3.1.1 Promote the Upgrade of Communications Methods to Realize Intelligent Interaction

The technical innovation of communication networks promotes the upgrading of communication methods. From voice and text to video calling, the experience of communication between people over the air is becoming increasingly convenient. However, even video calling, which closely mimics a "face-to-face" experience, still has certain limitations. For example, people who do not speak the same language cannot communicate directly, the two sides of a call cannot truly interact in real time, and special groups such as the elderly and the hearing impaired

may struggle to hear the other party's voice.

5G new calling, based on 5G audio and video calls, combines calls with multimedia processing, AI, and other such technologies to provide a series of innovative enhanced calling services and applications, such as real-time conversion between voice and text, real-time translation, intelligent interactive menus and remote assistance. These services facilitate the development of intelligent, interactive, and immersive video calling. 5G new calling can help special groups cross the digital divide, help people that do not share common languages build communication bridges, and help online customers improve service efficiency, thus making video calling services applicable to more scenarios. 5G new calling can also help special groups cross the digital divide, help people who do not speak the same language build a communication bridge, and improve the online customer service to efficiency. As a result, video calling service is becoming applicable to more scenarios, and calling business is transforming from "connection" to "service".

Figure 5 5G new calling interfaces

Case: sending new year's greeting through 5G new calling

One user was not able to go home and celebrate the New Year with his family due to a business trip, so he connected with them over a 5G new calling. During this call, personal cartoon avatars of both sides were displayed on the screen, and many expressions were triggered by the use of keywords and gestures. For example, when the user gestured "love" to the screen, a vivid love expression was shown on the family's screen; when the user said "Happy New Year", the family's screen showed an animation of New Year celebration. 5G new calling can also be highly beneficial to elderly people who are hard of hearing, as the screen can display a voice transcription that presents all spoken words in the form of text. This

upgrade of audio and video call interaction and display content can bring a convenient and heart-warming call experience to thousands of families.

Figure 6 Video calling interface

3.1.2 Promote the Upgrade of Entertainment, Social, and Office to Intelligent Immersion

XR applications such as VR games, VR live streaming, glasses-free 3D, and virtual social networking bring a virtual-reality convergence experience for users. To guarantee a good experience, the weight of XR terminals must be significantly reduced, and high-performance 5G networks are required to provide both large bandwidth and low latency.

XR terminals with 5G capability can offload rendering from device side to the cloud side, reduce the weight and costs of terminals, improve the practicality and mobility of terminals, and expand

outdoor mobile scenarios. Besides, combined with technologies such as X-Layer and network intelligence, a 5G network can intelligently determine a user's XR application experience according to multi-dimensional indicators such as uplink and downlink bandwidth, latency, and jitter, and trigger the network side to ensure stability providing a clearer, more immersive, and more realistic experience for entertainment and social.

Case: new entertainment and office experience with XR

5G enables a high-quality XR experience. In terms of entertainment, users can enjoy immersive experiences like the movie "Ready Player One". XR's ultra-high resolution and gesture interaction with low-latency blurs the boundaries between movies, games and the real world, allowing users to try on clothes through virtual avatars that look like themselves, watch games live, and visit attractions without ever leaving home. The entertainment experience will be diversified. Regarding offices, XR allows users to work anywhere and anytime. It can

integrate phones, tablets, computers, and other terminals, enabling users to simultaneously watch and freely arrange multiple office windows in the real world. Therefore, the work space are expanded in multiple directions to improve office efficiency. Remote work communication is no longer limited by geographic location. Multiple persons can discuss and collaborate in the same virtual environment where they can clearly see colleagues' body language and expressions and enjoy the same office experience as if they were interacting offline.

Figure 7 Experience virtual-reality equipment

3.1.3 Promote Intelligent Upgrade of Wearable Devices

Wearable devices mainly include smart watches, smart bands, medical monitoring devices and so on. Mobile communications technologies are becoming

increasingly integrated into wearable devices, represented by smart watches, which meet their needs in mobile scenarios such as telemedicine and outdoor sports. According to TSR statistics, the global shipments of cellular smart wearable devices are growing steadily by tens of millions, among which the Chinese market accounts for 30%. It is estimated that the shipment of cellular smart wearable devices in China will exceed 80 million[3] by 2025.

Currently, mainstream wearable devices use 4G Cat 4, Cat 1, or Cat 1bis. The popularization of 5G means it will be applied in the wearable field to update wearable products and facilitate the development of new forms of wearable devices like AR. Compared with traditional 5G terminals, RedCap can greatly reduce the size and power consumption of terminals through tailoring bandwidth and the number of transmitting and receiving antennas. Compared with 4G terminals, RedCap introduces R15/R16/R17 of 5G to save more power, meaning battery life can last for several days or even 1-2 weeks.

3 China Mobile 5G RedCap Technology White Paper: China Mobile, 2022

3.2. Industry: In-depth Intelligent Penetration

3.2.1 Accelerating the Intelligent Transformation of Traditional Industries

Industrial upgrade refers to the transformation and advanced development of an industry in terms of structures, organizations, and models driven by technology, economy, or government policies. Among these factors, technological innovation is the fundamental element of industrial upgrade[4]. With the rapid development of global digitalization and intelligence, the new 5G and related technologies like big data, cloud computing, IoT, mobile Internet, and AI will collaboratively propel current industrial upgrade and inject new impetus for the intelligent transformation of various industries.

1. Manufacturing industry: Horizontal and vertical expansion for all-domain intelligent manufacturing

Intelligent manufacturing integrates next-generation information technologies with advanced

4 Chuanzhong Du, et al. Research on China's Industrial Transformation and Upgrading at the Convergence of New Industrial Revolution and High-Quality Economic Development. Economic Science Press, 2021.

manufacturing technologies to improve innovation, supply, support, and application development capabilities. The development of intelligent manufacturing is the general trend in the global manufacturing industry that will significantly consolidate the real economy and foster new economic growth.

The intelligence of manufacturing industry is mainly reflected in R&D, design, production, operation management, including industrial simulations, equipment inspections, production scheduling, warehousing and transportation, automated process reengineering, etc. By integrating 5G and other emerging information and communication technologies, a new industrial Internet infrastructure will be built to support new construction or transformation of production lines, workshops, and factories. This will also create advanced factories featuring extensively connected production units with deeply converged information technology (IT) and operational technology (OT) systems that fully utilize data elements for more

efficient applications, enabling intelligence across all aspects of manufacturing.

(1) Deterministic networks promote intelligent upgrade of core manufacturing processes

With the gradual intelligent transformation of R&D, design, production and other core enterprises processes, best-effort networks can no longer meet user requirements, and instead enterprises are turning to wireless networks with deterministic capabilities. A 5G deterministic network system can achieve end-to-end SLA commitment, assurance, and verification to meet the high reliability, high stability, and low latency network requirements of industrial Internet applications. Deterministic network can support industrial equipment to monitor transmission data in real time and perform predictive maintenance to ensure smooth operation of automated production lines, reduces downtime and production line failures, and optimizes production and maintenance processes. 5G deterministic gateways also guarantee stable remote precision control services, enabling unmanned processes.

Application case: 5G drag chain cables

Some reciprocating industrial production actions rely on drag chain cables for communications. However, constant movement and bending can lead to breaks in the drag chain cables, resulting frequent downtime for maintenance of the entire production line. To address these issues, a washing machine factory in Qingdao replaced drag chain cables with 5G deterministic network, which can provide 16 ms latency under 99.99% reliability. This implementation helps the factory to reduce monthly downtime by 20 hours for maintenance, resulting in improving overall productivity.

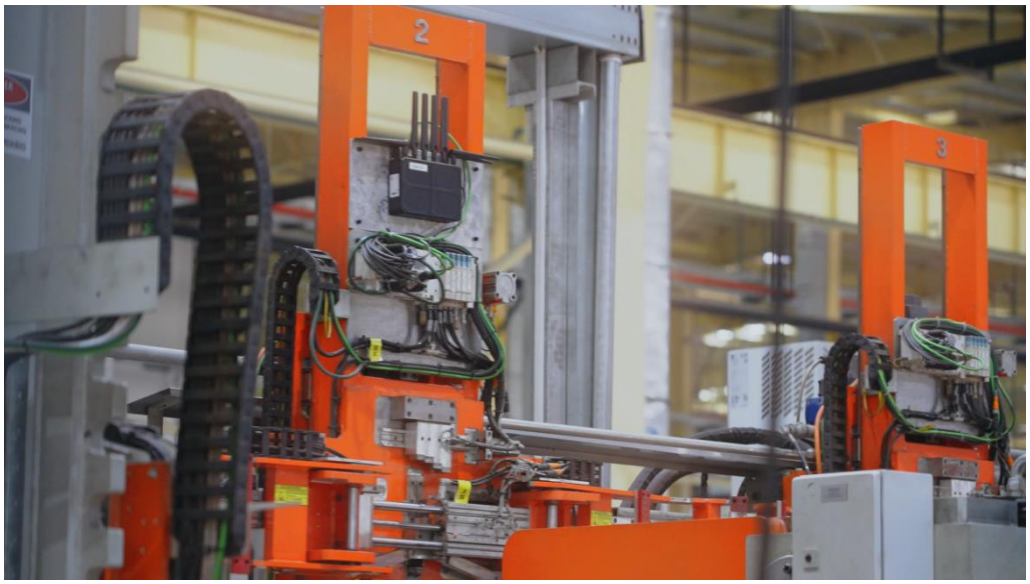

Figure 8 5G drag chain cable application in a washing machine factory in Qingdao

(2) RedCap's optimal performance and cost help intelligently transform factory terminals

Factories mainly involve control-, collection-, and connection-oriented digital terminals. Among them, data collection terminals, like those that collect sensor and video data, are large-scale , which impose high requirements on network performance and terminal costs. However, the high cost of traditional 5G terminals has limited the widespread use of 5G here and has become one of the challenges that hinder the intelligent upgrade of the manufacturing industry. RedCap terminals are more affordable than 5G eMBB terminals, and can be combined with URLLC, slicing, MEC, and other 5G features to adapt to diverse latency, reliability, and security requirements of more service scenarios. This creates more affordable construction options for 5G fully-connected factories.

(3) 5G high uplink bandwidth supports full connectivity of smart factories

With more extensive usage of 5G technologies in smart factories, 5G networks have to meet higher uplink bandwidth requirements. 5G high uplink

solutions can meet these requirements by utilizing Distributed Massive MIMO technology, frequency spatial division multiplexing, and uplink multi-layer technology to improve cell capacity by 300% compared with common cells.

Application case: Midea's 5G fully-connected factory in Jingzhou

The first phase of Midea's fully-connected factory in Jingzhou, China, requires 5G connections for more than 2,500 points, mainly for uplink services. It has high uplink requirements for services like AI-based quality inspection, and its terminal access locations were uncertain due to plans for capacity expansion and production line adjustment. To adapt to the needs of new intelligent factory services, 5G networks need to provide deterministic uplink capacities and terminal rates. Distributed Massive MIMO technology increases cell capacity by 300% compared with common cells. China Mobile innovates with Distributed Massive MIMO technology by combining it with algorithms such as pairing capability enhancement between terminals and indoor

distributed base stations and anti-interference, which increases uplink capacity by extra 20%. Currently, the Midea's washing machine factory in Jingzhou has used these high uplink capabilities to achieve real-time, multi-angle, and high-definition monitoring, and improve its defect detection rate by 10% with the help of AI algorithms.

Figure 9 Midea's fully-connected factory in Jingzhou

2. Logistics: Enabling intelligent upgrade for the full life cycle of logistics

The logistics industry is at the core of the supply chain which determines the efficiency of production elements supplying for a myriad of industries. The changing economic environment poses supply chain disruption risks, and the industry-wide pursuit of lean management and the enhanced concept

of fast response in supply chains have created strong demand for intelligent and highly resilient supply chain construction.Passive IoT provides the logistics industry with a cost-effective digital base that covers all manner of factors. This helps implement identification and sensing throughout full process and full life cycle of logistic industry, which can meet the requirements of intelligent logistics for storage management systems, demand planning and forecasting, smart warehouse management, storage automation, smart transportation, logistics trading platforms, logistics management platforms, intelligent procurement platforms, supply chain orchestration, and even the design of supply chain financial products. This accelerates the digital identification of all elements, intelligent management of full processes, and flexible reconstruction of all businesses in the logistics field. According to iResearch Consulting Group[5], the AI + logistics market in China will have a market space of nearly 10 billion in 2025.

5 Research Report on the Development of Artificial Intelligence + Logistics in China: iResearch Consulting Group, 2020

The new passive IoT is cost-effective and maintenance-free, which plays an important role in smart logistics. It supports automatic data collection and item identification, so that can improve the management efficiency of warehousing and logistics and help save management time and reduce labor costs. In addition, passive IoT tags can be used in combination with sensors to achieve real-time monitoring and tracking of items. Passive IoT tags can also be used on logistics crates, pallets, goods and other items to monitor the logistics process, inventory status, and delivery status in real time, improving the efficiency, accuracy, and reliability of the supply chain. Moreover, passive IoT can also be used for source tracing and tracking of items to ensure the quality and safety of products in the supply chain. Finally, passive IoT technology can provide a faster and more accurate payment and settlement process, enhancing process efficiency and usage experience.

Application case: Smart park asset management

Large-scale parks have diverse assets that are

frequently transferred from place to place. Manual asset auditing is time-consuming and hindered by inaccurate information and difficulty in searching and positioning. By deploying RFID tags on the assets, a new passive IoT system and visualized management platform are implemented to achieve asset digitization with minimum investment and automated management of all dimensional information, including asset locations, types, and quantity. This meets the smart park's requirements for efficient, accurate, and convenient asset management, and significantly improves the efficiency of asset auditing by shortening the auditing period from weeks to minutes, reducing 80% of labor costs and minimizing the loss of untraceable assets.

Figure 10 Full lifecycle management of assets in a large smart park

3. Electric power industry: new 5G technology

supports the intelligent transformation of the electric power industry

The electric power industry involves a large number of digital innovations, such as the digital electronic asset management platform for energy asset management, the intelligent inspection and remote monitoring equipment for improving grid and pipeline O&M efficiency, the virtual grid for optimizing the supply-demand relationship, and the dynamic monitoring system for adjusting energy reserve schemes.

New 5G technology can be applied to each process of the electric power industry, including power generation, transmission, transformation, distribution, and consumption, to drive the intelligent development of the industry. In the power transformation process, a large number of emerging power IoT and smart substation applications, such as substation video and environment monitoring, substation inspection robot, and mobile operation/inspection, have high requirements for bandwidth, reliability, and mobility. Deterministic

networks can meet these requirements. In the power distribution process, cost-effective RedCap terminals can meet the communication needs of diverse types of grid equipment, power terminals, and customer equipment that arise from large-scale distribution network automation, low-voltage centralized metering, distributed energy access, and two-way user interaction services.

Application case: Smart grid power distribution applications

Although the service volume of power distribution is small, the corresponding intelligent applications have demanding requirements for low latency and high reliability. For example, differential protection requires a latency of less than 80 milliseconds and 99.99% reliability, and second-level load control requires a latency of 1 second and 99.99% reliability. RedCap takes full advantage of the excellent technical features of 5G networks in uRLLC and slicing to meet the needs of power business in terms of low latency, high reliability, and security isolation, while reducing 5G terminal costs. The

first commercial deployment of RedCap in the electric power industry has been completed in Zhejiang, China, and has been applied to the second-level load control and pole-mounted switch systems. This has demonstrated RedCap's ability to support slicing, deterministic experience, and other 5G native capabilities to meet the requirements of electric power services in security isolation, latency, and reliability.

Figure 11 Second-level load control terminal for electric power

4. Agriculture and animal husbandry industry: New 5G technology supports intelligent farming

In the agriculture and animal husbandry industry, data is collected and organized manually, which results in low efficiency and difficulty in finding and tracking information. The new passive IoT provides intelligent management means for the

industry applications and promotes the transparency and safety of the farming and animal husbandry process.

In agriculture, the use of new passive tags in the planting, logistics, and source tracing of agricultural products makes the tracking of products more efficient, thereby improving agriculture in terms of overall production and marketing value. For agricultural equipment, passive IoT can strengthen the efficiency for the use and O&M of the equipment and boost overall agricultural productivity. In animal husbandry, RFID ear tags are added to livestock to record relevant information into the database. This implements modern fine-grained breeding and information traceability, and resolves issues of traditional breeding methods, such as low efficiency, error-prone processes, and information lag.

Scenario example: Livestock management

In the future, new passive tags with ultra-low cost, extremely low power consumption, and flexible forms will play an important role in livestock

management. Ear tags or implantable passive tags can provide unique identification for livestock. Base stations can be set up at key checkpoints and areas such as entry and exit channels, and work with big data technology to achieve accurate collection of livestock information and livestock tracking. In addition, passive tags can be combined with temperature and humidity sensors to monitor livestock indicators and ranch environments in real time, allowing for accurate feeding, as well as intelligent monitoring and timely warning for diseases.

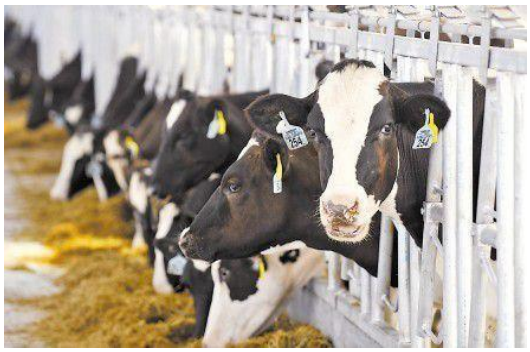

Figure 12 Smart ranch solution

3.2.2 Intelligence Enables Business Innovation

Industrial upgrading, changes in demand, technological innovation, and new applications enable the diversification of industrial value chains and cross-industry integration. This gives rise to emerging business models and new service models.

Emerging industries often become the high-end links in the industrial value chain, stimulating growth and sustainable development.

1. Low-altitude industry: built-in sensing enables new intelligent low-altitude business

Born from the traditional aviation industry, the low-altitude economy integrates new low-altitude production services supported by drones and digital technologies. This can enable the synergistic development of interrelated fields, and help form a highly dynamic and creative economic system, that complements the ground transportation industry.

According to the Foresight Industry Research Institute, the market size of China's civil drone market in 2022 has reached CNY44.358 billion, and the market size of China's industrial drones will reach CNY313.8 billion by 2027[6].

Although the drone industry has great potential, there are many challenges in the development of low-altitude drone industry: First, the regulatory mechanisms are still underdeveloped. The current use

6 White Paper on Low-Altitude Network Information Service Capability: China Mobile (Chengdu) Industry Research Institute, Research Institute of China Mobile Communication Group, 2023

of drones faces difficulties in identification, supervision, and processing. A unified regulatory mechanism is urgently needed to achieve effective control of drone access, authentication, authorization, and flight operations, etc.

Second, low-altitude network services need to be optimized. A large number of drones still rely on single-point communication with ground base stations, which greatly limits the flexibility and autonomy of aerial drone operations, and results in serious information silos. This weakens the economic value of data resources.

Third, there is insufficient assurance for low-altitude services. Drones need to have a high level of intelligence, for sensing, identification, decision-making, control, and various technical supports, which pose high requirements on uplink and downlink bandwidth, latency, and link stability of the network.

5G networks provide reliable access and location management for drones. With the help of new technologies such as integrated communication and

sensing (ISAC) and AI, 5G networks can provide new capabilities such as region-wide supervision and more efficient drone services. This enables effective drone supervision and secure and intelligent flight, and stimulates the development of low-altitude economy.

2.Autonomous driving: new 5G technology helps commercialize advanced autonomous driving

Autonomous driving is a product of deep integration of the automobile industry and the new generation of information technology industry. It senses the surrounding environment by carrying a variety of sensors, and uses artificial intelligence and other technologies to realize autonomous planning of the driving paths and autonomous control of vehicles.

According to the analysis of GONYN.com, the global market size of autonomous vehicles is expected to reach CNY261.119 billion in 2023, and it is estimated that the market size will reach CNY2057.341 billion by 2029, with a growth rate of 41.06%[7].

7 Current Situations Inside and Outside China - 2023-2029 Market Research and Assessment Report on Autonomous Vehicles in China - gonyn.com, Gonyn Industry Research Institute, 2022.

The ISAC solution integrates sensing capability into a communication system, and implements the sensing and fusion of roadside and vehicle information using the low-cost continuous coverage 5G networks. In addition, it provides connectivity and computing capability with low latency and high reliability by building a cloud-edge-terminal coordinated computing network architecture. This significantly improves the interaction efficiency of autonomous vehicles and enhances the safety of autonomous driving.

Deterministic networks can provide services with deterministic quality in bandwidth, latency, and jitter for data transmission, ensuring "on-time and accurate" information transmission for autonomous driving. Deterministic network technologies combined with 5G will further improve the sensing and positioning accuracy of autonomous driving, enabling advanced autonomous driving services.

Use case: 5G-enabled unmanned logistics services

The existing terminal unmanned distribution mode has the following pain points: First, low safety

factor leads to frequent accidents,and the real-time video is fuzzy. Second, the model is overloaded due to the rapid growth of autonomous driving data, and the distribution of computing power is not balanced. Third, vehicle-side data adopts manual written, rough screening and labeling. The data acquisition efficiency is low, the amount of data is limited, and online data closed-loop cannot be formed.

The ISAC technology is introduced to solve these problems by constructing a cloud-edge-terminal coordinated computing network architecture. The solution meets the needs of unmanned delivery through stable 5G network transmission, data cleaning, and tagging at the cell edge; ISAC-based roadside sensing, and side computing balance to meet the needs of unmanned delivery.

A Beijing-based company has built an unmanned vehicle logistics business through the commercial application of V2X with integrated sensing and computing. This model has slashed the cost of single-vehicle computing power by 30%, reducing the AI development cycle from weeks to days, and improving

driving speed from 12 km/h to 25 km/h.

Figure 13 5G-enabled unmanned distribution logistics vehicle

3.3. Society: Ubiquitous Intelligent Services

3.3.1 Public Safety: Intelligent Emergency Communications Help Protect People's Safety

Public safety is basic needs for all, and is essential for social stability and healthy economic development. In the event of major natural disasters, accidents, and other public emergencies, capabilities such as emergency reporting, early warning, on-site command and rescue all require stable communications to ensure the accessibility and smooth flow of information.

Using cellular networks, combined with broadband satellite communications, the air-to-ground communications network can achieve full coverage over

land, air, and sea. The network provides efficient transmission of voice, video and data information in offshore and remote areas that cannot be reached by ground networks and in areas where communications networks have been severely damaged.

Example: Direct satellite communications

Mobile phone users around the world mainly receive services from terrestrial mobile communication networks. Human activities are expanding with the portability, mobility, and popularity of wireless services, which make direct satellite communications an ideal choice for integrated air-to-ground communication networks for the general public.

An integrated network based on direct phone-satellite communications can connect land, air, and sea to form an integrated and ubiquitous network. Direct phone-satellite connections are characterized by wide coverage, disaster tolerance and other advantages. They can be applied in diverse scenarios, from exploration in sparsely populated mountains, deserts, and polar regions, to emergency maritime and

aviation communications, and to emergency relief for natural disasters such as earthquakes and floods. Satellite connections can rapidly and continuously provide a wide range of public, professional, and personal emergency communications for rescue services in extreme circumstances with damaged or otherwise limited networks.

Figure 14 Mobile device direct to satellite connection for emergency communications

In densely populated areas, transmission over existing mobile communication networks may be inhibited by serious latency and freezing. When natural disasters hit, some communications infrastructure may be damaged, transmission congestions may occur as a result of insufficient network capacities. 5G MBS can transmit the same content to multiple mobile or fixed terminals at the same time, bypassing network congestion, and significantly improving the coverage and efficiency

of information circulation.

Example: major natural disasters and accident rescue communications

In sites affected by major disaster or accidents, immediate decision-making and rescue are critical. However, large numbers of rescue workers and the complexity of rescue tasks can generate massive load pressure on the mobile communication networks, compromising communication efficiency for relief and rescue. 5G MBS technology can efficiently transmit voice, video, and data to each rescue team. This enables medical personnel to perform assessments more efficiently and the emergency command center to make more accurate decisions, thereby significantly improving the overall efficacy of relief and rescue efforts.

Figure 15 On-site rescue emergency communications

3.3.2 Green and Low Carbon: 5G Smart Terminals Help Reduce Carbon Emissions

Green and low-carbon technology is fundamental in protecting the environment and enabling sustainable development. According to forecasts by GSMA, the number of global IoT terminal connections will reach 25 billion in 2025, with 11 billion consumer IoT terminal connections and 14 billion industrial IoT terminal connections. These IoT terminals consume massive amounts of energy, and those powered by batteries need to consume billions of batteries each year, generating additional labor costs and environmental damage.

The simplified RedCap terminals enhance the power saving capability. Compared to 5G NR terminals (100 MHz bandwidth), RedCap terminals (20 MHz bandwidth) in connection states are expected to save power consumption by 10%-20%. IoV, electricity, wearable and other scenarios have a 10 million terminal scale. The use of RedCap terminals will help reduce terminal industry energy consumption.

The new passive IoT based on cellular networks

reduces terminal power consumption through "seamless coverage", and the communication distance of terminals is increased to 100 meters when combined with the new ambient passive IoT tags. This expands the scope of application for passive IoT terminals and replaces a number of active IoT terminals. Relative to existing active IoT terminals, such as Bluetooth and Zigbee, the power consumption of the new passive IoT terminal is reduced from milliwatt level to microwatt level. The new passive IoT terminals do not need manual battery change and therefore reduce waste battery pollution. New passive IoT can be widely applied in industrial manufacturing, warehousing and logistics, smart power, smart city, smart home and other scenarios. AIOT Star Chart Research Institute predicts that in 2025, the shipment of UHF passive tags will exceed 52 billion[8]. If passive IoT tags were to be widely applied in these fields, energy consumption would be reduced significantly.

Example: underground pipeline monitoring

8 2023 RFID Passive IoT Ecology Report Series: AIOT Star Chart Institute, 2023

Underground pipelines include water supply, drainage, oil and gas, heat, electricity, telecommunications, and other pipelines. They are critical urban infrastructure. As of June 2022, 7,500 km of pipeline lanes had been or were being built in China[9]. Traditional underground pipeline monitoring relies on the deployment of active sensors to form a sensor network, usually with wired connections. These sensor networks not only consume massive energy, but are characterized by high cabling costs and difficult maintenance. The new passive IoT system transforms the traditional underground pipelines. By deploying low-cost, temperature-resistant, flood-resistant, corrosion-resistant passive IoT tags, we can achieve wireless, quasi-real-time monitoring of temperature and humidity, water levels, toxic gas levels, etc. in the pipelines. This solves the problems of battery changing, long construction cycles, and high maintenance costs.

9 Development Trend and Existing Problems of Integrated Urban Underground Pipe Corridor: Municipal Pipe Maintenance Network, 2022

Figure 16 Underground pipeline monitoring

3.3.3 Promoting Inclusive Livelihood: 5G Smart Ultra-Long-Reach Coverage Helps Bridge the Digital Divide

The earth has long coastlines and vast maritime areas, but these important places have woefully inadequate network coverage. The lack of ultra-broadband, low-latency networks in coastal and maritime areas limits the availability of massive data connections and access, and the communication needs of fishermen for both production and living cannot be met. In addition, some regions still have shortcomings in information infrastructure and digital construction, hence the need to narrow the "digital divide" between different regions. The new 5G technology expands the coverage of high-quality

networks and provides inclusive services to a wide range of places, such as the maritime and rural areas.

Scenario example: Smart Ocean improves the working and living environments of fishermen

China has about 160,000 fishing boats. Currently, marine networks are constructed mainly based on satellite and narrowband private network communications, which can satisfy basic voice communication and simple data collection service needs, but not the communication needs of fishermen. The 5G marine ultra-long-reach coverage solution, which uses 2.6 GHz TDD + 700 MHz FDD multi-band coordination, provides 3D coverage within a 100 km radius over the sea, forming a "terrestrial-sea-air-space integrated broadband network". This network achieves the same user experience and speed on land and on the sea. It provides an improved user experience for coastal areas, stable signals near maritime areas, and reliable calling for remote offshore areas.

Figure 17 5G marine ultra-long-reach coverage

Scenario example: Pest and disease prevention and control in rural areas

Pests and diseases can have enormous impacts on food production, with heavy economic and social costs. The application of 5G technology in "digital villages" plays a key role in the prevention and control of crop pests and diseases across multiple stages. For the first stage, which is the pest and disease incubation period, the satellite remote sensing, 5G high-definition video monitoring, and other means are used to monitor the environment from multiple dimensions and identify pests and diseases in advance. This enables timely intervention and preventive measures. For the second stage, which is the early stage of pest and disease infestations, analysis is conducted based on the data uploaded by the 5G network to detect and identify risks and provide intelligent expertise solutions to prevent

disasters early. For the third stage, 5G drones or robots are used to spray pesticides to rapidly eradicate pests and diseases and reduce the impact of outbreaks, protecting harvests and the livelihoods of farmers.

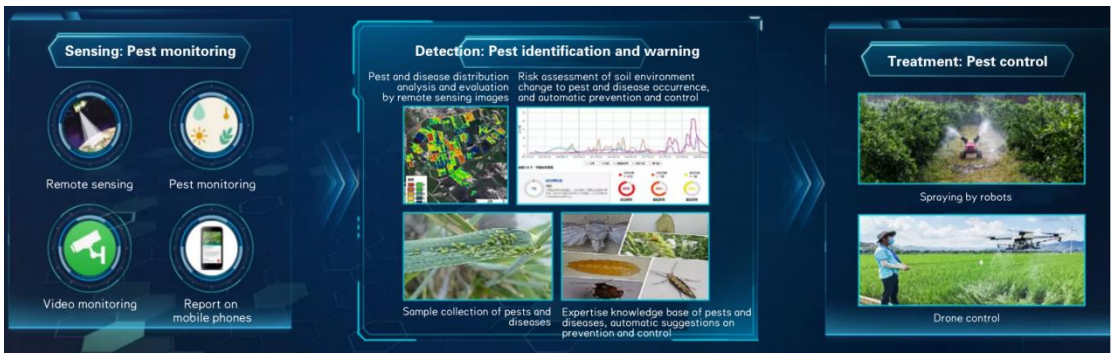

Figure 18 Pest and disease prevention and control in "digital villages"

5G technology innovations are having a profound impact on all of society and the entire global economy. This is exemplified by the value created by and typical applications of the nine new 5G technologies. 5G applications in China cover nearly 20 key areas of the digital economy, including smart cities, industrial Internet, information consumption, public safety, and smart campus.[10] "5G empowering thousands of industries" is becoming a reality.

10 White Paper on 5G Application Innovation Development - Insights from the 5th "Bloom Cup" 5G Application Competition in 2022: China Academy of Information and Communications Technology, 2023

4. New 5G Business Models Drive Value Realization

5G application innovations and value creation require the 5G industry to provide integrated services of "connectivity + computing power + capability" in the individual consumer and industry markets. New business models are thus urgently needed. Telecom operators, as 5G network builders and industry leaders, should work closely with the upstream and downstream partners of the 5G industry chain to jointly explore and promote business model innovations, so as to fully release the power of 5G-enabled economic and social development.

4.1. New 5G Applications Create New Demands on Business Models

For the individual consumer market, new models are being explored for different application scenarios, such as billing by time, terminal connection, network capabilities, content, and functions. Billing by traffic is the main pricing method of telecom operators for individual customers,

but this method is not well adapted to high traffic 5G applications. In the 5G era, Internet applications are evolving towards high definition, virtualization, and interactive user experiences. XR, as the representative of 5G applications, consume large volumes of traffic. For example, a VR application with 4K resolution and 90 frame rate consumes up to 15 GB of traffic in 20 minutes. This will result in high traffic costs for customers if they are charged by traffic volume. Operators need to explore new models, such as billing by hour, terminal connection, and network capabilities. Moreover, for new 5G services such as 5G new calling, customers can also be billed by new functions or capabilities.

For the industry market, in addition to providing 5G private network products, operators can expand value-added network services horizontally and explore integrated and converged industry applications vertically. Industry customers' requirements on personalized networks expand the space for value-added services of 5G network products. Operators can explore billing models for the value-added services

that go beyond basic network functions to meet customers' needs in network acceleration, security, and O&M. Furthermore, digital applications in the industry market require a general-purpose capability base for the integration of 5G with new technologies such as cloud computing, big data, artificial intelligence, and blockchain, in order to support the digital transformation of diverse industries. In addition, some industry customers tend to choose integrated solutions that cover networks, terminals, capabilities, applications, and services, and 5G network connectivity services are often integrated into these digital solutions.

4.2. Exploring New 5G Business Models

4.2.1 Exploring New 5G Business Models in the Individual Consumer Market

1. Scenario-specific tariff exploration based on terminals or applications

Innovative tariff schemes are combined with terminals and Internet applications. Operators can offer these schemes directly to consumers, or cooperate with application providers or terminal

manufacturers to serve individual customers using a 2B2C model. This can ensure optimal business experiences and promote the development of 5G terminals and applications.

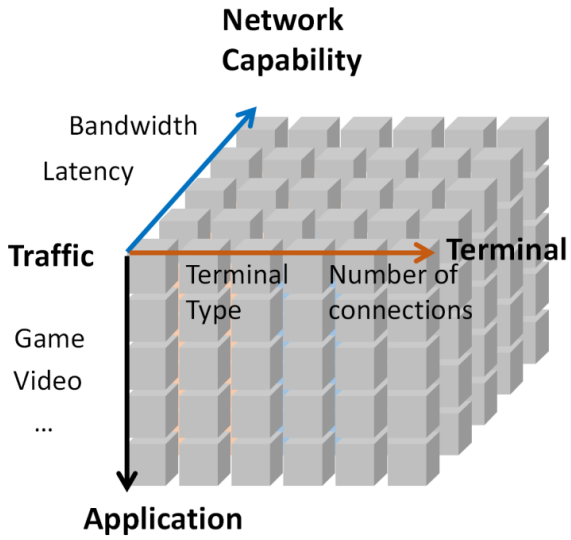

Figure 19 Expandable pricing dimensions for the 5G individual market

(1) 2C business model

Network service tariffs with pricing dimensions such as time, number of connections, and network capabilities are designed according to terminal usage scenarios. Customers who have purchased network service tariffs can receive guaranteed network services from operators when using terminals such as XR devices and drones.

Based on Internet application usage, network service tariffs are designed with pricing dimensions such as time and network capabilities, as well as the content or functionality of the Internet applications. For Internet applications such as ultra-high-definition live streaming and cloud gaming, customers can purchase network service tariffs to receive network guarantees from the operator for those applications. For the 5G new calling service, operators can adopt an hourly billing model for HD audio calls, which can be aligned with user habits, and use flexible billing models (by time or number of uses) for the voice transcription, real-time translation, and fun calling services. For advanced features or content with IP rights, operators can provide an in-application purchase model.

(2) 2B2C business model

In addition to providing network service tariffs directly to individual customers, operators can also cooperate with application service providers or terminal manufacturers to provide network assurance services to their application users or terminals.

Operators' network assurance services can be integrated with the products and services of application service providers or terminal manufacturers to ensure a better service experience for target customers. The application service providers or terminal manufacturers then pay the operators for the network assurance services based on the number of individual customers or hours of coverage.

4.2.2 Exploring New 5G Business Models in the Industry Market

In the new technology market, operators should consider their role and value from a broader perspective, with the goal of driving industry digital transformation. Operators should build on their role as 5G network operators and work with industry partners to expand the upstream and downstream in the value chain and explore new roles such as platform enablers and solution providers. For value creation, operators can design new billing models, add new billing dimensions, and develop new revenue sources.

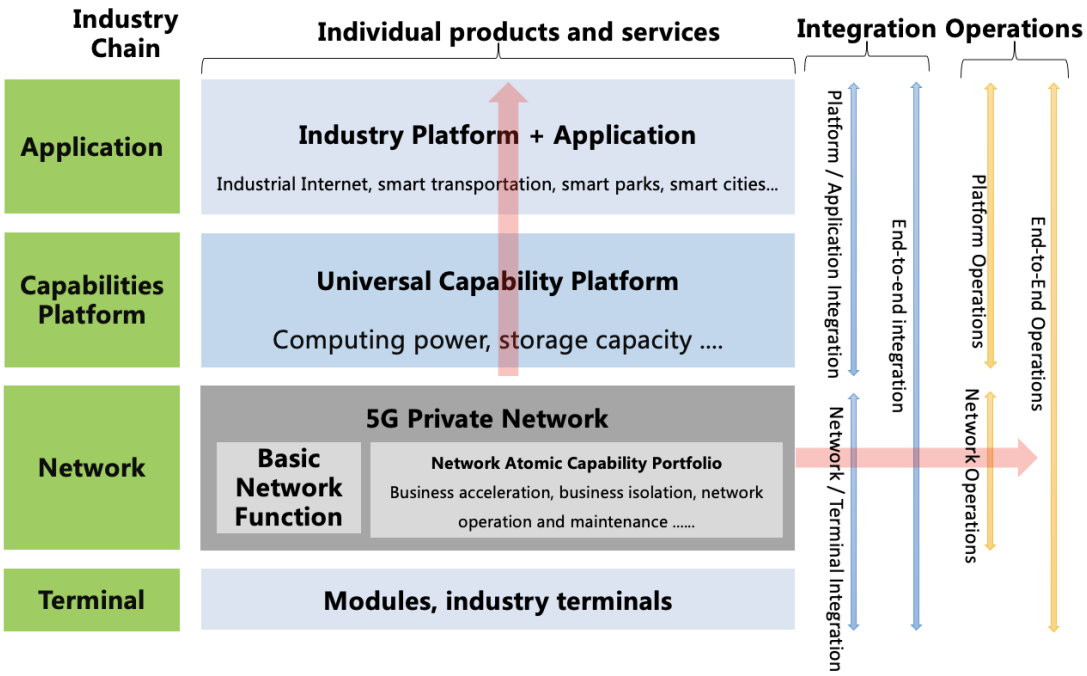

Figure 20 Operator role expansion in the 5G industry market

1. Network operator: Expanding from traffic-based billing to network value-added-service-based billing

Customer requirements for networks are constantly changing, and a single business model of billing by traffic volume is insufficient for the needs of industry customers for stable and reliable network performance, personalized network capability, manageable and visible network resources, and timely response to network faults. Operators need to atomize network capabilities such as bandwidth, speed, connections, latency, isolation, and security, and

add personalized services such as network design and planning, network optimization, network O&M, and dedicated network protection to offer flexible networks and customized services with multiple billing dimensions.

The billing models for operators in this role include 5G private network construction fees, traffic fees, and network value-added service fees for a combination of different network atomic capabilities.

Business model case: China Mobile's BAF business model for 5G private networks

China Mobile has developed a BAF business model for 5G private networks of enterprise customers[11], offering multi-dimensional billing solutions for customers. "B" refers to three basic network functions: public network for public use, public network for private use, and private network for private use; "A" refers to 13 advanced value-added network services, which can meet customer needs for personalized services such as service acceleration and isolation; "F" means that customers can flexibly

11 White Paper on 5G Business Model Innovation, China Academy of Information and Communications Technology, 2021

combine the basic network functions and value-added services with business scenarios and needs to achieve flexible customization of network atomic capabilities.

2. Platform enabler: Integrating 5G with new ICT technologies to build a cloud-network general capability platform and develop new business models

5G technology is integrated with other emerging ICT technologies such as cloud computing, big data and artificial intelligence to form a general capability platform across industries and enterprises. This provides computing power, network IaaS services, and common PaaS capabilities such as IoT, big data, and AI for industry digital business and applications. Operators act as information infrastructure providers to support rapid development and flexible deployment of industry applications, empowering various industries.

The billing models for operators in this role mainly revolve around platform service fees, which are charged by capability type, service time, and number of invocations on platform capabilities such as computing power, cloud rendering, and image

recognition.

Business model case: Singtel Paragon platform

Singtel launched Paragon, a converged platform that combines 5G, MEC, cloud and other services, in February 2022. With the help of the Paragon platform, industry customers can easily deploy 5G applications, and technology partners can easily develop solutions. In June 2022, Singtel partnered with Hyundai Motor Group. Using the Paragon platform, Hyundai's electric vehicle factories can manage and analyze the electric vehicle manufacturing process, and allow customers to customize their vehicles and monitor the on-site manufacturing process on their smart devices.

3. Solution provider: Working with industry partners to deliver integrated solutions

In addition to providing network connectivity and general capability platforms, operators can also provide specialized industry platforms and applications for key industries and businesses, such as video surveillance platforms, drone platforms, and instrument networking management platforms, and work with partners to integrate internal and external

products to form integrated solutions.

Relative to the first two roles, the billing models under this role are further expanded to industry platform usage fees, application service fees, overall solution fees, and revenue sharing based on the effectiveness of industry customer usage.

Business model case: Swisscom total solution

Swisscom provides total 5G-based IT solutions for customers in the fields of healthcare, finance, and defense. Its solutions include communication integration solutions, IT infrastructure, IT security and cloud services, jobsite solutions, SAP services, IoT, and outsourcing services for financial sectors and healthcare. Swisscom's total solution business is growing rapidly, with a year-on-year increase of 6.6% in the second quarter of 2022.

4.3. New Business Models Drive Industry Development

4.3.1 Driving Operator Revenue Transformation

According to analysis conducted by GSMA Intelligence, 16 major operators still had up to 76% of their revenue coming from traditional telecom

services of the channel category in 2021. Innovative business models can drive a shift in revenue mix. In the individual market, where it is difficult for telecom operators to see major growth in traffic revenues, scenario-based innovative tariffs that combine 5G with applications and terminals open up new growth space for operators. In the industry market, as shown in the figure below, 5G network services account for about 15% to 20% of the value of the 5G industry application industry chain[12]. Through service expansion and business model innovation, operators can obtain platform service revenue and service operation revenue in addition to 5G network connection fees, expanding the growth space and achieving sustainable and healthy revenue growth.

12 The data is provided by China Mobile Intelligence based on the report of the China Academy of Information and Communications Technology and the Ministry of Industry and Information Technology's Measures for the Preparation of Communications Construction Estimates and Budgets.

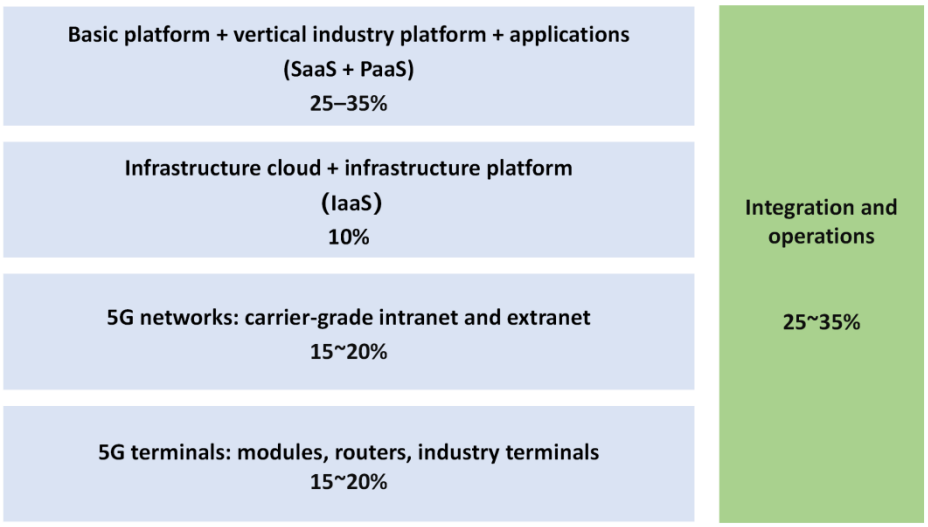

Figure 21 Value distribution of the 5G industry application industry chain

4.3.2 Forming Closer Relationships with Customers

In the individual market, operators have transformed from providing customers with traffic in the 4G era to providing "traffic + terminal + application + network capability" integrated services in the 5G era. The coupling of networks, services, and terminals has been enhanced, which helps improve customers' value perception and loyalty to operators. In the industry market, operators have transformed from network operators in the 4G era to platform enablers and solution providers in the 5G era. They have established deeper cooperation and closer

relationships with industry customers, and become the customers' reliable partners in digital and intelligent transformation.

4.3.3 Promoting Win-Win Cooperation Across the Industry Ecosystem

While enhancing value for customers, 5G business model innovation can also drive the continuous growth of the investment in network equipment and related supporting facilities, promote the iteration of consumer terminal equipment and the upgrade and innovation of industry terminal equipment, and promote the integration, innovation, and application of new technologies such as cloud computing, big data, AI, and blockchain. These will all help boost the value of the 5G industry chain.

5. Suggestions on Global Industry Cooperation

As a leading next-generation information and communications technology, 5G is a critical part of the information infrastructure that supports the transformation towards a digital, connected, and intelligent economy and society. 5G technology is constantly evolving, creating new technologies and capabilities in the process, which in turn lead to more new services and applications. New 5G technologies can create value for customers only when integrated into various industries and addressing customer needs.

In order to better unlock the value of 5G, it is recommended that the global 5G industry strengthen cooperation in four areas: technological innovation, standard solutions, digital intelligence applications, and industry ecosystem.

In terms of technological innovation, technical exchanges and joint research should be carried out to promote the integration and innovation of communications networks, cloud computing, big data,

AI, security, blockchain, and other next-generation information technologies. 5G spectrum, as the key to the development of the 5G ecosystem, will greatly affect the global diffusion of digital technologies. Therefore, it is necessary to further enhance global cross-region coordination to ensure appropriate, fair, efficient, and economical use of spectrum resources.

In terms of standard solutions, the global 5G industry should engage in all-round and in-depth international exchanges on 5G-Advanced and 6G standards via multiple channels, via international organizations such as GSMA and GTI. It should also promote cross-border, cross-organization, and cross-industry standardization cooperation to form globally unified standards and innovation solutions. This will enable standards to better play their fundamental and leading role in driving industry development, and will promote interconnection and interoperability of global information infrastructure, thereby expanding the scale effect.

In terms of digital intelligence applications, a communication and sharing mechanism should be

established to globally share the best practices of creating value with 5G, so as to accelerate the scaled promotion of industry applications such as smart factories, smart mines, and smart power. The entire industry should jointly create and share digital intelligence applications, promote the development of 5G New Calling, 5G messaging, cloud XR, and other 5G featured services, and accelerate the cultivation of new industries, business forms, and modes for information services.

In terms of industry ecosystem, the whole industry should create a favorable atmosphere of "openness, cooperation, inclusiveness, and sharing", and build a new, diversified, and symbiotic global digital intelligence ecosystem. It should also share the global market space, build a community with a shared future in cyberspace, and integrate information services into thousands of industries and make them accessible to everyone in the world.

List of Abbreviations

Abbreviation	Full Spelling in English	Full Spelling in Chinese
2G	The 2nd Generation Mobile Communication	第二代移动通信
4G	The 4th Generation Mobile Communication	第四代移动通信
5G	The 5th Generation Mobile Communication	第五代移动通信
5G-A	5G-Advanced	5G 演进
6G	The 6th Generation Mobile Communication	第六代移动通信
AAU	Active antenna unit	有源天线单元
AGV	Automated guided vehicle	自动导引车辆
AI	Artificial intelligence	人工智能
AR	Augmented reality	增强现实
ARPU	Average revenue per user	每用户平均收入
CA	Carrier aggregation	载波聚合
Cat	Category	能力等级
CPE	Customer premise equipment	客户终端设备
DL	Download	下载
eMBB	Enhanced Mobile Broadband	增强移动宽带
FDD	Frequency division duplex	频分双工
FWA	Fixed wireless access	固定无线接入
IaaS	Infrastructure as a service	基础设施即服务
ICT	Information and communications technology	信息与通信技术
IMS	IP multimedia subsystem	IP 多媒体子系统
IP	Internet Protocol	互联网协议
IT	Information technology	信息技术
MBS	Multicast and broadcast service	组播广播服务

MCS	Mission critical service	关键任务服务
MEC	Mobile edge computing	移动边缘计算
MES	Manufacturing execution system	制造企业生产过程执行系统
MIMO	Multiple-input multiple-output	多输入多输出系统
MTP	Motion-to-photon	运动到成像
NR	New Radio	新空口
OPEX	Operating expense	企业运营支出
OT	Operational technology	操作技术
PaaS	Platform as a service	平台即服务
PDA	Personal digital assistant	掌上电脑
QAM	Quadrature amplitude modulation	正交幅度调制
RedCap	Reduced Capability	轻量能力
RFID	Radio frequency identification	射频识别
RRU	Remote radio unit	射频拉远单元
SaaS	Software as a service	软件即服务
SAP	System Applications and Products	企业管理解决方案
SBA	Service-based architecture	基于服务的架构
SLA	Service level agreement	服务等级协议
SUL	Supplementary uplink	补充上行链路
TDD	Time division duplex	时分双工
TSN	Time-sensitive network	时间敏感网络
UDD	Unified time & frequency division duplex	时频统一全双工
UL	Upload	上传
UPF	User plane function	用户平面功能
URLLC	Ultra-Reliable & Low-Latency Communication	低时延高可靠通信
VR	Virtual reality	虚拟现实

WRC-23	World Radiocommunication Conference 2023	2023 世界无线电通信大会
XR	Extended reality	扩展现实

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