هيئة تنظيم الاتصالات والحكومة الرقمية
TELECOMMUNICATIONS AND DIGITAL
GOVERNMENT REGULATORY AUTHORITY

United Arab Emirates

WHITE PAPER

5G ROLES IN INDUSTRY DIGITALIZATION IN THE UAE

TELECOMMUNICATIONS AND DIGITAL
GOVERNMENT REGULATORY AUTHORITY

CHINA ACADEMY OF INFORMATION
AND COMMUNICATIONS TECHNOLOGY

KHALIFA UNIVERSITY

EMIRATES ICT INNOVATION CENTER (EBTIC)

Contents

List of Figures

List of Tables

0 Introduction

Currently, a new wave of technological revolution and industry transformation is reshaping the structure of the global economy. All the world's major economies now view digital transformation as a pivotal strategic goal. The acceleration of digital transformation through the use of next-generation information technologies in order to boost the overall economy has become an important trend in various economic and societal domains. 5G, as a key new infrastructure on which the IoE can be developed, is penetrating into many areas of the economy and society as whole. As operators race to put 5G into commercial use, network construction and application deployment have become critical to 5G development and competitiveness.

This white paper discusses the development path of 5GtoB applications in the UAE through comparison with other countries and regions as well as by looking at 5G development and industry digitalization as a whole. It consists of six chapters and aims to act as a guide for promoting 5GtoB converged applications.

Chapter 1 briefly describes the characteristics, application scenarios, and standard development of 5G technologies. It explains how 5G converged applications drive the development and iteration of 5G terminals, networks, and applications in the supply chain and promote the evolution from 5GtoC to 5GtoB.

Chapter 2 summarizes 5G development trends in major countries and regions around the world. In terms of policies, these countries and regions prioritize 5G development in their digital economy strategies. Strategic layout, project establishment, and an inclusive 5G application innovation environment is favorable for 5G-driven economic and social digitalization. In terms of networks, 5G networks are now undergoing large-scale construction globally, the number of users is increasing rapidly, and multiple countries and regions are actively exploring how to build 5G campus networks to meet the needs of vertical industries. Operators and equipment vendors in China work with industry customers to explore 5G campus networks, providing customized network templates for vertical industries. 5GtoC applications, including XR, cloud gaming, and HD video, are still in their infancy globally. 5GtoB

applications are currently undergoing extensive verification and demonstration to adapt to scenario requirements, and therefore few applications are currently mature enough to be replicated on a large scale.

Chapter 3 analyzes the 5G development requirements and situation in the UAE. The UAE government actively develops 5G strategies, and the TDRA releases 5G standards and policies. The UAE deploys 5G networks mainly on C-band and the 2.6 GHz band, making 5G outdoor coverage possible in major cities and 5G campus networks feasible in key industries. According to industry surveys, digital transformation enhances the opportunities of new ICT technologies in vertical industries. Currently, 5GtoB applications in the UAE are still in the requirement introduction phase.

Chapter 4 analyzes the promotion path of the 5GtoB converged applications, and explores the needs of four pilot sectors: energy, manufacturing, public service, and transportation. These sectors feature a good digital foundation, strong digital transformation need, and promising industry prospect, thus making them ideal for exploring the development of 5G converged applications.

Chapter 5 studies the development path of 5G converged applications in the pilot sectors in the UAE, expounds on the industry challenges, requirements and main 5G application scenarios in key industries, analyzes the technical compliance and implementation difficulty of each application scenario, and provides phased suggestions for 5G application scenarios in each pilot sector.

Chapter 6 provides phased suggestions for 5G converged application development in the UAE from the perspectives of policies, networks, and applications by drawing upon the 5G experience of other countries and regions around the world. The immediate goal is the implementation of 5G applications in key vertical industries. The medium-term goal is the large-scale replication and promotion of 5G converged applications in key industries. The long-term goal is a healthy industry ecosystem to promote the large-scale replication and promotion of 5G applications in most industries in the UAE.

1 5G Features

1.1 5G Technologies Driving Mobile Communications into a New Era

Compared with previous generations of mobile communications technologies, 5G (the 5th generation of the International Mobile Telecommunications IMT) applications have expanded from the traditional mobile Internet to the Internet of Things (IoT). 5G is deeply integrated with cloud computing, big data, and artificial intelligence (AI) technologies to achieve Internet of Everything (IoE) and build key infrastructure for digital transformation of various industries. International Telecommunication Union (ITU) defines three 5G application scenarios, as shown in Figure 1-1.

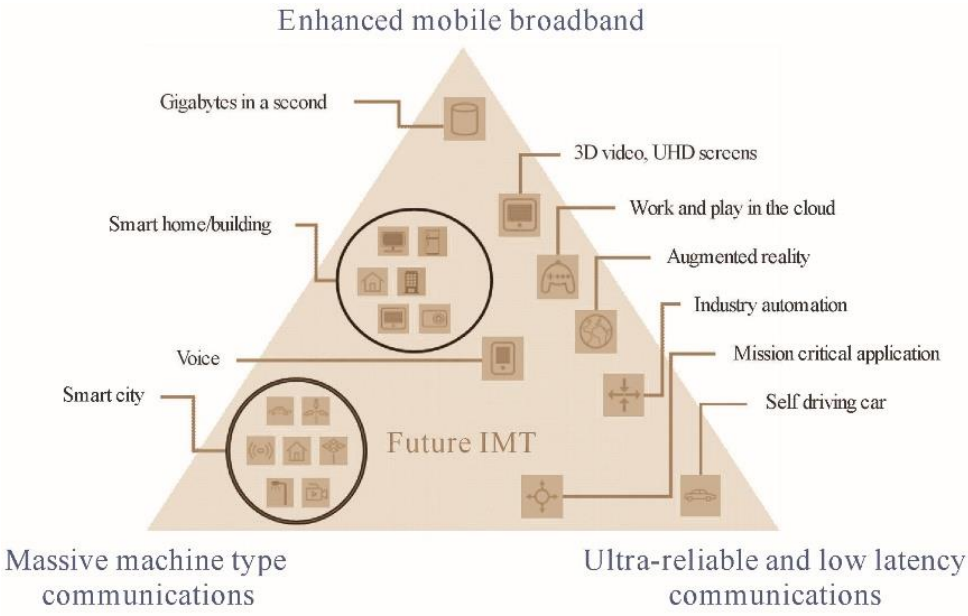

Figure 1-1 5G's three capabilities and application scenarios

Source: ITU

- Enhanced Mobile Broadband (eMBB) focuses on services requiring ultra-high bandwidth, such as high-definition video (4K/8K), virtual reality (VR), and augmented reality (AR), meeting user demands for a digital life. This is the evolution of high throughput where the minimum speed in downlink is 100 Mbps and may reach to Gbps under certain conditions.

- Massive Machine-Type Communications (mMTC) focuses on scenarios requiring high-density connections, such as intelligent transportation, smart grid, intelligent manufacturing (Industry 4.0), and smart logistics, meeting user demands for a digital society. This feature differentiates 5G for its support to the Internet of Everything by taking Machine to Machine (M2M) to the next level where a dense network of these devices can be served with adequate network connectivity.
- Ultra-Reliable and Low-Latency Communications (uRLLC) focuses on latency-sensitive services, such as live remote-control operations of cranes and robotic arms, remote surgery, synchronized remote machines, networked orchestra, autonomous driving/assisted driving, Internet of Vehicles (IoV), etc. The target latency of 1ms is still not achieved as the current best scenario latency achievement is around 3 ms based on certain conditions. However, even 4ms provides users with the notion of real time to human sensory perception.

With the expansion of 5G application scenarios, 5G focuses on more diversified performance indicators. These are used along with traditional indicators such as peak rate, mobility, latency, and spectral efficiency, and include: user-experienced data rate, connection density, area traffic density, and network energy efficiency. For details, see Figure 1-2.

More specifically, 5G must feature a 100 Mbps to 1 Gbps user experience rate to ensure excellent user experience of mobile VR/AR services. Moreover, the connection density must support 1 million devices/km^2 to meet the target mMTC services. The area traffic density must be up to 10 Mbps/m^2 in order to accommodate the thousands of times increase in mobile traffic. 5G must also provide millisecond-level latency to support the stringent requirements of IoV and industrial control.

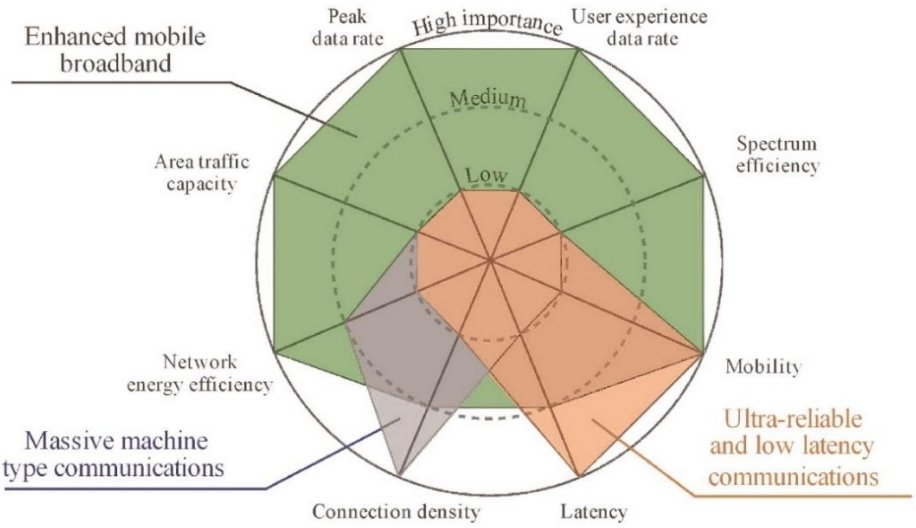

Figure 1-2 Enhancement of key capabilities from 4G to 5G

Source: ITU

1.2 Frequently Updating 5G Standards, Deepening 5GtoB Applications

The 3rd Generation Partnership Project (3GPP)[1] continues to promote the development of 5G international standards as planned, releasing a new version every 15 to 18 months to continuously optimize the performance of existing standard technologies and introduce new technologies for new services and scenarios.

In June 2018, 3GPP released the first 5G standalone networking standard, Release 15. This standard focuses on eMBB services requiring higher network transmission rate and targeting high-bandwidth services such as Ultra High Definition (UHD) video and AR/VR.

In June 2020, 3GPP launched Release 16 to support low-latency and high-reliability services as well as applications such as 5G IoV and industrial Internet.

[1] The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners” providing their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.

In June 2022, 3GPP completed the formulation of Release 17 focusing on differentiated IoT applications and medium- and high-speed massive connections. R17 supports more intermediate- and high-frequency spectrum resources, seeks deeper and wider network coverage through coverage enhancement and non-terrestrial communications technologies, and supports multiple-input multiple-output (MIMO) capabilities of more frequency bands, such as low frequency FDD. Moreover, Release 17 provides a wider range of service support capabilities, such as medium- and high-rate IoT with low power consumption, submeter-level positioning, and radio slicing enhancement.

Currently, 3GPP has started the planning of the Release 18 standard project. Release 18 will evolve and enhance on the following aspects: continuous enhancement of broadband capabilities, refined design for vertical industries, and discussion of new services.

1.3 5G Campus Networks, Empowering 5GtoB Applications

As 5G converges with industries, diversified industry requirements entail high 5G network customization costs. Not only that, more enterprises want to operate the network independently. These requirements will drive the evolution of 5GtoC networks to 5G campus networks.

5G campus networks, also known as 5G public networks for private/industrial use, refer to the high-quality dedicated virtual networks that can meet service and security requirements of industry users based on the 5G public network. It is the core carrier for providing customized and partially autonomous network services to industry users.

The 5G campus network provides three network architectures: virtual private network mode based on public network slicing, hybrid virtual private network mode based on on-premises user plane, and independent private network mode.

Public network slicing mode: Operators leverage 5G slicing to provide customized dedicated channel services for industry enterprises on public service-oriented networks. In this way, services are preferentially guaranteed, services are logically isolated, and optimal network quality for an application is ensured. This mode is applicable to small- and medium-sized enterprises that are not highly sensitive to data security and latency.

On-premises user plane mode: Functional NEs such as User Plane Function (UPF) and Edge Cloud (MEC) deployed on operators' core network side are now deployed inside enterprises to provide local data breakout, local storage, computing resources, security, and real-time performance of enterprise data when building applications. This mode is applicable to large and medium-sized enterprises that fully understand the 5G industry network requirements. Enterprises can partially control the 5G industry network and customize the network as required.

Independent private network mode: Enterprises build dedicated 5G networks to independently carry their own service applications. A dedicated network and on-demand customization protect the security of enterprise data, low network latency, and independent controllability. This mode is applicable to large-sized enterprises that are financially and technically better and have high requirements on network controllability and data security.

The 5G campus network comprises two important support technologies: network slicing (as shown in Figure 1-3) and edge computing (as shown in Figure 1-4). Network slicing enables End to End (E2E) 5G campus network construction and cross-region campus network implementation, ensuring logical or even physical isolation between campus networks and public networks. Edge computing containing UPF is used to build dedicated or partially dedicated virtual network resources in areas such as factories and campuses. The two technologies can also be used together to guarantee the resources and quality of 5G campus networks.

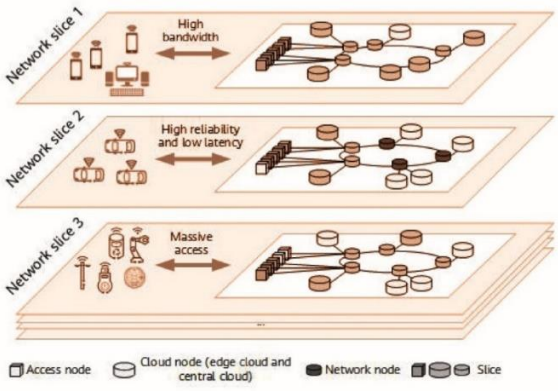

Figure 1-3 Network slicing providing multiple logical networks on the shared network infrastructure

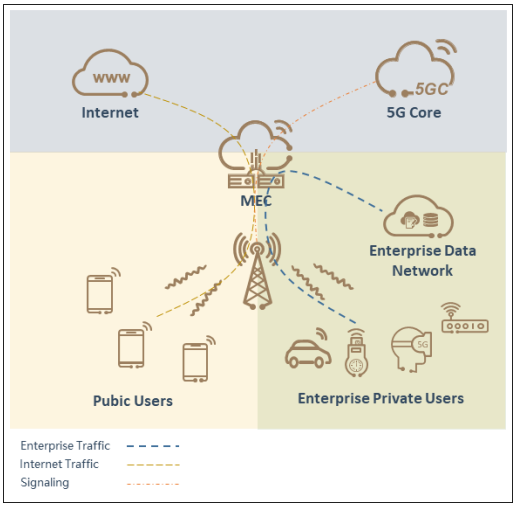

Figure 1-4 MEC providing computing and storage capabilities near data users

1.4 5G Industry Chain Extension, Promoting the Convergence of 5G and Industries

The implementation and development of 5G use cases in the industries has brought following requirements:

(1) Networks: independent Operation and Maintenance (O&M), low costs, and high security

(2) Terminals, modules, and chips: intelligent convergence, market fragmentation, and customization

(3) Application solutions: industry mechanism performance optimization and function optimization

To meet the requirements of 5G applications, the traditional 5G industry chain must transform into a new 5G application industry chain system. On the whole, the 5G application industry chain retains the traditional 5G industry chain structure, including networks, terminals, applications, and security, as shown in Figure 1-5. In terms of networks, industry-oriented customized core networks, industry-specific network devices, and existing network systems of industries converge to provide low-cost, secure networks. In terms of terminals, general-purpose terminals, modules, and chips are developed together with industry-specific terminals, modules, and chips to deliver flexible industry scaling. From an application perspective, 5G converged application solutions that are oriented toward industry, energy, and

healthcare have become a major turning point. As for security, the industry 5G network security and industry system are integrating and cooperating with all of the stakeholders engaged for a greater 5G network and industry security.

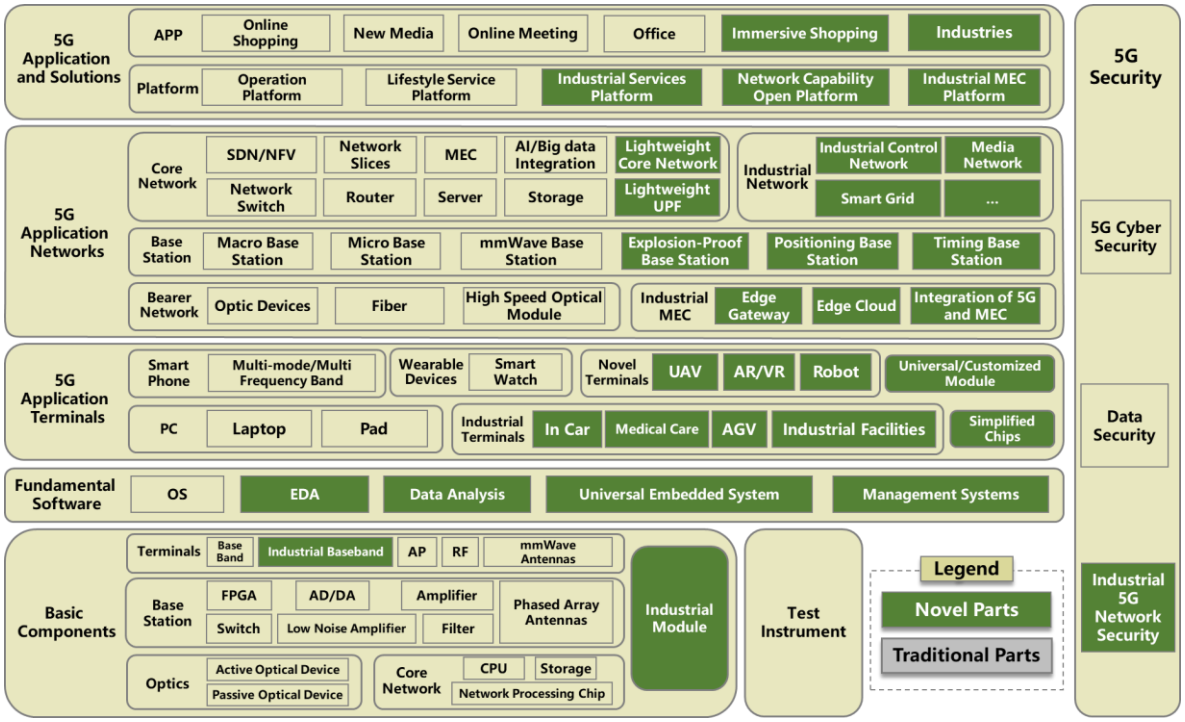

Figure 1-5 5G application industry chain

2 Global 5G Development Trends

As the commercial rollout of 5G becomes more and more widespread, network construction and application deployment are critical to future 5G development and competition. Major countries and regions around the world have accelerated the publication of 5G policies and network construction to seize the opportunities for application development.

2.1 Policies

Major countries and regions around the world prioritize 5G in their digital economy strategies, set goals at the national level, and release favorable policies to support 5G development. Industrial policies are a powerful driver for the development of emerging fields, helping to build an inclusive 5G application innovation environment, foster a 5G application industry ecosystem, and promote the adoption of 5G technologies in vertical industries. The government's enthusiasm toward developing 5G applications can stimulate investment of industry enterprises, help reduce risky investment by enterprises adopting 5G and resolve key issues in the development of 5G applications. 5GtoB applications develop rapidly and there are many cases of mature applications in countries and regions where industry policies have been issued early and have been strongly promoted. Currently, governments and regulatory authorities in major countries and regions around the world have recognized the huge opportunities that 5G brings to the economy and society. They have built an inclusive 5G application and innovation environment by means of strategic layout, project establishment, and other means based on their country's strengths, striving to leverage 5G technologies to drive the digital transformation of the economy and society.

2.1.1 5G Application Development Policies in China

The Chinese government attaches great importance to the development of 5G applications. Governments at all levels have released guiding, programmatic, and industry-specific policy documents to jointly promote the in-depth expansion of 5GtoB applications.

At the national level, the Ministry of Industry and Information Technology (MIIT) have released documents such as the *Promotion Plan for the "5G+ Industrial Internet" 512 Project*, the *Notice*

on Accelerating 5G Development, the *Notice on Improving 5G Service Quality*, and the *"Sailing" Action Plan for 5G Applications (2021-2023)*. The *"Sailing" Action Plan for 5G Applications (2021-2023)* is jointly released by the MIIT, National Development and Reform Commission, Ministry of Education, Ministry of Finance, and Ministry of Culture and Tourism. It is a guideline for 5G applications, and provides clearly-defined proposals for 5G converged applications in 15 industries in terms of information consumption, real economy, and people's livelihood services. The 14th Five-Year Plan includes accelerating 5G network deployment and building 5G application scenarios and industry ecosystems, thereby codifying the development direction of 5G applications in key industries. Indicators for 5G network applications and construction standards are included into the outline of 14th Five-Year Plan and the *"Sailing" Action Plan for 5G Applications*. In addition, dedicated funds have been established by the Chinese governments to support key industries and key technologies.

Table 2-1 5G network applications and construction standards outlined in the "Sailing" Action Plan for 5G Applications

5G network applications and construction standards	Value
5G User Penetration Rate	40%
Number of 5G Base Stations per 10k People	18
Number of 5G Campus Networks	3000
5G Penetration Rate in large Industrial Enterprises	35%
Number of 5G Application Benchmarks for Key Industries	100

At the local government level, region-specific policies are released to promote the implementation of 5G applications. Based on the characteristics of the local economy and industry, each province and city in China released local 5G application promotion policies. These policies specify the development direction of the local 5G industry and key applications, and propose action objectives, measures, application scope, and support policies for high-quality 5G construction. According to the China Academy of Information and Communications Technology (CAICT), by the end of December 2021, 583 5G support policy documents had been released, including 70 provincial-level documents, 264 municipal-level documents, and 249 county-level documents.

All departments collaborate to promote the convergence of 5G applications and vertical industries. Multiple ministries jointly released implementation solutions for 5GtoB applications, organized pilot and demonstration projects, encouraged local governments to build pilot areas and demonstration bases, and guided the development of 5G converged applications in key industries and enrich 5G application scenarios. The MIIT and National Health Commission jointly released the *Notice on Organizing the Application of 5G+Healthcare Pilot Projects*. The National Development and Reform Commission, National Energy Administration, Office of the Central Cyberspace Affairs Commission, and the MIIT jointly released the *5G Application Implementation Plan in the Energy Sector*, which contains proposals to expand 5G+smart grid application scenarios and explore new business models and forms of 5G applications that are replicable and promotable in order to support the high-quality development of the energy sector. The Ministry of Culture and Tourism released the *Opinions on Promoting the High-quality Development of the Digital Culture Industry*, in which it was mentioned four times that technologies such as 5G should be utilized by the cultural industry.

2.1.2 5G Application Development Policies in South Korea

The South Korean government has formulated a top-down continuous and systematic strategic plan for 5G application development.

In terms of policies, South Korea's Ministry of Science and ICT (MSIT) announced that it would build a world-leading 5G commercial network in March 2019. SKT, KT, and LG U+ will jointly build 5G networks to accelerate 5G deployment, effectively utilize resources, and reduce repeated investment. In 2019, MSIT released the *5G+ Strategy to Realize Innovative Growth*, making the systematic promotion of 5G+convergence services a national strategy. In 2020, MSIT released the *5G+ Strategy Development Status and Future Plan Draft*, pointing out that the South Korean government planned to invest KoreaWon (KRW) 650 billion in exploring and promoting convergence application services. In 2021, MSIT released the *2021 5G+ Strategy Promotion Plan (Draft)* and *MEC-based 5G Convergence Service Development Plan*, and announced that the 5G+ convergence ecosystem would come to the public for the first time in

2021 and that it intended to invest KRW165.5 billion in developing new 5G convergence technologies.

In terms of promotion system, the South Korean government has taken a leading role in establishing a top-down promotion system. South Korea has established the 5G Working Committee, 5G Strategy Committee, and 5G Policy Committee, forming an industry alliance involving the government, enterprises, academia, and research institutes, in order to promote cooperation between entities involved with innovation.

In terms of promotion methods, the government released strategic plans to promote the development of 5G applications continuously and systematically. In recent years, the South Korean government has continuously released annual promotion plans based on the "5G+ Strategy", reviewed the implementation effectiveness of the plan in the previous year, and formulated support policies and objectives for development in the current year accordingly. In August 2021, the South Korean government released the *5G+Convergence Service Development Strategy*, developed the 5G+convergence service expansion implementation solution, and set quantitative expectations in terms of application scenarios, enterprise quantity, and technical level to guide the cultivation and large-scale development of 5G+converged applications.

2.1.3 5G Application Development Policies in the United States

The U.S. government focuses on its advantages in 5G technologies, and has released top-down policies to strengthen 5G infrastructure construction.

In 2016, the Federal Communications Commission (FCC) voted to open more than 24 GHz of wireless spectrums. In addition, the U.S. government plan to invest United States Dollar (USD) 400 million in promoting 5G network trials in multiple cities.

In 2017, U.S. President Trump issued the *National Security Strategy*, which regards "deploying the fifth-generation mobile communications (5G) network nationwide" as one of the top actions and explicitly states that the U.S. federal, state, and local governments would work with private companies to improve the U.S. telecommunications and digital infrastructure through the deployment of secure 5G networks across the country.

In 2018, FCC released the *FCC's 5G FAST Plan*, which strategically promotes 5G network construction in terms of spectrums, infrastructure policies, and the modernization of outdated regulations, to strengthen the U.S.'s advantages in 5G technologies.

In 2021, the Center for Strategic and International Studies (CSIS) released a report, *Accelerating 5G in the United States*, proposing measures such as accelerating spectrum reuse and supporting and funding key industries.

In March 2021, U.S. President Biden announced a USD2.3 trillion infrastructure plan, as part of the "*Build Back Better*" plan, which aims to rebuild aging U.S. infrastructure. Specifically, USD100 billion will be used for expanding high-speed network connections, and USD180 billion for developing cutting-edge technologies.

2.1.4 5G Application Development Policies in Europe

Europe released a series of policies to systematically promote 5GtoB applications and build a clear path for converged applications for 5G and vertical industries.

The European Commission officially released the *5G for Europe: An Action Plan*. It includes the following actions: Release the test plan and start testing in March 2017, develop a complete 5G deployment roadmap by the end of 2017, start initial commercial trials in 2018, provide 5G services in member states and in at least one of their respective cities in 2020, and provide 5G services in urban areas and along major highways and railways of member states in 2025. The official release of the EU's 5G action plan shows that it has entered the 5G trial and deployment phase. At the beginning of 2021, the European Commission launched the “Digital Decade”, which takes 5G as the core pillar and vigorously expands 5G network coverage. The goal is to achieve 100% coverage in urban areas by 2025 and 100% coverage in densely-populated areas by 2030. The European Commission has established the “Recovery and Resilience Facility fund” worth EUR723.8 billion, and will invest 20% of this fund into digitalization, especially 5G deployment.

In March 2017, the Department for Digital, Culture, Media and Sport (DCMS) and the HM Treasury jointly released the *Next Generation Mobile Technologies: A 5G Strategy for the UK*. It specifies the UK's 5G development initiatives from the following key aspects: practical 5G

cases, appropriate regulatory solutions, regional management and deployment capabilities, coverage and capacity of 5G networks, secure 5G deployment, spectrums, and technologies and standards.

In 2017, the Bundesministerium für Verkehr und digitale Infrastruktur (BMVI) released the *5G Strategy for Germany*. It includes the following actions: Strengthen 5G network output, improve the spectrums required by 5G networks, strengthen cooperation between the telecom industry and the 5G network application industry, conduct more coordinated and targeted research, and realise national coverage of 5G networks in towns and villages.

The European Commission released the *Horizon 2020: Work Programme 2018 – 2020*, in which an investment plan worth EUR30 billion was proposed, of which, EUR1.7 billion will be invested in digitalization and transformation of European industries and services. The investment plan will help integrate digital technologies, such as 5G, high-performance computing, AI, robotics, big data, and IoT, with innovations in other technical fields, enhance cyber security, and address the social impact of digital transformation.

2.2 Networks

5G networks are under large-scale construction globally. By the end of March 2022, the 5G network population coverage is 24.53%. 5G networks cover more than 50% of the population in 37 countries and regions. The United States, Australia, some European countries such as Germany and Spain, and some Asian countries such as the Philippines use low frequency bands to quickly expand 5G network coverage, covering over 80% of the population. By March 2022, 215 operators in 85 countries and regions had started to provide 5G services (including fixed wireless and mobile services), as shown in Figure 2-1. China has the largest number of 5G base stations, and South Korea has the world-leading number of base stations per 10,000 people and network population coverage. By the end of May 2022, 1.7 million 5G base stations had been deployed in China, covering 100% of prefecture-level cities and counties as well as 92% of towns and townships across the country, with an average of 12 5G base stations per 10,000 people.

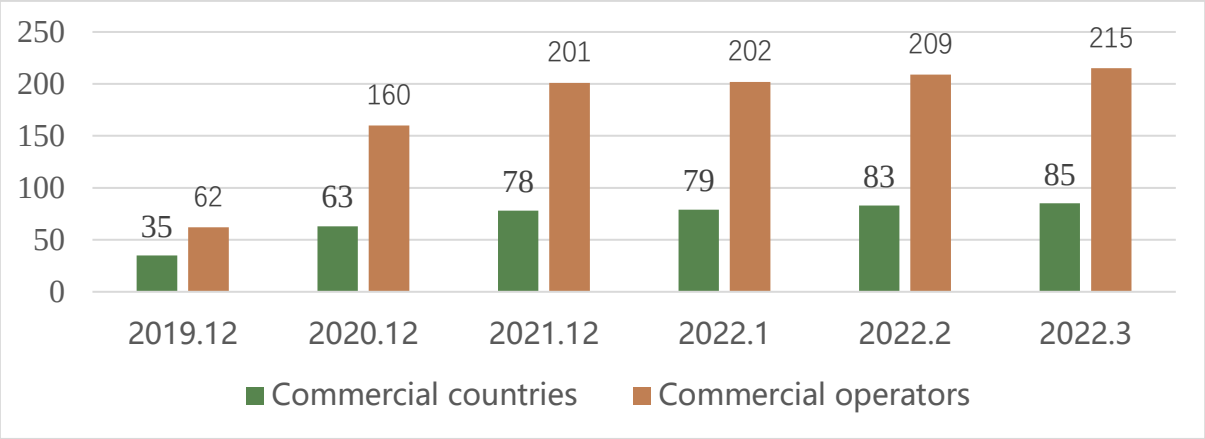

Figure 2-1 Global 5G commercial situation

Source: CAICT

Table 2-2 Global 5G network development as of December 2021

Country and Region	Number of Base Stations	Number of Base Stations per 10,000 People	5G Coverage Rate (%)	Band
China	1,559,000	11.04	55.7	Mid- and low-bands: 700 MHz, 3.5 GHz, and 4.9 GHz
South Korea	203,000	39.5	98.0	Mi- and high-bands: 3.5 GHz and mmWave (for hot spot coverage)
US	68,000 (as of 2020 Q4)	2.04	94.9	Low-, mid- and high-bands: 600 MHz, 700 MHz, 80 MHz, 2.5 GHz, C band, 28 GHz, and 29 GHz
UK	15,000 (estimated as of 2021.6)	2.20	42.6	Low- and mid-bands: 700 MHz and 3.5 GHz
Germany	31,000 (estimated)	3.69	92.7	Low- and mid-bands: 700 MHz, 1800/2100 MHz, 3.5 GHz, and mmWave (for hot spot coverage)

Source: MIIT, GSMA, websites of regulators, public news, etc.

To meet the industry requirements for 5G networks, **operators and device vendors in China work with industry customers to explore the 5G campus network construction mode and provide customized network templates for vertical industries to meet industry requirements.** As of July 2022, 6518 5G campus networks have been built in China, with a year-on-year increase of nearly 300%.

The number of 5G users is increasing rapidly, and over 90% of users come from China, the United States, Japan, and South Korea. By the end of June 2022, the number of global 5G users is 742 million, 87% of which are from China, the United States, Japan, and South Korea. Particularly, the number of 5G users in China has reached 455 million. According to the GSMA, the 5G user penetration rate is over 30% in regions and countries like South Korea, Hong Kong, China, and Japan, and 19.42% in the UAE, which is the leader in West Asia, as shown in Figure 2-2.

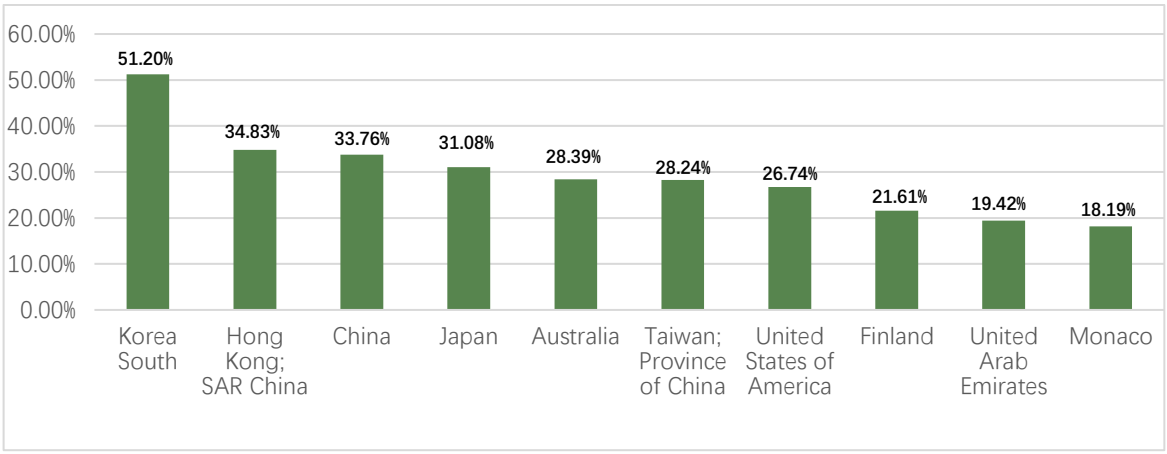

Figure 2-2 5G user penetration rate worldwide

Source: GSMA, Q2 2022

2.3 Applications

Global 5GtoC applications are still in infancy. Operators focus on XR, cloud gaming, and HD video services to highlight the immersive experience. The development bases of 5GtoC applications include the following: Wide and in-depth network coverage to provide good user experience, high user penetration rate, and application direction that adapts to technical characteristics and is supported by terminals. Currently, most 5GtoC services rely on high

bandwidth and low latency of 5G networks to improve the audio-visual experience of users. The primary 5GtoC terminals are smartphones, and there are few new terminals because they are costly. 5G services provided by global operators for consumers are mainly entertainment applications, such as gaming, live broadcast and interactive sports events and performances, as well as VR/AR. XR, HD, and immersive experience are keywords for 5GtoC applications.

Global 5GtoB applications are under extensive verification and demonstration and are leveraged in multiple domains on a small scope. According to the CAICT, global 5GtoB applications are carried out in three directions: industrial digitalization, digital governance, and intelligent life[2]. Among the 5GtoB application tests or deployments that have been carried out, 58.2% are innovative applications in the industrial digitalization direction. Considering the industries in which applications are carried out and their deployment status, 5GtoB applications in major countries are in the initial phase. In most industries they are still in the scenario adaptation phase. There are a large number of demonstration projects, but few mature applications can be replicated on a large scale.

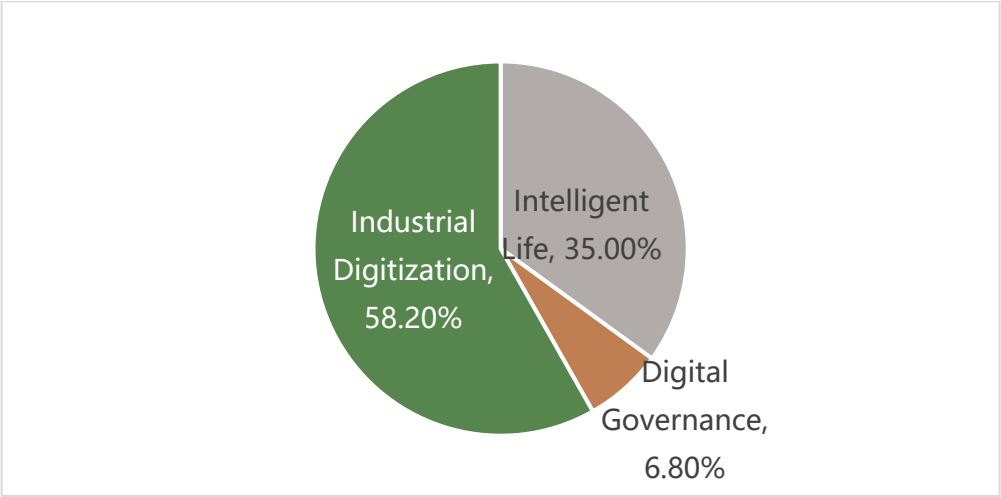

Figure 2-3 5GtoB application in three directions

Source: CAICT

[2] Intelligent life includes arts & entertainments, education, tourism and smart home, etc.

2.3.1 5G Application Development Status in China

China promotes the development of 5G applications by establishing alliances and holding 5G application competitions. Under the guidance of the MIIT, CAICT works with operators, equipment vendors, Internet enterprises, application development enterprises, financial investment institutions, and research institutes to set up a 5G Application Industry Array (5G AIA) to carry out research on key technologies and standards for 5G converged applications, and promote the development of the industry as a whole. The MIIT has held the "Bloom Cup" 5G Application Competition for five consecutive years to promote 5G application scenarios and inspire ideas for 5G development.

Currently, 5G applications in China are entering the stage of large-scale exploration. All players are continuously exploring the converged application of 5G in various industries. 5G has been approximately applied in 200 smart mines, 1000 smart factories, 180 smart grids, 89 ports, and more than 600 grade-A tertiary hospitals in China. According to the 4th "Bloom Cup" 5G Application Competition in 2021, 5G has been employed in more than 12,000 innovative projects in over 30 industries, including industry, energy, healthcare, culture and tourism, and education (as shown in Figure 2-4 and Figure 2-5). In addition, 5G applications have gradually been employed in core processes in addition to auxiliary processes, covering the full lifecycle process from R&D design and production to operation management and product services. From the perspective of geographical locations, 5G applications have been launched in 330 prefectural-level cities in 31 provinces, cities, autonomous regions, and Hong Kong Special Administrative Region in China.

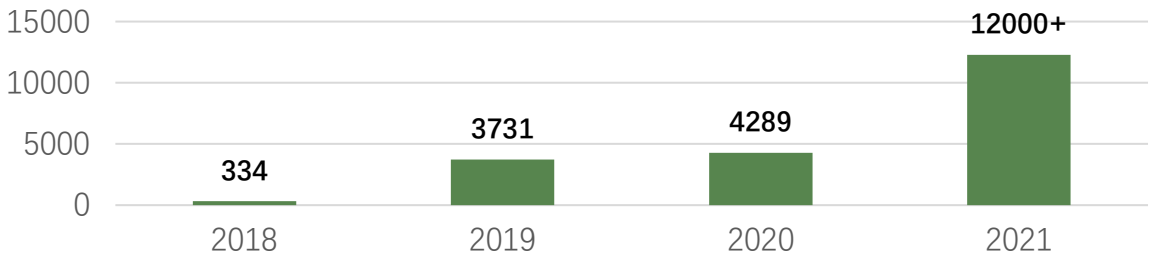

Figure 2-4 Number of 5G application cases collected from the "Bloom Cup" 5G Application Competition

Source: CAICT

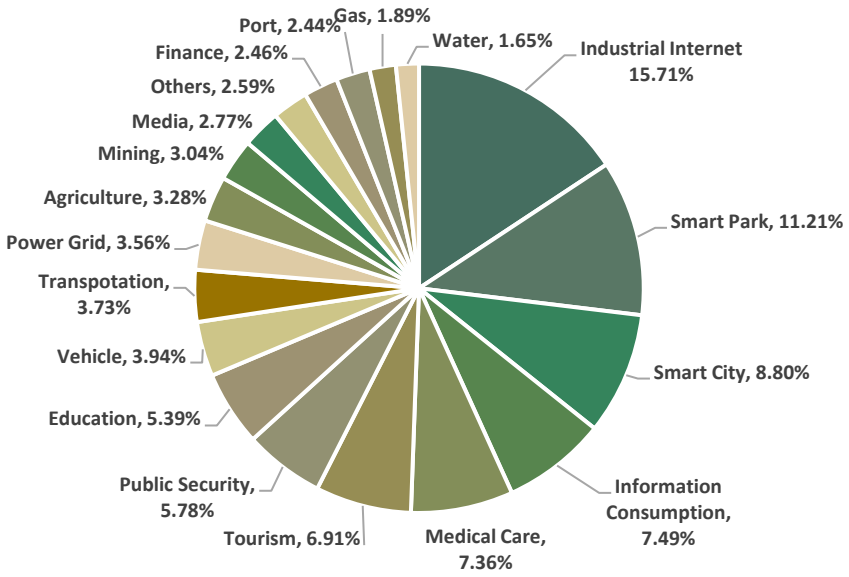

Figure 2-5 Proportion of 5G applications in various industries in China

Source: CAICT

2.3.2 5G Application Development Status in South Korea

South Korea's policy initiatives to promote 5G plus convergence services have made some achievements. **In terms of 5GtoC applications**, South Korean operators focus on XR and cloud gaming to develop 5GtoC applications and pay more attention to content ecosystem construction. For example, the operator LG U+ cooperated with a content production technology company to build a U+VR platform, and worked with a holographic photography company to build an AR content production studio. **In terms of 5GtoB applications**, South Korean operators focus on five core services (immersive virtual content, smart factory, autonomous driving, smart city, and digital healthcare) and cooperate with vertical industries to develop solutions. For example, LG U+, solution companies, and Hyundai Oilbank leveraged 5G real-time high-precision positioning technologies to carry out 5G+ autonomous driving robot applications. KT and Samsung Seoul Hospital built a 5G smart hospital to explore applications such as remote consultation, teaching via real-time surgery video, and real-time interpretation of pathology reports. SKT cooperated with South Korea's largest take-out

company to offer delivery services using robots. Currently, some demonstration projects have been commercialized.

South Korea strongly supports 5G development in traditional sectors. Public departments invest in 5G to implement secure and effective management of city infrastructure such as transportation. South Korea attaches great importance to the development of the content industry and promotes the development, production, and commercialization of VR/AR content through project funds.

2.3.3 5G Application Development Status in the United States

In terms of 5GtoC applications, with the high-speed feature of mmWave 5G networks, operators can provide enhanced mobile wireless access services for consumers in hotspot areas such as airports, stadiums, arenas, shopping centers, and university campuses. In the United States, operators cooperated with professional companies such as content companies and game companies to actively provide VR/AR, HD video, and cloud gaming services. For example, AT&T cooperated with Bookful, a 3D and AR reading app, to provide 5G-based immersive AR experience for reading children's books, bringing stories to life. Stadiums and arenas are core places for operators to deploy mmWave 5G networks. 5G application development focuses on enhancing onsite experience, such as HD live broadcast of sports events/performances and VR/AR.

In terms of 5GtoB applications, major players in the industry chain in the United States cooperate closely and leverage their advantages to promote 5G application in various industries, including industrial Internet, healthcare, and IoV. The mmWave 5G networks deployed in the early phase provide a good network foundation and test environment for the United States to develop 5GtoB applications. By leveraging digital technologies such as edge computing and advanced manufacturing technologies, the industries collaborate with each other and use entities such as innovation centers and incubators to build a favorable ecosystem for 5GtoB applications. For example, T-Mobile cooperated with Sarcos Robotics to integrate 5G functions into industrial robots. Verizon used Microsoft Azure cloud to launch on-premises 5G edge services. The logistics company Ice Mobility has used Verizon 5G Edge and

Azure Stack Edge to help with computer vision-assisted product packaging to improve onsite quality assurance.

2.3.4 5G Application Development Status in Europe

5GtoC applications in Europe mainly include three types. **5G fixed wireless access (FWA)**: Optical fiber coverage is insufficient in Europe, where 5G FWA is the driving force for operators to develop 5G. **Differentiated content services such as cloud gaming and VR/AR**: Major operators such as Vodafone, Koninklijke PTT Nederland (KPN), and Telecom Italia cooperate with specialized companies to launch 5G cloud games for consumers. **UHD live streaming of sports events and performances**: Technical advantages of 5G have been leveraged to transform how people view live sports events and entertainment, providing greater immersion for viewers.

5GtoB applications in Europe have entered the large-scale trial phase. By promoting technical standard R&D, test platform construction, onsite verification in specific industries, and large-scale application, Europe has built a clear roadmap for converged applications of 5G and vertical industries. By March 2021, EU member states had widely carried out 5GtoB application trials in multiple vertical industries, including Industry 4.0, agriculture, smart city, smart building, healthcare, public security, automobile, and transportation. Current statistics estimate that up to 258[3] 5G trials had been announced in 27 EU countries, the UK, Norway, Russia, Switzerland, and Türkiye. Multiple applications in industry, healthcare, port, and other fields have been put into commercial use.

European operators, industry enterprises, and research institutes teamed up in groups to explore the application of 5G and carried out a large number of tests on applications in

[3] The European 5G Observatory. This page lists 5G trials that have been publicly announced in EU27, UK,Norway, Russia, Switzerland and Turkey[EB/OL]. (2021-11-01)[2022-03-12].http://5gobservatory.eu/5g-trial/major-european-5g-trials-and-pilots/.

autonomous driving, industrial field, healthcare, and other sectors. For example, 5G PPP[4] has started 5G infrastructure tests and verification projects since July 2018 to establish a pan-European verification platform, an E2E test platform, and a 5G demonstration system. Furthermore, for industries with enormous potential for commercialisation, 5G application innovation clusters were formed in countries or cities to showcase innovative applications. These clusters also function as a platform for sharing technologies, with the ultimate goal of fostering new applications that are easily replicable. Examples include the exploration of 5G adoption in industries in Berlin, Germany, future factories in Belgium, Ireland, and Norway, smart energy in Italy, and smart city in Ireland and Norway. Not only that, Europe has established an industry cooperation ecosystem to promote the industrialization of 5G applications.

[4] The 5G Infrastructure Public Private Partnership (5G PPP) is a joint initiative between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and researcher Institutions).

3 5G Development in the UAE

3.1 Policies

The UAE Telecommunications and Digital Government Regulatory Authority (TDRA) was established in 2003 to regulate the Information Communications and Telecommunications (ICT) sector in the UAE and to ensure sustainability, competitiveness and transparency among service providers, customers, and shareholders. The TDRA's vision is for the UAE to be a global leader in ICT. Being the host for Expo 2020, UAE initiated the 5G as an initiative to make Expo the best-connected place aligning with the Expo vision of "**Connecting Minds** and Creating the Future". The TDRA collaborated with operators, equipment vendors, governments, and other departments to develop a regulatory framework for 5G to promote the development of 5G technologies in the UAE.

The UAE government issued the "*UAE Strategy for 5G and Beyond*" in 2019 to meet customers' needs for high network rates, low latency, massive device connections, and high mobility. First, the TDRA establishes a cooperative and win-win regulatory environment to push successful deployment and development of 5G networks. Second, the TDRA established steering and executive committees for 5G to plan and manage 5G spectrums and help deploy networks. Not only that, the TDRA set a target of 100% 5G coverage in the UAE by 2025, in a bid to become a technology leader in the Middle East.

The TDRA also established the regulatory framework for implementing the 5G deployment strategy, through the development of standards, guidelines and frameworks aiming at accelerating the deployment of 5G networks nationwide. The UAE uses quarterly reports to monitor the progress of 5G network deployment, network performance, and 5G application deployment. Moreover, the UAE updates and revises corresponding regulations every two to three years based on the 5G development status. The following table lists the 5G policies and some other industrial policies that have been issued.

Table 3-1 TDRA's initiatives to develop 5G

	Year	Policy
1	March 06, 2019	TDRA Regulatory Procedure-IoT
2	April 15, 2019	TDRA Regulatory Policy -IoT
3	December 2019	TDRA Radiocommunications Policy
4	December 15, 2019	UAE Strategy for 5G and Beyond
5	February 2020	TDRA Future Spectrum Outlook 2020-2025
6	2021	Establishing Executive Committee for 5G Implementation 5G Implementation Plan for 5 years based on KPIs
7	2021	Establishing Steering Committee for 5G Implementation

In addition, TRDA launched the 5G & IoT Open Lab in December 2019 and started collaborative efforts with the government, non-government, and academic institutions to grow awareness, expand competencies through joint projects and implement future.

3.2 Networks

The UAE builds 5G networks with the C-band and 2.6 GHz band. There are two operators in the UAE, with each acquiring abundant 5G spectrum resources. Of the n78 frequency band, 300 MHz (3300 MHz to 3600 MHz) is allocated to e& and 200 MHz (3600 MHz to 3800 MHz) to du, while in the n41 frequency band, 100 MHz (2496 MHz to 2596 MHz) is allocated to du, and 94 MHz (2596 MHz to 2690 MHz) to e&. Both operators have focused their 5G network construction on the n78 and n41 bands, while in the future, 5G network construction will be extended to sub-3 GHz frequency bands. In 2021, the UAE allocated 5G mmWave, which offers higher data transmission rates and a larger communication capacity per square kilometer while ensuring service quality and enhancing performance. In 2021 both e& and du were allocated 1 GHz each of millimeter wave spectrum in 25.5-27.5 GHz to support eMBB applications. Due to carrier aggregation, the UAE operators was ranked as the fastest mobile operators globally. The Expo 2020 site was declared as the “best connected site”.

The UAE lays a strong foundation for 5G network infrastructure construction. e& and du have obtained licensed 5G frequency bands. Currently, 5G outdoor coverage is available in major

cities of the UAE, and users can access 5G networks in urban areas and on major roads. According to the global connectivity index issued by Carphone Warehouse, the UAE achieved in 2019 the first place amongst the Arab countries and the fourth place globally in launching and deploying 5G networks. The following table lists the number of 5G base stations, number of 5G subscribers, and 5G penetration rate in the UAE.

Table 3-2 5G deployment of operators in the UAE

Indicator	Unit	Value
Number of 5G Base Stations	Number	Total for both operators: approximately 7000
Number of Users	Number	Approximately 1.9 million
Penetration Rate	Percentage (5G users/mobile users)	Approximately 19.4%
Number of Base Stations per 10k Citizens	Number	Approximately 7

The UAE's 5G networks are gradually shifting from public networks serving the consumer segment only to public networks serving private/industrial segments. The UAE has multiple large cloud providers, laying a foundation for normal running and secure storage and processing of related data services. In addition, driven by the requirements of vertical industries, the UAE is exploring, testing, and verifying the use of 5G public networks for private/industrial use (5G Campus Networks) in different sectors such as energy, public security, and manufacturing. 5G Campus Networks can provide dedicated wireless connections in specific areas, which are the key to 5G penetration in vertical industries.

3.3 Applications

Considering 5G's role in industry digitalization of the UAE, we conducted surveys on enterprises, covering vertical industries such as energy, public services, and transportation. These surveys cover the basic information, digitalization foundation, and 5G requirements of enterprises.

Based on the survey results analysis, following are the discussion and key findings:

1. **Digital transformation in vertical industries drives enterprises to adopt new ICT technologies in the UAE.**

Digital transformation is an inevitable development trend for traditional industries. The survey shows that most enterprises are undergoing digital transformation, whereby 95% of them have undergone digital transformation for at least one year and 60% for over three years. In vertical industries, enterprises are willing to apply new technologies, such as 5G, AI&ML, big data, cloud, blockchain, edge computing, and IoT, to enhance their services. Currently, traditional networks, such as optical fibers and Wi-Fi, are dominant in production and operation, while 5G networks are deployed in few enterprises as a connection, highlighting a need for more widespread adoption of 5G networks.

Table 3-3 Survey questions and results related to digital transformation of vertical industries in the UAE

No.	Questions	Results
1	Which statement best describes the status of your company's digital transformation process?	60% executing their DT over 3 years 25% executing their DT 1-3 years 5% less than a year
2	Which of the following new ICT technologies are/will be applied to support the business processes of your company?	5G 11.67%, AI&ML 18.33%, Big Data 13.33%, Cloud 18.33%, Blockchain 15%, Edge Computing and IoT 6.67%
3	Which network technologies are you using for indoor, campus, and enterprise levels in your company?	Indoor: Wi-Fi, Ethernet, WLAN, Public 4G/3G/2G network are dominant. Campus: The optical fiber is dominant, and to some degree Satellite, according to the sectors of the respondents. The other infrastructures vary according to each sector. Enterprise (wide area, multi - campus): SD-WAN, WLAN, Public 4G/3G/2G network and optical is in use without a dominant technology.

2. **The 5GtoB applications are still in infancy in the UAE, requiring the introduction and implementation of specific industry requirements.**

Currently, there are few 5G applications in the UAE due to a range of factors, including to-be-improved technical standards, immature industry chains, and unclear business models. However, the following survey shows that 80% of enterprises are now familiar with the concept of 5G technologies. What's more, 5G networks are more secure and reliable, improving industry productivity, and cutting labor costs. Therefore, most enterprises are willing to deploy 5G in operation, development, and production environments.

In terms of 5G performance, the following survey shows that enterprises prioritise high reliability, followed by features including high network throughput, density of endpoint devices, support for low latency and real-time applications, flexibility of deployment (i.e., as compared with fixed networks), cyber security, high mobility, and customisation via network slicing. **In terms of 5G application scenarios**, remote inspection and UHD video surveillance are the most demanding application scenarios, followed by remote control, AR/VR, IoV, and machine vision. **In terms of 5G terminals**, the most important terminals accessing 5G networks are phones (67%), followed by laptops, cameras, and sensors. **In terms of 5G networks**, vertical industries, such as energy, public services, and logistics, have high requirements on 5G campus networks, and 58% of these enterprises are willing to deploy 5G campus networks.

Table 3-4 Survey questions and results related to 5GtoB development in the UAE

No.	Questions	Results
1	Which of the following best describes your level of understanding of 5G?	80% responded they are familiar with 5G technologies and applications
2	In order to meet the challenges and difficulties related to digital transformation, does your company plan to apply/ has applied 5G technologies?	20% responded they are using 5G in some aspects; 30% plan to adopt 5G in next 6 months; 40% consider using 5G in 12 or more months.
3	What do you think are the advantages that 5G can bring to your company?	Improve productivity: Very important (50%), Important (40%), Not important (10%), I don't know (0%) Reduce cost: Very important (40%), Important (35%), Not important (15%), I don't know (10%) Improve safety and reliability: Very important (60%),

No.	Questions	Results
		Important (25%), Not important (5%), I don't know (10%) Open new business opportunities via digital transformation: Very important (40%), Important (50%), Not important (0%), I don't know (10%) Highest: Safety and reliability. Others are also considerably important. But 15% don't see or 10% don't know if cost reduction is a driver or impact to the business.
4	Are you expecting/Do you expect the following features of 5G to be part of your company's business?	Highest: high reliability Lowest: diverse deployment options Moderate drivers: high network throughput, density of endpoint devices, support for low-latency and real time applications, flexibility of deployment (i.e., as compared with fixed networks), cyber security, high mobility, customization via network slicing
5	In which department does your company intend to apply 5G technologies in the future?	Operation department (28.95%) Development department (23.68%) Production department (21.05%)
6	Based on your company's main business activity, which of the following 5G use cases interest you?	Highest: 5G for remote inspection, 5G HD video surveillance Lowest: 5G for vehicular communication, 5G for AR/VR, 5G for machine vision Moderate: 5G for remote control of devices
7	Which terminals are currently used in your digital application? Are you using 5G for these terminals?	Phones (67%) Laptop, cameras, and sensors (35%)
8	Which type of 5G network does your company intend to use in the future?	5G public network (32%) 5G private network based on public network (58%)

3. **Vertical industry requirements for 5G applications in the UAE**

Currently, vertical industries in the UAE believe that 5G networks, terminals, modules, and business models need to evolve. 5G networks in industries face a number of challenges,

including high construction costs, difficult O&M management, and high service costs. In terms of the business ecosystem, terminals, modules, and 5G solutions are less mature and few types are available in the market, restricting the development of 5GtoB applications. In terms of business models, no clear model has been formed. Enterprises expect operators to offer a monthly subscription charging model, with an option for unlimited data capacity that does not compromise on speed.

Table 3-5 Survey questions and results related to 5G application requirements of vertical industries in the UAE

No.	Questions	Results
1	What are the difficulties and problems in 5G network construction?	Highest: 5G network deployment is difficult and costly. 5G operation and maintenance are difficult and costly. Charges for 5G network services are high.
2	What are the difficulties and problems related to 5G terminals or modules?	Highest: lack of variety; low availability; high cost
3	What are the difficulties and gaps in the 5G business ecosystem?	Highest: 5G application solutions are not mature enough. The cost of 5G application solution is high.
4	What kind of business model would you expect the 5G application service to offer?	Flexible per usage, per time, per region and QoS based; Private 5G network with dedicated frequency spectrum; Business model that is tailored to sectors; Monthly subscription charging, with an option to have unlimited data capacity and no speed degradation based on usage; Connecting sites, so we can provide our local network and use IOT sensors for data analysis and a smart automotive system

4 UAE's Vertical Industries' Opportunities for 5G Application Development

This white paper analyzes the industry-specific digital foundation, digital transformation requirements, and market prospects in the UAE, and selects 10 vertical industries suitable for pioneering application of 5G in the UAE, namely energy, public service, construction, transportation, manufacturing, finance, retail, culture and tourism, education, and healthcare.

4.1 Industry-specific digital foundation

The digital foundation in an industry can be reflected by the digital maturity and IT technology investment in the industry. Figure 4-1 shows the digital maturity of vertical industries in the UAE. The mining, manufacturing, public service, and transportation industries show a high level of digitalization. Figure 4-2 shows the IT investment in various industries in the UAE. The government, finance, energy, and manufacturing industries have a large amount of IT investment, whereas the education, construction, and healthcare industries have a relatively low IT investment.

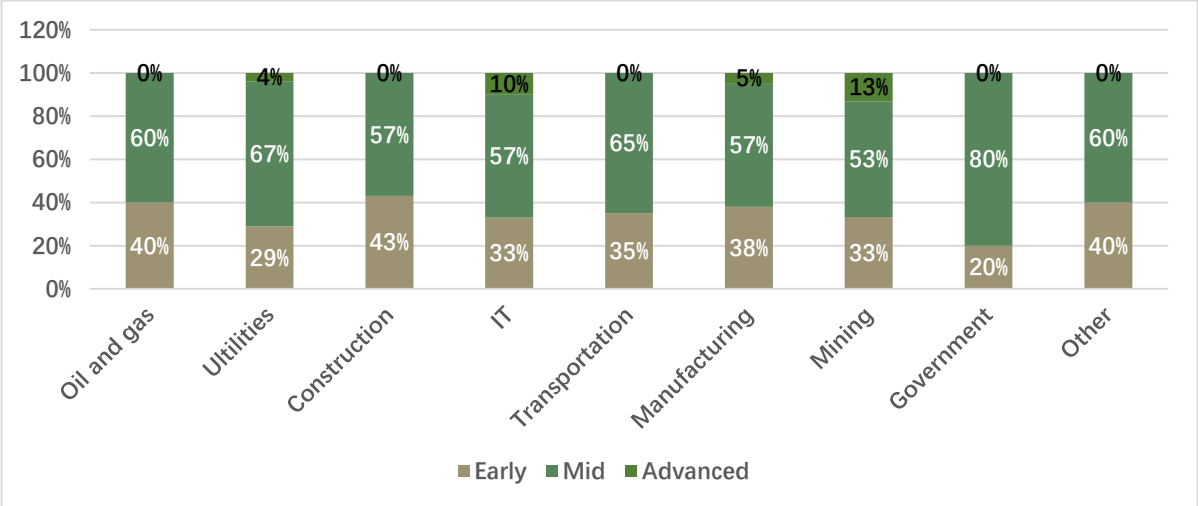

Figure 4-1 Digital maturity of vertical industries in the UAE (source: Preparing for the digital era--The state of digitalization in GCC businesses)

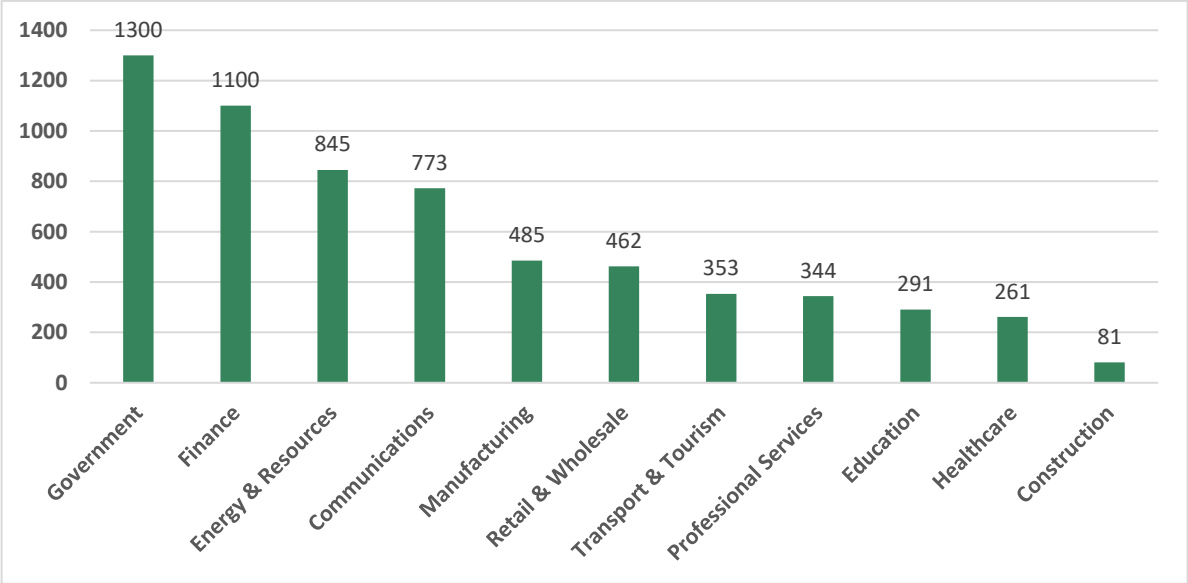

Figure 4-2 IT investment in various industries in the UAE (Unit: USD1 million) (source: IDC Industry Spending Guide)

4.2 Industry-specific digital transformation requirements

Industry-specific digital transformation requirements can be reflected in two dimensions: government's support for the industry and the impact of digitalization on the industry. According to the existing research data (see Figure 4-3), the government provides strong support for industries such as transportation, healthcare, public services, education, and ICT, and digitalization has a great impact on these industries. The retail, hotel and catering, and construction industries have low government support, and digitalization has little impact on these industries.

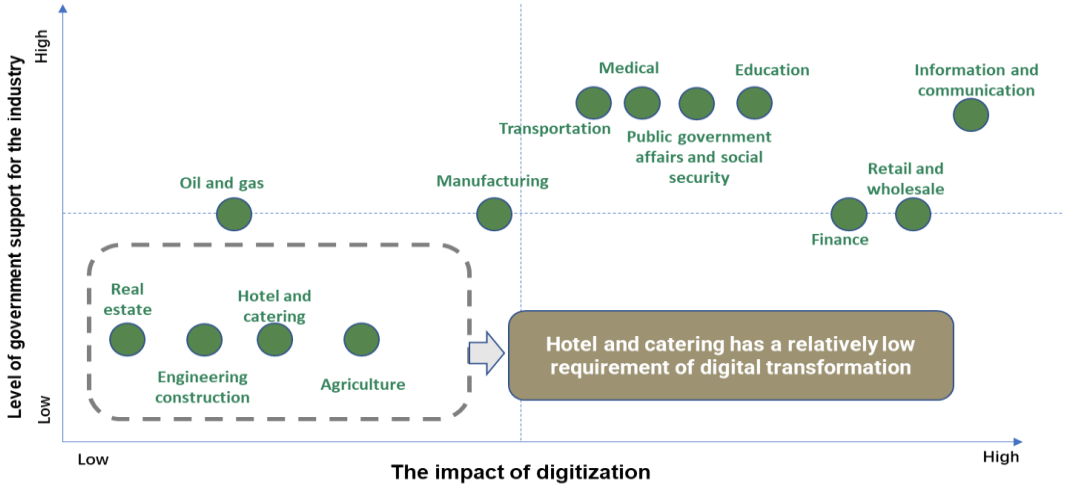

Figure 4-3 Digital transformation requirements of various industries (source: Insights into digital economy development models in major overseas countries)

4.3 Industry-specific market prospects

Industry-specific market prospects can be analyzed from the aspects of economic gains and service improvement brought by 5G applications. According to IHS Markit's estimation (as shown in Figure 4-4), 5G will significantly increase economic output in the manufacturing, retail, public service, and transportation industries by 2035. In addition, according to the CAICT, 5G significantly improves service quality and efficiency in the manufacturing and energy industries (as shown in Figure 4-5).

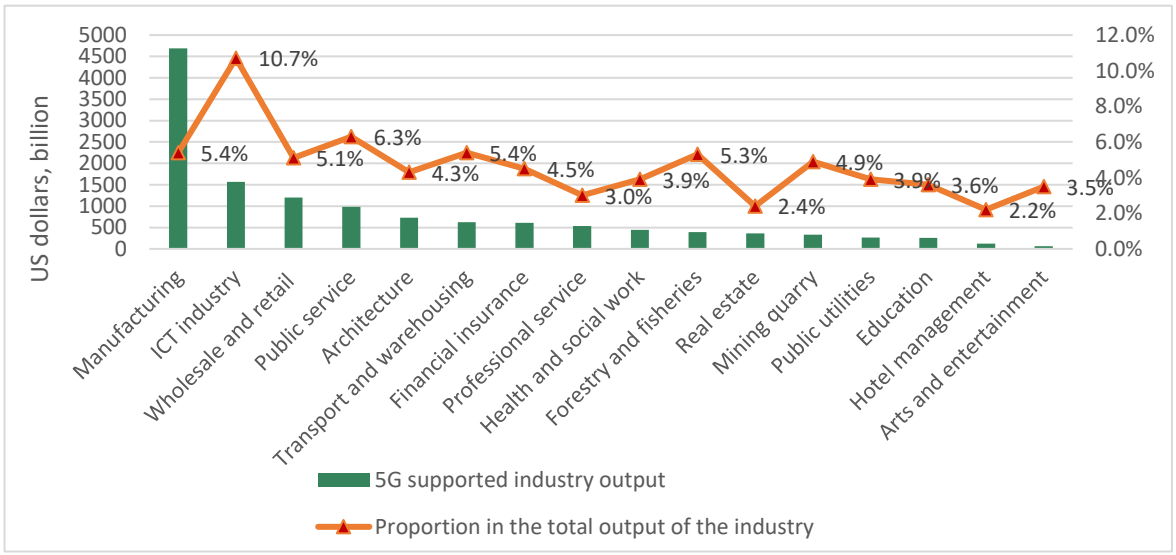

Figure 4-4 In 2035, 5G will drive the economic output of the world and major industries (Unit: USD1 billion) (source: HIS Markit)

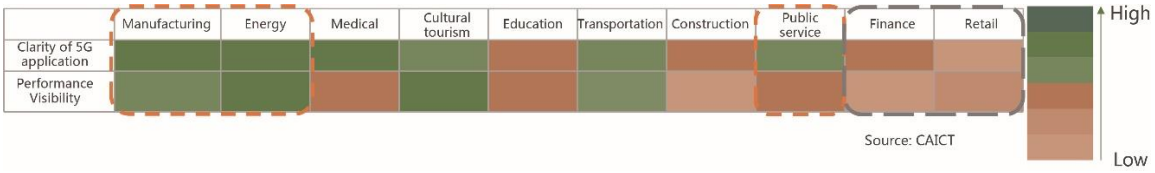

Figure 4-5 Performance improvement brought by 5G applications in various industries

In conclusion, among the aforesaid 10 industries, the energy, manufacturing, public service, and transportation industries in the UAE have a good digital foundation and have strong requirements for digital transformation. Moreover, they have a broad market prospect. Therefore, these four industries are suitable for pioneering application of 5G in the UAE and 5G industrial applications should be preferentially promoted in these industries.

5 5G Application Development in the UAE - Path and Methodology

Challenges and requirements of vertical industries lead to various 5G application scenarios. This white paper builds a promotion path model for 5G application scenarios, as shown in Figure 5-1. This model analyses 5G converged application scenarios from the perspectives of technical feasibility and implementation difficulty to obtain the development path of 5G application scenarios.

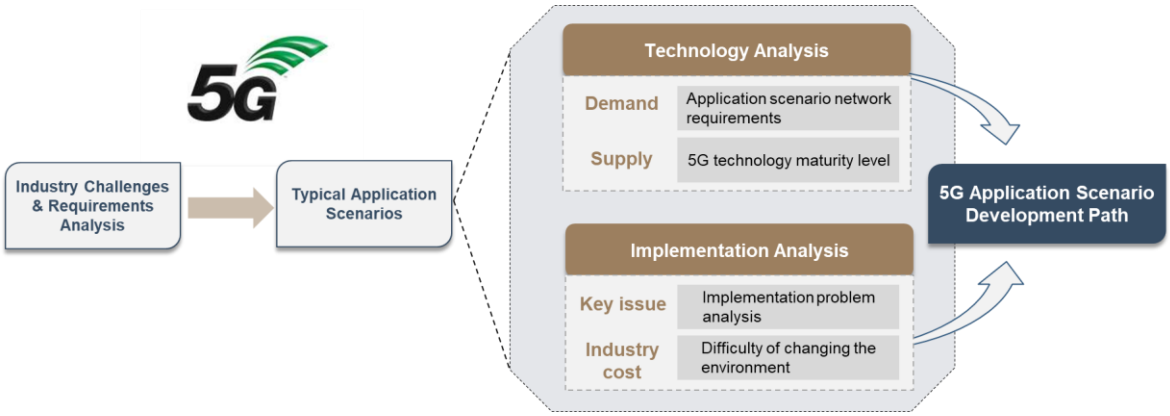

Figure 5-1 5G application development path

In terms of technical feasibility, the network requirements of application scenarios on the demand side and the 5G technology maturity of suppliers are analysed to obtain the satisfaction level of 5G technologies for application scenarios. In terms of implementation difficulty, the issues that 5G application deployments may face are analysed to obtain the difficulty of implementing 5G applications in existing industry environments. The following analysis is of the development path of 5G application scenarios in the pioneering industries in the UAE.

5.1 5G+Energy Industry

5.1.1 Industry Challenges and Requirements

The energy industry covers coal, oil, natural gas, electric power, and heat. The UAE has rich oil and gas resources, making the oil and gas industry a pillar industry in the energy field in the UAE. The oil and gas industry face the following challenges and requirements:

- The environment at an oilfield is harsh and the terrain is complex. As a result, it is difficult to deploy wired networks, the construction duration is long, and the costs are high.
- During many activities such as oil extraction, oil wells are prone to release a large amount of toxic and harmful gases. However, it is usually impossible to monitor work sites in real time and remotely handle incidents. This makes work sites potentially dangerous.
- Oil and gas pipelines are long and have many sealing points. Traditional manual inspection is a work-intensive task and potential equipment risks and emergencies cannot be detected and handled adequately in a timely manner.

5.1.2 Typical Application Scenarios

In the oil and gas industry, 5G can be used for various procedures in oil exploration, extraction, production, and transport, as shown in Table 5-1.

Table 5-1 5G applications in the oil and gas industry

Application	Oil Exploration	Oil Extraction	Oil Production	Oil Transport
5G+Oil and Gas Seismic Exploration	√			
5G+Equipment Operation Monitoring	√	√	√	√
5G+Safety Monitoring	√	√	√	√
5G+Inspection Robots			√	√
5G+Firefighting Robots			√	√
5G+Smart Logistics			√	√
5G+Remote Device Control		√	√	
5G+UAV Patrol		√		√

(1) 5G+Oil and Gas Seismic Exploration

Seismic exploration is an important technology for oil and gas exploration and extraction and involves the deployment of numerous seismographs to collect seismic wave data generated by manual drilling and blasting. By analyzing the data, personnel can determine the presence and location of underground oil and gas reserves. Traditionally, cables are used to connect seismographs. Cables are heavy, resulting in difficult deployment and heavy manual workloads. Moreover, it is difficult to adapt to various terrains. Seismic exploration requires the network to support the access of tens of thousands of terminals and the transfer of terabytes of data. The high bandwidth and massive connectivity of 5G networks are able to fully satisfy such requirements. The data collected by seismographs is transmitted to the data center and is then analysed using big data technologies. The analysed results are then returned to the onsite equipment center. With 5G, the efficiency of oil and gas seismic exploration and data analysis is significantly improved. It takes only 3 to 5 seconds to connect tens of thousands of seismographs and perform data upload, greatly reducing human labor requirements and improving work efficiency.

(2) 5G+Equipment Operation Monitoring

5G sensors and cameras are deployed to collect data from oilfield stations, wells, instruments, and other devices. The massive quantity of collected data is transmitted to the cloud in real time through the 5G network. AI and big data technologies are used to analyse the data, achieving unified data management and improving device O&M efficiency. This resolves the challenges of traditional wired monitoring solutions such as physical remoteness and difficult cabling, and allows for intelligent data collection, prediction, and analysis.

(3) 5G+Safety Monitoring

5G HD cameras are deployed at oilfields to collect videos from work sites. Workers' behaviors are analysed in the cloud using AI and big data technologies. Analysed results are then transmitted to the control center in real time. If risks are detected, remedial measures are automatically deployed, effectively guaranteeing the safety of personnel and providing a much safer work environment.

(4) 5G+Inspection Robots

Intelligent inspection robots are deployed in areas such as storage tank areas. SLAM+3D lidar navigation, visual recognition, and infrared detection technologies are used in conjunction with the robot's onboard detection systems and gas detection sensors to automatically collect gas concentration information. The collected data is transmitted to the cloud in real time through the 5G network for data analysis. When the gas concentration exceeds the threshold, the platform automatically triggers an alarm to alert production management personnel of the risk in a timely manner and improve inspection efficiency.

(5) 5G+Firefighting Robots

Firefighting robots come equipped with infrared cameras and fire extinguishing devices. They automatically perform regular inspections during which they collect information such as the ambient temperature, gas composition, and smoke concentration. Such information is transmitted and analysed in real time so that incidents such as oil and gas leakage and fire can be detected in a timely manner. This effectively reduces risks and losses caused by incidents. The firefighting robots can quickly locate leakage points and handle dangerous incidents such as fires in place containing human personnel, ensuring the safety of emergency services personnel and reducing the risk of injuries.

(6) 5G+Smart Logistics

5G-based unmanned forklifts/AGVs receive instructions from the cloud scheduling system platform. In conjunction with other technologies such as lidar and 3D digital twins, they can automatically identify shelves and transport goods in oil refineries, warehouses, and dangerous areas with flammable, explosive, or corrosive chemical risks. In this way, fewer personnel are needed for transportation, safety of personnel is guaranteed, and the logistics efficiency is improved.

(7) 5G+Remote Device Control

UHD cameras are deployed at production sites and video feeds of the sites are transmitted via 5G networks to remote control rooms. Personnel in the control rooms view the video feeds and remotely deliver instructions to control drilling platform devices. This effectively

reduces the number of onsite personnel and improves worker safety in production environments.

(8) 5G+UAV Patrol

UAVs equipped with UHD cameras are used to inspect pipelines and production sites. UAVs automatically perform inspection along preset flight routes that take meteorological conditions into account. UAVs can cover all inspection points on production sites and pipelines. Collected data is transmitted in real time via 5G networks. AI algorithms are used to detect improper operations and abnormalities such as leakage around pipeline corridors. The use of UAVs can eliminate inspection blind spots and reduce or replace manual inspections, which significantly improves inspection efficiency and allows for quick response in the event of emergencies, such as fires.

5.1.3 5G Application Scenario Analysis

In terms of technical feasibility, we analyse the network requirements of each application scenario. Applications such as inspection robots, smart logistics, and UAV patrol have high requirements on network bandwidth and reliability. Remote device control requires a latency of less than 20 ms and 99.999% reliability.

In terms of application implementation, we summarise typical issues faced by 5G application scenarios in the oil and gas industry. Smart logistics and remote device control require integration with existing service systems and change the original service logic, process, and architecture. The transformation costs are high. The following details the typical issues mentioned in Table 5-2.

① Replacement of network transmission channels: Services in the oil and gas industry are carried by wired networks, Wi-Fi, or other wireless communication technologies. These transmission channels can be replaced by 5G networks to quickly take over services and improve bearer capabilities.

② New services: With the improvement of 5G network capabilities, new application scenarios emerge in the oil and gas industry, which can assist core services in each

production phase. New services do not require changes to original services and can be quickly deployed.

③ Compatibility with traditional terminal protocols: 5G-assisted information collection, for example, production environment information collection, requires compatibility with traditional oil and gas terminals and equipment.

④ Integration with existing service systems: Some 5G applications, such as remote device control, need to be integrated with existing service systems. Therefore, existing services need to be transformed to adapt to the processes and methods of running services used on 5G networks.

⑤ Change of original service logic or processes: Services carried on 5G networks will change the logic or processes of original production services, requiring in-depth transformation of production lines and integration with 5G networks.

⑥ Change of original system architectures: Original system architectures, including local deployment, cloud-based, automated, and intelligent architectures, need to be changed.

Table 5-2 summarizes the challenges of 5G application scenarios in the oil and gas industry in terms of technical feasibility and implementation.

Table 5-2 Challenges of 5G application scenarios in the oil and gas industry

Typical Scenario	Technology Analysis			Implementation Analysis	
	Data Rate	Delay	Reliability	Issues for Implementation	Transformation Difficulty
Oil and Gas Seismic Exploration	UL: approx. 30 kbps (1000-5000/ KM²)	≤ 100 ms	99.9%	①③	Easy
Equipment Operation Monitoring	UL: approx. 100 kbps	≤ 50 ms	99%	①②	Medium
Safety Monitoring	UL: 1080P ≥ approx. 4 Mbps	≤ 100 ms	99%	①③	Easy
Inspection Robot	UL: approx. 80 Mbps (8K)	10-100 ms	99.99%	①②	Medium
Firefighting Robot	UL: approx. 8 Mbps	≤ 50 ms	99.9%	①②	Medium
Smart Logistics	UL: approx. 0.1-20 Mbps	≤ 100 ms	99.99%	①②③④⑤⑥	Hard
Device Remote Control	UL: approx. 10-14 Mbps per device (2K camera)	≤ 20 ms	99.999%	①②④⑤⑥	Hard
UAV Patrol	UL: approx. 20 Mbps (4K)	≤ 100 ms	99.9%	①②	Medium

5.1.4 5G Application Promotion Path

The convergence of 5G applications in the oil and gas industry is deepening with the evolution of 5G technologies and standards. According to the preceding analysis, the promotion of 5G applications in the oil and gas industry falls into three phases:

Phase 1: In the short term, 5G can be used to replace original wireless or wired networks to give full play to the high bandwidth and massive connectivity of 5G. The main application scenarios include oil and gas seismic exploration and real-time safety monitoring.

Phase 2: As new services emerge, new application scenarios can be gradually introduced. The high bandwidth feature of 5G can be used in conjunction with AI and big data technologies to empower new intelligent services and make oilfields smarter. The main application scenarios include inspection robots, UAV patrol, firefighting robots, and equipment operation monitoring.

Phase 3: As 5G standards mature, the high reliability of 5G can be used to deploy remote control services and services based on convergence of 5G with original service systems. In this phase, service upgrades are the main scenarios, including remote device control and smart logistics.

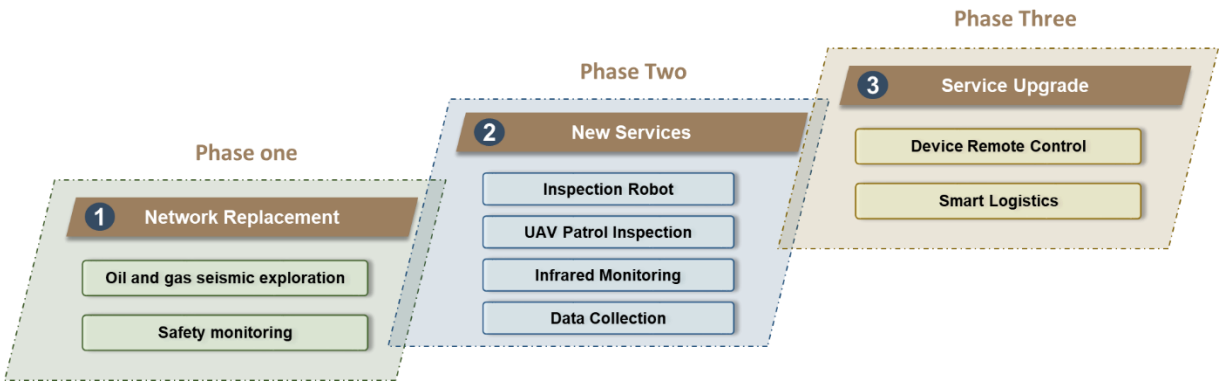

Figure 5-2 5G Application Scenario Development Path in Oil & Gas Industry

5.2 5G+Manufacturing

5.2.1 Industry Challenges and Requirements

The UAE is a leading Arab country home to diversified industries including steel, petrochemical, cement, aluminum, medicine, and building materials. The manufacturing industry in particular faces the following challenges:

- As a labor-intensive industry, it requires a large number of workers, resulting in high labor costs and recruitment challenges.
- The work environments might be dangerous, and certain manual operations come with safety risks.
- Experienced quality inspectors are needed to perform quality checks. Quality inspectors manually identify product defects, resulting in low efficiency and accuracy.
- Single-dimension information collection causes data silos in each phase, complicating production management.

5.2.2 Typical Application Scenarios

In the manufacturing industry, 5G can be used in R&D design, manufacturing, and operation management, as described in Table 5-3.

Table 5-3 5G applications in the manufacturing industry

Application	R&D Design	Manufacturing	Operation Management
5G+Collaborative R&D Design	√		
5G+Remote Equipment Control		√	
5G+Equipment Cooperative Operation		√	
5G+Machine Vision Quality Inspection		√	
5G+Factory Smart Logistics		√	
5G+Unmanned Smart Patrol		√	
5G+Flexible Manufacturing		√	
5G+Field Auxiliary Assembly		√	
5G+UHD Video Surveillance		√	√

(1) 5G+Collaborative R&D Design

5G AR/VR glasses are used to collect onsite experiment images and data in real time, which is then synchronously transmitted to researchers located in different places over the 5G network. In this way, remote collaboration is implemented, to accelerate information sharing for cross-region joint R&D, and boost communication efficiency.

(2) 5G+Remote Equipment Control

The 5G network sends onsite images to the scheduling room in real time, so that device operators can remotely and accurately control onsite industrial devices based on transmitted video images and data. This decreases the demand for onsite personnel and improves work safety.

(3) 5G+Equipment Cooperative Operation

Terminals such as cameras and sensors collect data covering device running tracks and process completion status in real time. With the help of the 5G network, statistics and planning methods are used to form an on-demand collaborative work system for multiple devices at the production site, implementing collaborative scheduling and cooperation of multiple devices, enhancing device utilisation, and reducing energy consumption during production.

(4) 5G+Machine Vision Quality Inspection

Quality inspection terminals such as industrial cameras or laser scanners are deployed at the production site. The terminals are connected to the 5G network through embedded 5G modules or 5G gateways to shoot HD images of products in real time, which are then transmitted to the edge and cloud platforms over the 5G network. AI algorithms are used for analysing the validity of materials or products, as well as enabling real-time defect detection and automatic alarm reporting. Machine vision quality inspection partially or completely replaces manual quality inspection, significantly improving the product quality inspection efficiency.

(5) 5G+Factory Smart Logistics

Devices such as built-in 5G modules or 5G gateways are deployed, to implement 5G network access for AGVs, automatic mobile robots (AMRs), forklifts, robot arms, and

unattended warehouse vision systems in the factory. The smart logistics scheduling system is deployed together with the 5G MEC+ultra-broadband (UWB) indoor high-precision positioning technology, achieving automated and smart full-process operations, including logistics terminal control, commodity receiving and storage, transportation, and sorting. This significantly improves the logistics and transportation efficiency, saving labor costs.

(6) 5G+Unmanned Smart Patrol

Robots and UAVs access the 5G network through built-in 5G modules or 5G gateways, to collect onsite videos and images, and automatically complete detection, patrol, data recording, and remote alarm confirmation. Related data is sent back to the smart patrol system in real time over the 5G network. The system uses algorithms such as image recognition and deep learning to analyze and determine the patrol result. In this application scenario, the patrol efficiency can be improved, enabling automatic and smart patrol.

(7) 5G+Flexible Manufacturing

Computer Numerical Control (CNC) machine tools access the 5G network through built-in 5G modules or 5G gateways, to implement wireless device connections, slashing network cable deployment costs, and shortening production line adjustment time. The 5G network works with the MEC system to empower flexible manufacturing applications, delivering real-time control, data integration and interoperability, and security and privacy protection for factories to achieve flexible manufacturing. A production line can be quickly reconstructed based on production requirements, and the same production line can be quickly configured and optimized according to the market requirements for different products.

(8) 5G+Field Auxiliary Assembly

Smart terminals, including AR/VR glasses, smartphones, and tablets, access the 5G network to collect data such as onsite images and videos. Data is transmitted to the onsite auxiliary assembly system in real time over the 5G network to generate auxiliary production information. Then, such information is delivered to onsite terminals over the

5G network to implement augmented reality (AR) overlay of operation procedures and visualization of assembly steps. This helps onsite personnel assemble complex or refined devices and enable a smart assembly process, improving the assembly efficiency.

(9) 5G+UHD Video Surveillance

UHD cameras are deployed in industrial parks, factories, and workshops to collect and transmit image data to the edge and cloud platforms over the 5G network using built-in 5G modules or 5G gateways. The data is analyzed based on AI algorithms, enabling high-precision identification, custom alarming, and area monitoring on production activities to remind users of abnormal status in real time. In this scenario, all-round smart security monitoring and management can be implemented at the production site, ensuring safe production management.

5.2.3 5G Application Scenario Analysis

In terms of technical feasibility, we analyse the network requirements of each application scenario. Applications such as remote equipment control, machine vision quality inspection, factory smart logistics, unmanned smart patrol, and onsite auxiliary assembly pose high demands on network bandwidth, latency, and reliability. Application scenarios such as equipment cooperative operation and flexible manufacturing have higher requirements on latency and reliability.

In terms of application implementation, we summarise the typical issues that 5G applications face in the manufacturing industry. Application scenarios such as equipment cooperative operation, flexible manufacturing, remote equipment control, and factory smart logistics involve integration with existing service systems, and changes to the original service logic, process, and architecture, resulting in high application transformation costs. The preceding section details the typical issues mentioned in Table 5-4.

Table 5-4 summarizes the challenges of 5G application scenarios in the manufacturing industry in terms of technical feasibility and implementation.

Table 5-4 Challenges of 5G application scenarios in the manufacturing industry

Typical Scenario		Technology Analysis			Implementation Analysis	
		Data Rate	Delay	Reliability	Issues for Implementation	Transformation Difficulty
Collaborative R&D Design		UL: approx. 10 Mbps (1080p) DL: approx. 10 Mbps (1080p)	≤ 100 ms	99.9%	①②	Medium
Remote Equipment Control		UL: approx. 10 Mbps (4K, single-channel) DL: approx. 10 Mbps (single-channel)	≤ 10 ms	99.99%	①②④⑤⑥	Medium
Equipment Cooperative Operation		≥ 100 Mbps	≤ 10 ms	99.999%	①②③④⑤⑥	Hard
Machine Vision Quality Inspection		UL: approx. 80 Mbps (8K)	< 10 ms	99.99%	①②④⑤	Medium
Factory Smart Logistics		UL: approx. 50 Mbps	≤ 20 ms	99.99%	①②④⑤⑥	Hard
Unmanned Smart Patrol	UAV Patrol	UL: approx. 80 Mbps DL: < 600 Kbps	< 10 ms	99.99%	①②	Easy
	Robot Patrol	UL: approx. 80 Mbps (8K)	10-100 ms	99.99%	①②	Easy
Flexible Manufacturing		Determined by services	Max. delay ≤ 1 ms	99.9999%	①②③④⑤⑥	Hard
Field Auxiliary Assembly		UL: > 5 Mbps	≤ 100ms	99.99%	①②④	Medium
UHD Video Surveillance		UL: approx. 80 Mbps (8K)	< 30 ms	99.9%	①②	Easy

5.2.4 5G Application Promotion Path

The convergence of 5G applications with the manufacturing industry is reinforced by evolving 5G technologies and standards. According to the preceding analysis, the promotion of 5G applications in the manufacturing industry falls into three phases:

Phase 1: Based on the capabilities and maturity of existing 5G standards, high-bandwidth services are mainly used in the short term. Service scenarios can be implemented by replacing networks and terminals. The main application scenarios in this phase include UHD video surveillance, which is the first application scenario, followed by unmanned smart patrol, and collaborative R&D design.

Phase 2: As standards are maturing, application scenarios are expanding to upgrade and reconstruct the original production line, integrate deeply with industrial systems, and even transform the original industrial production mode. In this phase, 5G is deeply integrated with technologies such as AI, big data, and cloud computing, allowing new or enhanced service forms to emerge. The main application scenarios include machine vision quality inspection, factory smart logistics, and remote equipment control.

Phase 3: This phase marks the in-depth integration of 5G and manufacturing. With the development of 5G technical standards and the deep convergence of 5GtoB applications, 5G is integrated with the production, control, and management system protocols of manufacturing. 5G technologies are widely used in various subsectors of manufacturing. Different types of 5G converged applications are used together to achieve smart production and bring industry transformation. These applications are mainly comprehensive applications, including flexible manufacturing and cooperative equipment operation.

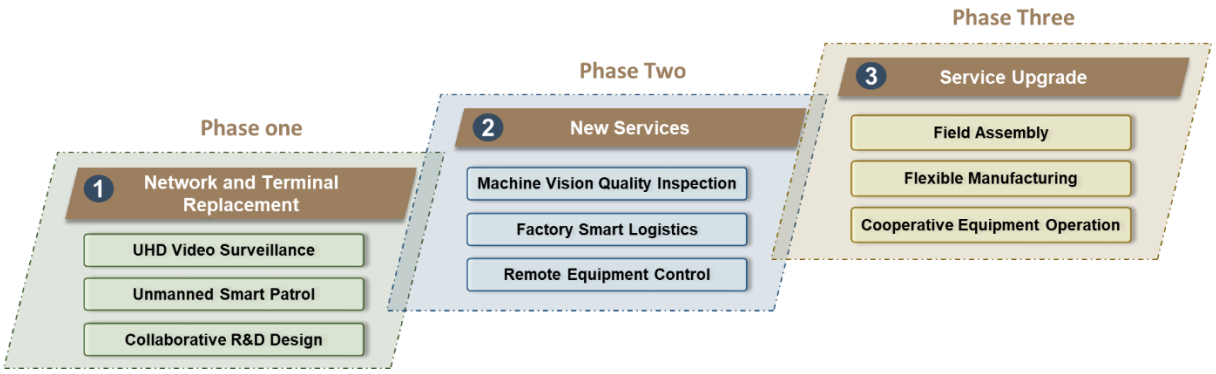

Figure 5-3 5G Application Scenario Development Path in Manufacturing

5.3 5G+Public Service

5.3.1 Industry Challenges and Requirements

Public services cover the national economy and people's livelihoods, including public security, environment protection and governance, and city services. Currently, the public service industry faces the following challenges:

- The government has a pressing need for urban security management, especially in personnel security, property security, and vehicle security. Comprehensive perception, monitoring, and emergency response linkage cannot be implemented.
- There is an increasing demand for environment monitoring, but monitoring and analysis methods for water and atmosphere are insufficient.
- City governance is challenging and calls for enhanced governance capabilities that utilise digital technologies.

5.3.2 Typical Application Scenarios

In the public service industry, 5G application scenarios include public security, smart environment protection, and city services, as described in Table 5-5.

Table 5-5 5G applications in the public service industry

Application	Public Security	Smart Environmental Protection	City Service
5G+UHD Real-time Surveillance	√		
5G+Robot Patrol	√		
5G+UAV Patrol	√		
5G+AR Glass Patrol	√		
5G+UAV Environment Monitoring		√	
5G+Sanitation Robot		√	
5G+Environment Monitoring		√	
5G+Smart Bus			√
5G+Facial Recognition and Temperature Measurement			√
5G+Digital Twins			√

(1) 5G+UHD Real-Time Surveillance

Multiple sensing devices, such as 5G UHD surveillance cameras and panoramic cameras, are deployed in cities. The collected data is transmitted to the data center in real time over the 5G network to implement multi-dimensional surveillance. AI and visual analysis technologies are used to implement smart identification and warning, improving security in cities.

(2) 5G+Robot Patrol

Robots are equipped with multiple HD cameras to record the environment in real time and the videos are then transmitted to the edge and cloud platforms over the 5G network, and algorithms are used to identify faces and behaviors, helping the police improve patrol efficiency and maintain public security.

(3) 5G+UAV Patrol

UAVs are equipped with UHD cameras and the collected images and data are sent back to the command center in real time over the 5G network. In this way, field situations can be provided to commanders quickly, improving work efficiency.

(4) 5G+AR Glass Patrol

Law enforcement personnel wear 5G AR glasses. The glasses collect facial image information and transmit it to the edge platform in real time over the 5G network. AI algorithms are used to compare the HD facial data recognized by the glasses with the blacklist to locate suspicious people in a timely manner, improving the effectiveness of law enforcement.

(5) 5G+UAV Environment Monitoring

UAVs feature 4K/8K UHD cameras and HD videos are sent back to the management platform over the 5G network to monitor air, soil, and water pollution in real time, implementing "zero blind spots" patrol, improving patrol efficiency, and ensuring campus security.

(6) 5G+Sanitation Robot

After connecting to the 5G network, floor scanning robots and sterilization robots can use the collected information of the surrounding environment to self-navigate around obstacles, and clean and disinfect public places. This reduces the workload of cleaners, cuts down the chance of cross infection, and improves cleaning and disinfection efficiency.

(7) 5G+Environment Monitoring

Various environment detection sensors are deployed at key locations such as drainage outlets, rivers, and forests. The collected data is transmitted to the data analysis platform in real time over the 5G network, implementing real-time monitoring of air, soil, and water pollution. This reduces the workload of environment monitoring personnel, while improving the efficiency of environment monitoring.

(8) 5G+Smart Bus

The bus body is equipped with HD cameras and radar sensors to collect data that is then transmitted to the device/cloud platform in real time over the 5G network. AI algorithms are used to generate warnings for lane deviation, forward collision, and blind spot

monitoring. Driving models are generated based on driving behavior and habits to analyse drivers' ability, speed, and safety, improving public safety on buses.

(9) 5G+Facial Recognition and Temperature Measurement

5G infrared cameras are deployed to collect personnel location and temperature measurement data in real time, which is then sent back to the command center over the 5G network. Based on information systems such as facial recognition, risks can be detected quickly and warnings can be generated. In this way, body temperature can be accurately screened.

(10) 5G+Digital Twins

Technologies such as 5G and AI are used to implement comprehensive city perception and smart interconnection. Based on technologies such as BIM modeling, GIS map, and 3D modeling, a virtual real-world space of a city is constructed, a digital city platform is built, and information resources are coordinated, enabling global management and collaboration for cities.

5.3.3 5G Application Scenario Analysis

In terms of technical feasibility, we analyse the network requirements of each application scenario. Certain applications, such as robot patrol, sanitation robots, smart buses, and digital twins, require high network bandwidth and reliability, whereas, others like UAV patrol, AR glass patrol, and UAV environmental monitoring, are more sensitive to latency and reliability.

In terms of application implementation, we summarise the typical challenges of 5G application scenarios in the public service industry. Particularly, digital twins integrate with the existing service system and change the logic, process, and architecture of existing services, thus requiring higher transformation costs. The preceding section details the typical issues mentioned in 0.

Table 5-6 summarizes the challenges of 5G application scenarios in the public service industry in terms of technical feasibility and implementation.

Table 5-6 Challenges of 5G application scenarios in the public service industry

Typical Scenario	Technology Analysis			Implementation Analysis	
	Data Rate	Delay	Reliability	Issues for Implementation	Transformation Difficulty
UHD Real-time Surveillance	UL: ≥ 4 Mbps (1080p)	≤ 100 ms	99%	①③	Easy
Robot Patrol	UL: approx. 20-100 Mbps	≤ 100 ms	99.99%	①②③	Medium
UAV Patrol	UL: approx. 80 Mbps (8K)	10-100 ms	99.9999%	①②③	Medium
AR Glass Patrol	UL: approx. 120 Mbps	≤ 10 ms	99.9999%	①②③	Medium
UAV Environment Monitoring	UL: approx. 80 Mbps (8K)	10-100 ms	99.9999%	①②③	Medium
Sanitation Robot	UL: approx. 20-100 Mbps	≤ 100 ms	99.99%	①②③	Medium
Environment Monitoring	UL: approx. 2-5 Mbps	≤ 200 ms	99.9%	①②③	Medium
Smart Bus	UL: approx. 20-100 Mbps	50 ms	99.99%	①②③	Medium
Facial Recognition and Temperature Measurement	UL: approx. 5-20 Mbps	50-100 ms	99.9%	①②③	Medium
Digital Twins	UL: ≥ 100 Mbps	≤ 50 ms	99.99%	①②③④⑤⑥	Hard

5.3.4 5G Application Promotion Path

According to the preceding analysis, the promotion of 5G applications in the public service industry falls into three phases:

Phase 1: Replace existing wireless systems or wired networks with 5G networks in the short term, to make full use of the 5G large bandwidth and wide connectivity features. The main application scenarios include UHD real-time surveillance, environmental monitoring, facial recognition, and temperature measurement.

Phase 2: Gradually introduce new application scenarios while developing new intelligent services by leveraging 5G high bandwidth network features and technologies such as AI and big data. The main application scenarios include robot patrol, sanitation robot, and smart bus.

Phase 3: Use mature standards and 5G high reliability features to provide remote control services and multi-system convergence services. This phase focuses on service upgrade, covering UAV patrol, AR glass patrol, UAV environmental monitoring, and digital twins.

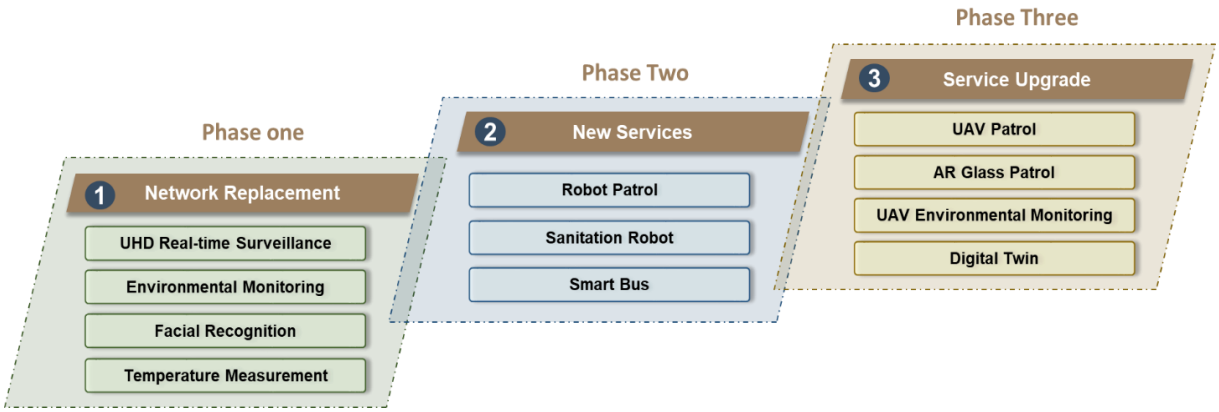

Figure 5-4 5G Application Scenario Development Path in Public Service

5.4 5G+Transportation Industry

5.4.1 Industry Challenges and Requirements

The transportation industry is a basic, leading, and strategic industry of the UAE's economy. Likewise, its road, aviation, and maritime transportation industries have developed well. The UAE government has formulated a series of national strategies to build a cleaner, more efficient, and more sustainable modern transportation system, of which this white paper focuses on port and campus logistics. Currently, the transportation industry faces the following challenges:

- With the expansion of global international trade, ports are facing rising labor costs, harsh working environments, poor operation efficiency, and high logistics costs.
- The campus is home to all kinds of work, various types of highly-specialized devices. For campus logistics, personnel should not only have extensive experience but also need to be engaged in physical labor, and thus are difficult to recruit.

5.4.2 Typical Application Scenarios

In the transportation industry, 5G applications include smart logistics and smart ports, as described in Table 5-7.

Table 5-7 5G applications in the transportation industry

Application	Smart Logistics	Smart Port
5G+AGV	√	
5G+Smart Stocktaking	√	
5G+AI Security Protection	√	√
5G+Unmanned Smart Patrol	√	√
5G+Remote Control		√
5G+Autonomous Driving		√

(1) 5G+AGV

The indoor distributed system of the 5G network is deployed to address signal interruption during cross-area and cross-floor operations of conventional AGVs. AGVs uniformly receive instructions from the cloud scheduling system platform in real time and automatically complete batch distribution and real-time material resource distribution throughout the material turnover process, achieving scheduled, location-based, and quantitative distribution of materials. This application scenario helps lower the cost of transportation personnel, and improve the efficiency of goods transportation.

(2) 5G+Smart Stocktaking

Industrial cameras are installed on devices, such as stackers and robotic arms, to collect images of goods, which are then sent back in real time over the 5G network. The AI algorithm is deployed on the MEC to implement smart stocktaking in the warehouse, reduce the number of stock takers, and improve the accuracy and efficiency of stocktaking, significantly cutting the stocktaking cost.

(3) 5G+ AI Security Protection

Devices such as UAVs and UHD cameras are used to collect and send HD images back to the management platform in real time over the 5G network. Moreover, technologies such as AI are used to identify images, implement various detection and device monitoring services, and generate warnings quickly in the event of exceptions such as dangerous operations and goods falling, for a safer working environment.

(4) 5G+Unmanned Smart Patrol

Built-in 5G modules or 5G gateways are deployed to implement 5G network access of mobile and smart security protection devices such as patrol robots or UAVs. This enables patrol attendance and collection of onsite videos, voices, and image data, for automatic detection, patrol, data recording, and remote alarm confirmation. Related data is sent back to the smart patrol system in real time over the 5G network. The smart patrol system uses smart technologies and algorithms such as image recognition and deep learning to obtain patrol results, boosting the security level, patrol efficiency, and security protection.

(5) 5G+Remote Control

HD cameras are deployed on harbor equipment such as container cranes and yard cranes, and image data is sent back to the central control room over the 5G network. With the help of multi-view HD videos, operators in the central control room can be fully aware of the onsite operation environment and perform remote scheduling through the control handle, implementing unmanned remote scheduling in the port area. It is estimated that each operator can control three to six gantry cranes, greatly reducing labor costs and improving operation security and reliability.

(6) 5G+Autonomous Driving

Container trucks are interconnected over 5G networks, and technologies such as edge computing, high-precision positioning, and autonomous driving are used to implement automatic hybrid orchestration of unmanned trucks. This greatly enhances the overall truck operation capability, improves port transportation efficiency, and reduces the number of truck drivers, improving onsite transfer efficiency.

5.4.3 5G Application Scenario Analysis

In terms of technical feasibility, we analyse the network requirements of each application scenario. Applications such as AGV, smart stocktaking, and robot patrol have high requirements on performance such as latency and reliability. Application scenarios such as UAV patrol, remote control, and autonomous driving have even higher requirements on latency and reliability.

In terms of application implementation, we summarise typical issues that 5G applications face in the transportation industry. Applications such as remote control, AGV, and autonomous driving integrate with existing service systems, and change the original service logic, process, and architecture, resulting in high application transformation costs. The preceding section details the typical issues mentioned in 0.

Table 5-8 summarises the challenges of 5G application scenarios in the transportation industry in terms of technical feasibility and implementation.

Table 5-8 Challenges of 5G application scenarios in the transportation industry

Typical Scenario		Technology Analysis			Implementation Analysis	
		Data Rate	Delay	Reliability	Issues for Implementation	Transformation Difficulty
AGV		UL: approx. 50 Mbps	≤ 20 ms	99.99%	①②	Easy
Smart Stocktaking		UL: approx. 80 Mbps	10-100 ms	99.99%	①②	Easy
AI Security Protection		UL: approx. 80 Mbps (8K)	< 30 ms	99.9%	①②	Easy
Unmanned Smart Patrol	UAV Patrol	UL: approx. 80 Mbps DL: < 600 Kbps	< 10 ms	99.99%	①②	Easy
	Robot Patrol	UL: approx. 80 Mbps (8K)	10-100 ms	99.99%	①②	Easy
Remote Control		UL: .10-14 Mbps per device (2K camera)	≤ 20 ms	99.999%	①②④⑤⑥	Hard
Autonomous Driving		UL: approx. 120 Mbps	≤10 ms	99.9999%	①②③④⑤⑥	Hard

5.4.4 5G Application Promotion Path

The convergence of 5G applications with the manufacturing industry is reinforced by evolving 5G technologies and standards. According to the preceding analysis, the promotion of 5G applications in the transportation industry falls into three phases:

Phase 1: Based on the capabilities and maturity of existing 5G standards, high-bandwidth services are mainly used in the short term. Service scenarios can be implemented by replacing networks and terminals, to fully harness the high bandwidth and massive connections of 5G. The main application scenarios include 5G convergence with AI smart security protection, robot patrol, and smart stocktaking.

Phase 2: As standards are maturing, application scenarios have expanded to upgrade and reconstruct the original production line and integrate heavily with the original service system.

In this phase, 5G is deeply integrated with technologies such as AI, big data, and cloud computing, allowing new or enhanced service forms to emerge. The main application scenarios include AGVs and UAV patrol.

Phase 3: As standards are maturing, the high reliability feature of 5G can be used to allow for remote control services and services based on convergence of multiple systems. In this phase, application scenarios focus on upgrading services, including autonomous driving and remote control.

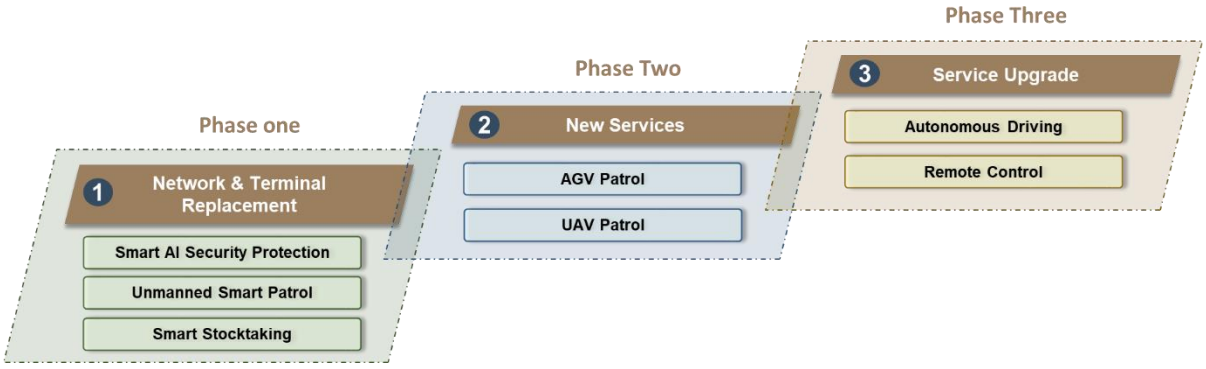

Figure 5-5 5G Application Scenario Development Path in Transportation

6 Suggestions

Based on the research into 5G rollout in major countries/regions, this paper proposes short-, mid-, and long-term suggestions for 5G development in the UAE regarding policies, networks, applications, and industries. The UAE began its 5G network rollout in 2018 and demonstrated live 5G at ITU Plenipotentiary Conference held at Dubai in October 2018. In May 2019, UAE became one of the leading countries to commercially launch 5G in all UAE. With three years of rapid development, its 5G networks mainly provide 5GtoC services (eMBB and FWA) with a world-leading experience rate. In the next phase, the UAE should utilise such advantages to continuously enhance network capabilities, promote the rapid development of 5GtoB applications, and achieve collaborative development of 5GtoC and 5GtoB applications.

6.1 Short-term Actions (2022-2023)

The immediate goal is the implementation of 5G applications in key vertical industries.

6.1.1 Policies

It is recommended that the government implements the “UAE strategy for 5G and Beyond” for 5G converged applications, providing top-level guidance and support to 5G projects. The 5G advisory committee should be expanded to include strong/capable leaders and industry experts to provide guidance and decision-making support for strategic and future-oriented issues for 5G applications in different verticals.

The government should lead all parties in the industry to establish a 5G application alliance and build a 5G application industry platform. This helps promote the development of 5G use cases and the industry ecosystem, and provide opportunities for both suppliers and industries.

The UAE Strategy for 5G and Beyond consists of pillars, initiatives and activities. In the short term, the TDRA should focus on network deployment and coverage as envisaged in pillar 1. The TDRA should also continue to support technical collaboration and testbeds; encourage innovation and research for 5G testbeds and trials as given in pillar 2 of 5G strategy. Collaborate

with industry to drive demand through raising awareness of benefits of 5G to verticals (Pillar 3).

White papers and case sets should be regularly released to attract more vertical industries to adopt 5G solutions. The 5G application alliance should conduct research into vertical industry requirements, 5G application promotion paths, and 5G application scenarios. Further, an international cooperation mechanism should be developed so that members of the 5G application alliance can share the industry ecosystem and give full play to each other's advantages.

National competitions should be held for 5G applications, to select best-in-class projects that are replicable and promotable, and offer them as case studies to promote large-scale 5GtoB applications.

Favorable industry policies and project funds are critical to facilitating 5G converged applications. A 5G Executive Committee should be set up to plan for 5G project funds and the government should set up dedicated industry cooperation funds, to support 5G network construction, application rollout, and industry innovation.

6.1.2 Networks

Operators must enhance the public coverage of 5G networks in key environments such as hospitals, schools, cultural and tourism spots, and industrial campuses.

Further researches are needed for key technologies and standards of 5G networks. Universities and research institutes are motivated to carry out joint research and standard formulation in partnership with vertical industries regarding key technologies such as 5G campus network architecture, network construction mode, and deployment solution, and organize tests, verification, and pilot projects for improving 5G capabilities.

Operators should fully utilise existing 5G networks in the UAE, and leverage 5G campus networks for 5GtoB applications. The UAE should deploy its 5G networks and strengthen its digital infrastructure supply capability in an objective and scientific manner by drawing upon the experiences of pilot countries. The government is advised to release the official 5G network construction indicators, quality standards, and 5G user penetration rate to drive

operators to improve the scale and quality of 5G network construction nationwide. By 2023, the proportion of 5G users will increase to 25%, and ten 5G base stations will be available per 10,000 people, further improving the wireless access capability. 5G experience rate at the cell edge rate can reach up to 100 Mbps in the downlink and 5 Mbps in the uplink.

A new technology innovation test mechanism is needed to conduct tests for new technology innovations such as IPv6 and high-precision indoor positioning. It is recommended for the government to join global industry organizations, establish local and global alliances, and improve the talent training mechanism.

The government should set up a fund appraisal and check mechanism for 5G projects, to implement reasonable use of exclusive funds and resolve problems in fund use and appropriation.

6.1.3 Applications

Operators, equipment vendors, and industry enterprises are encouraged to carry out pilot schemes to revolutionise typical scenarios in favorable sectors such as manufacturing, energy, transportation, and public services. The following 5G applications are initially incubated, such as mobile inspection, UHD live broadcast, and auxiliary assembly, which are mainly used for assisting production. Up to 100 5G campus networks must be available in this phase.

Development enterprises and research institutes must focus on the upstream and downstream ecosystems, invest in technologies such as network slicing, edge computing, and AI, and contribute to the 5G-integrated ICT technologies. In addition, ICT enterprises and industry customers should be encouraged to build joint 5G-based labs to carry out trial, verification, and R&D for 5G networks and applications.

6.2 Mid-term Actions (2024-2025)

In the mid-term, there is a demand for large-scale replication and promotion of 5G converged applications in key industries.

6.2.1 Policies

5G converged applications are technology-intensive and involve multiple industries. Through systematic policies, 5G converged applications can be deployed at the national, industry, and local levels and across multiple industries. The government should allocate portion of ICT funds with mechanisms for 5G projects, to enhance 5G use cases. The “UAE Strategy for 5G and Beyond” in mid- term should enhance the work on the three pillars by setting Quality of Experience KPIs. TDRA should also continue to support technical collaboration and testbeds; encourage innovation and research for 5G testbeds and trials as given in pillar 2 of 5G strategy. Collaborate with industry to drive demand through raising awareness of benefits of 5G to verticals (Pillar 3).

6.2.2 Networks

Operators should be supported to build 5G campus networks for key scenarios in vertical industries. Up to 500 5G campus networks must be available in this phase. Operators should work with equipment vendors and enterprises in key industries, such as manufacturing, energy, and transportation, to jointly study 5G campus network construction standards, improve network capabilities such as 5G uplink bandwidth and reliability, and provide network assurance for 5G industrial converged applications.

A network indicator appraisal mechanism is needed to track and evaluate released 5G network construction indicators and 5G network quality standards, and continuously promote 5G network quality improvement. The UAE should deepen/increase its 5G network construction. By 2025, the proportion of 5G users will increase to 50%, and 20 5G base stations will be available per 10,000 people, further improving the 5G experience rate at the cell edge rate to 100 Mbps in the downlink and 5 Mbps in the uplink.

Further, breakthroughs in technical features such as IPv6 should be added to new 5G networks to enhance service capabilities, while the government must ensure spectrum resource planning and release the 5G spectrum usage plan in time. Sufficient mid-band spectrums (such as 6 GHz, 3.8-4.1 GHz, and 2300 MHz) must be reserved for the 5G network as it must meet the requirements of 5GtoC, 5GtoH, and 5GtoB applications.

6.2.3 Applications

Strengthened cooperation between ICT enterprises and vertical industries will facilitate joint research and standard formulation for 5G converged applications, such as determining 5G's adaptability to fit service requirements of various industries.

Then, 5G applications are first promoted in pilot sectors such as energy, manufacturing, public service, and transportation. This helps explore 5G converged applications, industry requirements, and scenario-specific promotion paths based on experience of pilot projects, to promote the rollout of 5G applications in more industries.

A cross-industry 5G R&D platform must be built to encourage development enterprises and research institutes to develop and technically verify lightweight, low-cost and simplified modules and terminals as well as 5G solutions, laying a solid foundation for 5G applications.

6.3 Long-term Actions (2026 and Later)

Healthy, sustainable ecosystems are essential to the large-scale replication and promotion of 5G applications in most industries.

6.3.1 Policies

The government should strengthen the training of 5G application-related experts in the UAE. TDRA should review the “UAE strategy for 5G and Beyond” for the next phase of IMT-2030 (6G) expected in 2030 and collaborate with the industry for spectrum and research.

6.3.2 Networks

Research into 5GtoB network requirements helps better allocate spectrums, such as 6 GHz, to operators.

The UAE is advised to continuously enhance its network capabilities and seizes the opportunity for global leadership in 5G-Advanced deployment. By 2027, the proportion of 5G users will increase to 80%, and 30 5G base stations will be available per 10,000 people, further improving the 5G experience rate at the cell edge rate to 1000 Mbps in the downlink and 50–100 Mbps in the uplink.

Further, the large-scale application of key technologies, such as 5G LAN and IPv6, should be promoted in key scenarios.

6.3.3 Applications

The government should establish a national 5G application monitoring system and platform as well as a 5G application test indicator system to monitor and control the 5G applications development nationwide.

All parties in the value chain are supported by favorable policies, including 5G industrial consumers, operators, equipment vendors, development enterprises, and research institutes. This helps cultivate a batch of excellent suppliers providing 5GtoB terminals and application solutions. A database is needed to incorporate such solutions and suppliers for facilitating interconnection between suppliers and demanders.

Further, terminal R&D based on innovative technologies, such as IPv6-based network slicing, segment routing, BIER multicast, and autonomous driving networks, should be prioritised to build a unified and streamlined 5GtoB network.

Lastly, 5G-Advanced technologies are put into trial use for 5GtoB applications, such as high-precision indoor positioning and Passive IoT (PIoT), to explore new 5GtoB application scenarios brought by evolving 5G technologies, thus forming a virtuous cycle of application-driven technology evolution. Up to 2000 5G campus networks will be available in this phase.

Authors

Telecommunications and Digital Government Regulatory Authority	Mohamed Al Saadi, Hasan Sharif
China Academy of Information and Communications Technology	Du Jiadong, Zhou Jie, Hou Weibin, Wang Qi, Xu Yiyi, Du Bin
Khalifa University	Prof. Ernesto Damiani
Emirates ICT Innovation Center(EBTIC)	Dr. Nawaf Al Moosa, Prof. Rasool Asal

Acronyms and Abbreviations

Acronym and Abbreviation	Full Name
3GPP	3rd Generation Partnership Project
5G	the 5th generation of the International Mobile Telecommunications
5GtoB	5G to Business
5GtoC	5G to Customer
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AR	Augmented Reality
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur
CAICT	China Academy of Information and Communications Technology
CNC	Computer Numerical Control
DCMS	Digital, Culture, Media and Sport
E2E	End to End
eMBB	Enhanced Mobile Broadband
FCC	Federal Communications Commission
FWA	Fixed Wireless Access
ICT	Information Communications and Telecommunications
IMT	International Mobile Telecommunications
IoE	Internet of Everything
IoT	Internet of Things
IoV	Internet of Vehicles
ITU	International Telecommunication Union
KRW	Korean Won
M2M	Machine to Machine
MEC	Multi-acess Edge Computing
MIIT	Ministry of Industry and Information Technology
MIMO	Multiple-Input Multiple-Output
mMTC	Massive Machine-Type Communications
MSIT	Ministry of Science and ICT
O&M	Operation and Maintenance
PIoT	Passive Internet of Things
R&D	Research and Development
SD-WAN	Software Defined Wide Area Network
TDRA	Telecommunications and Digital Government Regulatory Authority
UAV	Unmanned Aerial Vehicle
UHD	Ultra High Definition
UPF	User Plane Function

uRLLC	Ultra-Reliable and Low-Latency Communications
USD	United States Dollar
VR	Virtual Reality
WLAN	Wireless Local Area Network

@TDRAUAE, www.tdra.gov.ae