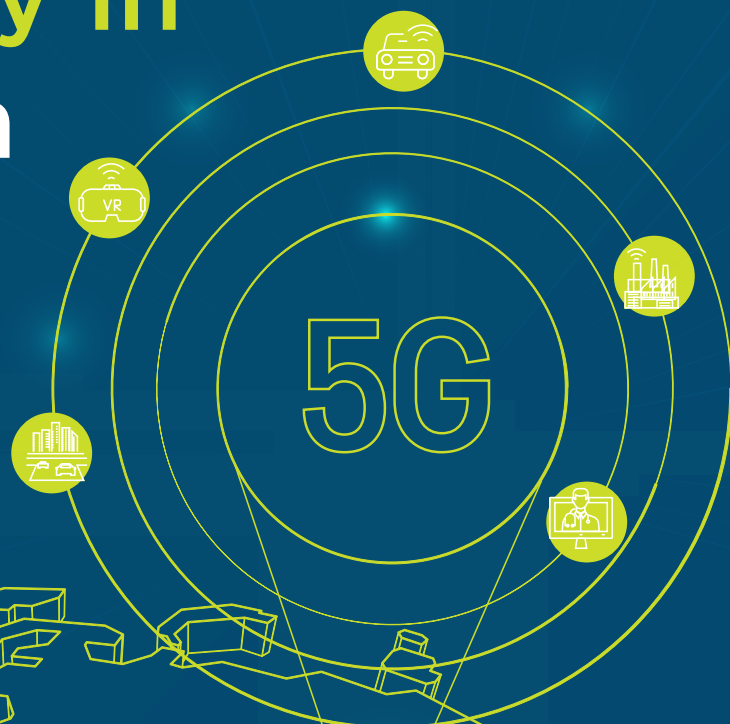


5G

The Driver for the Next-Generation Digital Society in Latin America and the Caribbean



Authors:

Antonio García Zaballos
Enrique Iglesias Rodríguez
Kyoung Woo Kim
Soontae Park



The Government of
the Republic of Korea



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Executive Summary

Introduction

5G is a revolutionary mobile communication technology that will usher in the 4th Industrial Revolution and will drastically change the society and economy of the future. With many countries already moving toward securing 5G infrastructure that will determine their national competitiveness, countries in the Latin American and Caribbean (LAC) region should make plans to actively deploy and utilize 5G infrastructure for the future economic growth and the improvement of quality of life it will bring to us.

This study explores the challenges that LAC countries may face when deploying and utilizing 5G mobile networks and proposes specific solutions to these challenges and a step-by-step roadmap. In addition, it describes the technical characteristics of 5G and its expected social and economic effects. It also presents cases from South Korea, which commercialized the world's first 5G service, as a reference that LAC countries can use as a benchmark.

Overview of 5G

At the beginning of 2010's, when 4G LTE was being built, the International Telecommunication Union (ITU) began researching 5G mobile communication technology to prepare for the expected data explosion after 2020 and to meet various service requirements for future mobile communications. After several years of research, three service

scenarios and technical requirements of 5G were developed: eMBB (enhanced mobile broadband), which provides data rates up to 20Gbps—much faster than traditional mobile technologies; uRLLC (ultra-reliable low latency communication), which minimized the latency to 1ms; and mMTC (massive machine type communication), which supports up to 1 million connections per 1 GHz, 10 times more than LTE.

To meet the diverse service scenarios and high technical requirements, 5G introduced new network implementation technologies, such as beamforming, MIMO, network slicing, and mobile edge computing. To provide high-speed service, millimeter-wave spectrum, where large amount of contiguous spectrum is available worldwide, was introduced. Along with millimeter-wave spectrum, sub-6 GHz was introduced as a standard band to overcome the main shortcoming of millimeter-wave frequency: difficulty in securing coverage.

The emergence of 5G is expected to create enhanced 5G-convergence services and to more deeply integrate existing industries with mobile telecommunication. This will result in momentous social changes in various aspects. Through the adoption of 5G technology, existing ICT innovation services, such as self-driving cars, smart factories, drones, and healthcare, are expected to experience tremendous changes in service paradigms, leading large new markets. The integration of 5G with basic industries will bring about increased sophistication in various fields, such as manufacturing, agricultural and livestock industries, finance,

distribution, and energy. KISDI, Korea's prestigious ICT state-run think tank, predicts that the annual growth in major related industries of 5G will be 43.3 percent and that 1,161 trillion won in global markets in 26 years will be created. IHS Markit, a global market research firm, estimates that 5G will account for 4.6 percent of the world's total production in the future.

The World's First 5G Commercialization in South Korea

With the experience of having become an ICT powerhouse by leading the development of the next-generation network, South Korea actively pushed ahead with 5G deployment, realizing that 5G will be at the core of global competitiveness in the future. In April 2019, South Korea was the first country to commercialize mobile 5G service, which was more than a year ahead of its original plan. As of December 2019, the 5G network in South Korea expanded to the 85 municipalities where 93 percent of Korea's population live. This is the world's heaviest penetration of 5G networks.

For the world's first commercialization, the Korean government presented national blueprints for 5G implementation. The national plans presented diverse measures for implementing 5G, including R&D and standardization, spectrum allocation, global cooperation, tax reduction, and joint use of 5G essential facilities. It also presented a detailed roadmap, including schedules and budgets. In parallel with the government's establishment of 5G national master plans, private sector actors played an important role in the development of 5G core technologies and linking technologies to patents and standards.

As the first step of 5G deployment, the Ministry of Science and ICT (MSIT) conducted an auction of 5G spectrum for 280MHz in sub-6GHz band (3420–3700MHz) and 2400MHz in millimeter-wave (26.0–28.4GHz) in the first half of 2018. Prior to the auction, the Korean government secured spectra for 5G in the sub-6GHz band by withdrawing and relocating 22 wireless stations which had been used for mobile TV station at the time. Considering the competitive environment of the 5G market and its impact on the activation of the network deployment, MSIT finalized the details of the spectrum auction, including the spectrum cap, the reserve price, the auction method, and network deployment obligations (Table A). The auction ended two days after its launch, providing 100 MHz, 100 MHz and 80 MHz respectively in sub-6 GHz band for the three mobile network operators in the country, and 800 MHz in millimeter-wave band for each of the operators. The total winning bid was set at US\$3.29 billion for sub-6GHz band (3420–3700MHz) and millimeter-wave (26.0–28.4GHz) together.

Following the 5G spectrum auction, the Korean government took the following measures to facilitate the 5G network deployments: deducting corporate tax when investing in 5G base stations, facilitating the joint use of essential facilities such as pipelines and electric poles, inducing operators to set reasonable 5G service rates, and establishing a new certification system for 5G equipment and terminal devices.

In addition to presenting the measures for the activation of 5G deployment, MSIT established the '5G + plan' to maximize the use of 5G. The goal of the plan is to foster 5G-related industries and fully integrate 5G across the economy and society. In the plan, 10 5G core industries such as next-generation

TABLE A Spectrum Auction

Band	Bandwidth	Reserve price	Usage period	Auction method	Network deployment obligation
3.5 GHz	3420–3700MHz (280MHz bandwidth)	US\$2.20 billion	10 years	Clock	15% of total number of base stations in nationwide network in 3 years
28GHz	26.5–28.9GHz (2400MHz bandwidth)	US\$0.52 billion	5 years	Clock	30% of total number of base stations in nationwide network in 5 years

Source: Author's elaborations.

smartphones and VR/AR devices, and five 5G core services such as smart factories and autonomous vehicles were selected. On top of that, five strategic areas—public sector leading investment, private investment expansion, institutional improvement, industrial foundation creation, and support for overseas expansion—were presented to activate 5G strategic industries, vitalize the related market, and improve quality of life through 5G.

Future Challenges and Policy Implications

Although 5G was initially intended to be commercialized around 2020, it is becoming available worldwide one or two years earlier than predicted. Many countries around the world are in a hurry to adopt 5G to quickly secure the significant economic and social benefits that 5G will bring. Given the enormous opportunities that 5G networks will create, LAC countries also need to actively adopt 5G. However, to successfully deploy 5G networks in LAC countries, it is important to resolve the challenges that they will face, including the high implementation costs, securing spectrum, the need to

develop institutions, and issues around activation of the 5G use.

The high cost of deployment is the biggest obstacle to 5G deployment in LAC countries. 5G deployment is costly because of the high increase in the number of base station installations, introduction of high-frequency band and expand backhaul and fixed-line networks due to huge increase in network traffic. As a solution to the high cost of 5G deployment, an infrastructure sharing method that shares a network with other operators should be considered. Construction costs can be greatly reduced by sharing electronic components such as base stations and cables, as well as passive elements such as pipelines, streetlights, and poles. Public investment funding, which is being promoted by many governments such as the United Kingdom and China, can facilitate private investments on 5G infrastructure. One way to raise funds is to utilize 5G spectrum auction revenue. In addition, the government may encourage private operators to build 5G networks through tax cuts, as in the case in which the Korean government cut up to 3% corporate tax when they invest 5G base stations.

Securing and allocating/assigning broad 5G spectrum is also not an easy task. Not all the frequency bands can be utilized for 5G. 5G bands must be selected among international standard bands to facilitate roaming of mobile communication between countries and to secure economies of scale of related products such as chips, terminals, and equipment, which cannot be expected in non-standard bands. Therefore, if there is insufficient 5G standard spectrum available in a specific country, it is essential to withdraw and relocate spectrum for securing available 5G spectrum. After securing spectrum by withdrawal and relocation, it is necessary to prepare an allocating/assigning scheme suitable for 5G spectrum with the different characteristics than 3G and 4G bands. A spectrum auction plan including band supplied, total spectrum cap, auction method, network deployment obligation, and others should be elaborated, taking various factors into account, such as competitive

TABLE B Challenges and Solutions

Challenge	Possible Solutions
High implementation costs	<ul style="list-style-type: none"> • Public-private partnership • Infrastructure sharing • Public investment • Tax cuts
Securing and allocation of 5G spectrum	<ul style="list-style-type: none"> • Withdrawal and relocation of spectrum • Standardize country's available spectrum
Institutional issues	<ul style="list-style-type: none"> • Re-establish telecommunication regulation policies • Regulate use of certified equipment
Expansion of 5G specialized services and application	<ul style="list-style-type: none"> • Develop public projects by government • Government direct investment • Induce private sector investment • Provide fair competition environment
5G National Master Plan	<ul style="list-style-type: none"> • IDB technical cooperation projects • Establish whole-government control tower

Source: Author's elaborations.

demand for 5G frequency, the effect of auction results on the activation of network deployment, and the effect of the spectrum variation among operators on market competitiveness. It is also necessary to solve the institutional problems caused by the many differences between 5G networks and the existing networks below 4G. Human health problems caused by high power density due to the introduction of 5G small cells have been found, and a great number of 5G equipment installations can come into conflict with the current regulations for the preservation of the environment and the history in each country. While network slicing, one of the new features of 5G, can provide diverse applications with different requirements, it can enable mobile network operators (MNO) to discriminate against specific customers, leading to violations of network neutrality. These negative impacts should be dealt appropriately by collecting stakeholders' opinions, holding public consultations and reflecting research results.

Also, preventing 5G networks from hacking or breakdowns is of paramount importance. If 5G-connected devices such as self-driving cars and smart cities malfunction or break down, this could cause information theft or financial damage, threaten people's lives and safety, and cause catastrophes in society as a whole. Therefore, a security certification system for 5G equipment and continuous monitoring and response to network security should be adopted to maintain security and stability of 5G networks.

Active utilization of 5G networks is as an important point as 5G network deployment. To activate the utilization of 5G networks and enhance social and economic benefits, preemptive public 5G demand creation projects should be carried out and the private sector should be induced to invest in 5G utilization projects. Governments can implement 5G-based real-time monitoring of SoCs and hazardous facilities such as nuclear power plants. They can also supply 5G solutions in the fields of education, medicals, agriculture, the environment, and others to improve quality of life. Efforts should be made to boost private investment on 5G

utilization by creating testbeds, supporting demonstration projects, and fostering start-ups. In addition, 5G accessibility of the disadvantaged, such as people living in rural areas, the poor, the elderly, and the disabled should also be improved. In rural areas where voluntary network deployment by private operators is not likely to happen due to its low profitability, it could be a good way for the government to directly invest in network construction, or to induce or enforce the network deployment by private operators. Introducing policies such as approving rates and operating universal service fund can be considered for enhancing affordability of 5G services.

To build a 5G network and maximize its utilization, countries need to establish comprehensive 5G plans tailored to their needs. Even in developing countries with limited economic capacity, a 5G master plan should be prepared urgently, considering the social and economic importance of 5G in the future. LAC countries that lack experience and expertise in 5G deployment can receive external support to develop their own 5G master plans. The IDB is supporting technical cooperation (TC) projects to conduct feasibility studies using the Korea Trust Fund (KTF). Through the fund, LAC countries can benchmark best practices and experiences of countries and companies which have already started to deploy 5G networks.

Roadmap to 5G

In order for 5G networks to be successfully established and utilized in LAC countries, governments must first take a number of actions, including regulatory improvement, establishing institutions, and providing financial support related to investment in the 5G network.

The government's activities related to 5G implementation can be divided into three phases. The first phase is preparation of 5G master plans for deploying and utilizing a 5G network. The deployment plan consists of specific plans for spectrum supply, institutional improvement, stimulation of private investment, financial support, co-development

plans, etcetera. It should be based on analysis of related status such as demand for the 5G network, potential network builders, institutional and financial difficulties, spectrum status, and stakeholder position. In addition, a utilization plan should be drawn up to maximize the utilization of 5G networks, such as developing new 5G application services, integrating with other sectors, and enlisting the cooperation of the public sector.

The second phase is the deployment phase, when the plans established in the first phase are implemented. In this phase, spectrum auctions and various support activities to stimulate investment in 5G are carried out. Additionally, by continuously monitoring the network construction situation, various issues like the need for institutional improvements

and the failures of MNOs to meet network deployment obligations should be resolved.

The third phase is the utilization phase, when full-scale network utilization goes into effect after the 5G network is established. In this phase, the government promotes the expansion of 5G public services, implements new 5G services, and integrates 5G into existing industries. The government should also try to strengthen the relevant institutions to enhance 5G accessibility and affordability and induce private investment to facilitate 5G utilization. Especially, cybersecurity in response to hacking and viruses should be strengthened, and the stability of 5G network operation should be maintained by preparing proper countermeasures against unexpected disasters and accidents.

Introduction

5G is emerging as key infrastructure in the era of the 4th Industrial Revolution, when digital technology converges across industries and drastically transforms the economy and society as a whole. 5G combines the characteristics of its fast speed, low latency, and mass connectivity to provide a variety of new 5G-specific services. It also merges with other sectors to maximize the efficiency of industry, which was far less expected from previous generations of mobile communication technology. The World Economic Forum (WEF, 2018) has predicted the huge impact this new generation would bring by stating, “5G will impact every industry—autos, health care, manufacturing and distribution, and energy services, among others. We believe that 5G will change the world even more profoundly than 3G and 4G; that it will be as revolutionary as electrification or the automobile, benefiting entire economies and entire societies.” The Organisation for Economic Co-operation and Development (OECD, 2019: 5), touting 5G’s vast potential, asserted, “The next generation of wireless networks holds the potential to stimulate innovation and meet the increasing demands of the digital economy.” Viewing 5G as a measure of national competitiveness and future social development, countries around the world are making efforts to develop 5G networks to grow the 5G ecosystem into a huge market, and devising ways to utilize 5G services to improve the quality of life. Countries that are leading the way on 5G, such as South Korea, the United States, and some countries in the European Union, have already begun to provide 5G services, and many other countries are

also planning to build 5G networks in the near future. However, deploying and utilizing 5G networks brings challenges, such as high cost, lack of spectrum, and institutional obstacles. It would be more difficult for developing countries in Latin America and the Caribbean (LAC) to overcome those challenges, considering their economic condition and lack of experience and know-how in this field.

Against this backdrop, this report seeks to propose solutions to various challenges that developing countries—especially LAC countries—would face when deploying 5G network. Chapter 1 defines 5G and its technical and service characteristics and the economic and social benefits that it can bring. Chapter 2 presents the South Korean government’s approach to 5G deployment as a best practice. It describes the efforts of South Korean governments and the private sector to lead the world 5G market, including the establishment of a national master plan, technology development and standardization, pilot projects, and others. The auction of 5G spectrum and several institutional improvements to induce 5G investment will be also explained. In Chapter 3 delves into the challenges inherent in deploying 5G, in the areas of cost, know-how, institutional development, activation of 5G usage, and the establishment of a 5G national master plan. It also offers recommendations to overcome these challenges. Finally, Chapter 4 suggests three phases (preparation, deployment, and utilization) and ways to utilize the Inter-American Development Bank (IDB) and private sector experiences in deploying 5G.

5G Overview

The changes ushered in by 5G mobile communication technology are expected to be quite different from past evolutions of mobile technology. While technological evolution up to 4G focused on enhancing transmission speed to improve the quality of mobile phone service, 5G will not only provide faster speed, but will also connect with numerous types of devices such as sensors, robots, and autonomous vehicles in a wireless environment, and will enable them to transmit useful information to each other in real time. The new technical characteristics of 5G are expected to create new 5G-based industries while promoting innovation in existing industries by moving beyond simple telecommunication infrastructures of the past. Thus, 5G technology is not merely an extension of existing development. It is integrated infrastructure that will revolutionize societies. It is more than the currently emerging disruptive technologies, such as artificial intelligence (AI), Internet of things (IoT), and data analytics; it is the foundation that will allow these technologies to grow and maximize their potential.¹

Which 5G technological characteristics will enable 5G networks to act as a future converged infrastructure, and what benefits will 5G bring to our lives and economies? This chapter takes a closer look at the technical characteristics and services of 5G that will lead to the revolutionary development of future society, including innumerable social changes and economic benefits.

5G Technology and Services

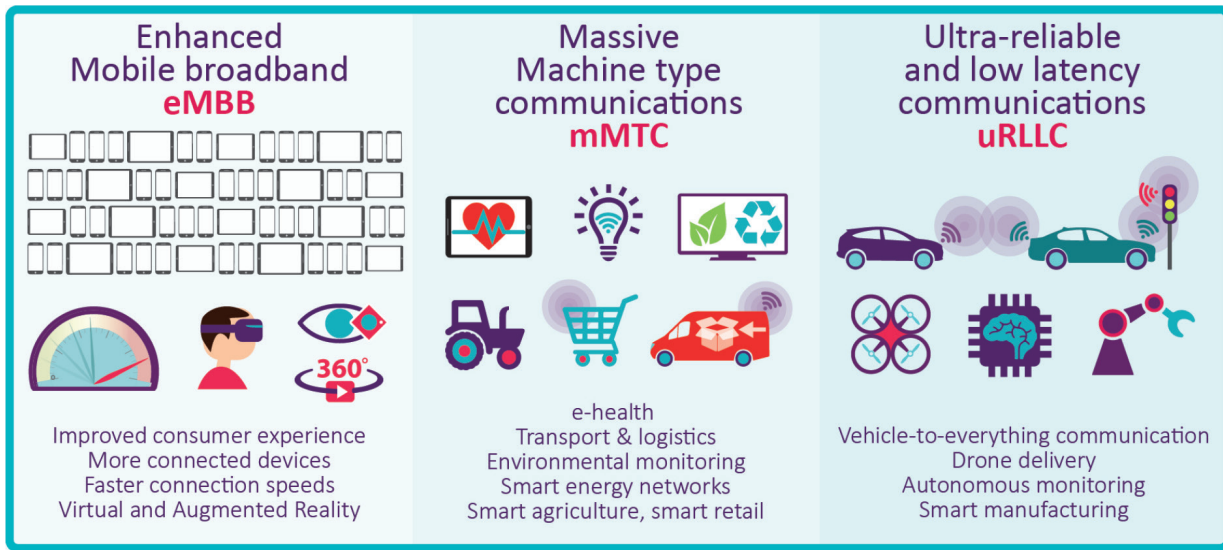
Definition and Performance of 5G

In the early 2010s, with the implementation of 4G LTE networks across the globe, the prediction that 4G and lower technologies would not be able to handle the expected data explosion in the 2020s accelerated the preparation for next-generation technology. After intensive research and discussion in academia, industry, and related organizations, in September 2015, the International Telecommunication Union (ITU)² suggested particular service scenarios and technical performance requirements of 5G—officially named as IMT-2020. The three scenarios, discussed in greater detail below, are eMBB, uRLLC, and mMTC. With this in mind, 5G should be able to deliver data much faster (eMBB) than the previous 4G; it should ensure uninterrupted, reliable service (uRLLC); and it should simultaneously accommodate more sensors and devices (mMTC).

¹ According to IHS Markit (2017), 5G network is considered a general purpose technology (GPT), such as the printing press, the Internet, and electricity. GPTs are catalysts for transformative changes that redefine work and processes and rewrite the rules of competitive economic advantage, established through pervasive adoption across multiple industries.

² The ITU is an international organization under the United Nations that defines and selects international standards for mobile communication technologies.

FIGURE 1.1 Expected Uses of 5G

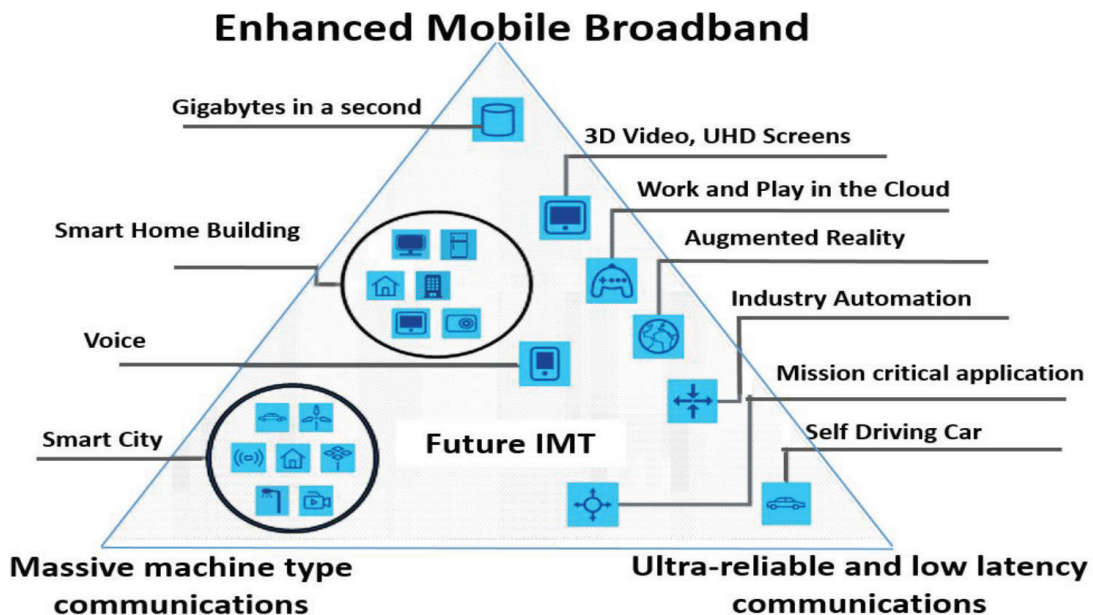


Source: Ofcom (2017).

1. Ultra-wide mobile broadband (eMBB)
By using greater frequency bandwidth and more antennas, eMBB aims to increase up to 20Gbps transfer rate from 100Mbps in 4G. Faster trans-

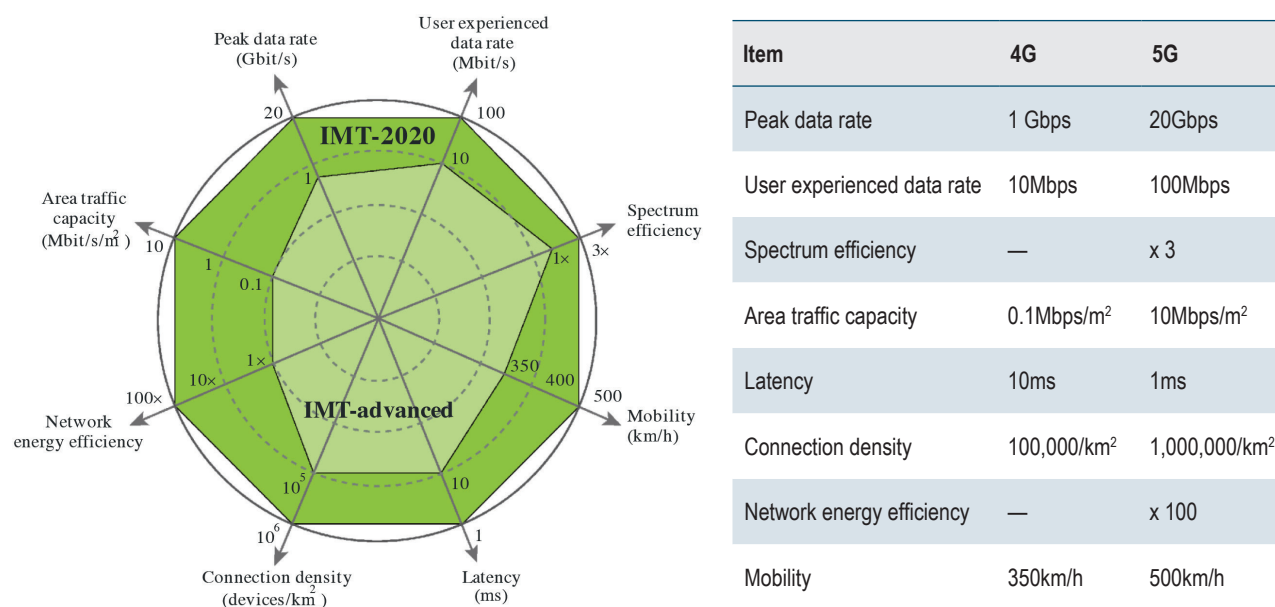
mission of high-capacity and high-definition data can provide realistic and immersive services, such as UHD-based AR/VR and hologram services.

FIGURE 1.2 Usage Scenario of IMT for 2020 and Beyond



Source: ITU (2017).

FIGURE 1.3 Enhancement of Key Capabilities from IMT-Advanced on IMT2020



Source: ITU (2017).

2. High confidence/low latency communications (URLLC)

The objective is to minimize the existing tens of milliseconds latency time in 4G LTE to the level of 1 ms³ by optimizing radio resource management or network design. Low-latency, real-time transmission enables remote control of robots, self-driving vehicles that share surrounding traffic situations through telecommunication, and real-time interactive games that require real-time response speed.

3. Massive Machine-Type Communications (mMTC)

With the goal of supporting 1 million connections per km², this will provide 10 times⁴ better connectivity compared to 4G LTE. By doing so, it provides a technical foundation for preparing for future hyper-connected environments such as Smart City and Smart Factory, where many sensors, facilities, and IoT devices for industrial and home use are densely connected and inter-operated.

In addition, ITU presented the technical performance requirements that 5G should have. As shown in Figure 1.3 and Table 1.1, 5G networks will have 20 times faster speed, 10 times lower latency,

and 10 times more devices connected per unit area compared to 4G networks.

Specific 5G Technologies

Detailed technical specifications for the three scenarios and technical requirements of 5G presented by ITU were created by 3GPP,⁵ an international organization for standardization which convenes major mobile telecommunication experts, mobile network operators (MNOs), manufacturers, and organizations

³ For example, downloading a 15GB high-definition movie will take 240 seconds via 4G at the speed of 500Mbps. With 5G, however, at 20Gbps, the same movie will only take 6 seconds to download (Samsung, 2018).

⁴ For example, on 4G, a connected autonomous vehicle traveling at 100km/hr will receive an emergency brake order with a delay time of 50 milliseconds(ms). This means that the vehicle will stop after traveling 1.4m. With 5G, however, the delay time will only be 1ms, and the vehicle will stop after traveling 0.028m (Samsung, 2018).

⁵ In the previous 3G and 4G standards, the ITU recognized and implemented multiple standards as 3G and 4G standards. However, it is likely that the 3GPP standard will be the only standard in 5G.

TABLE 1.1 Major Changes Due to the Evolution of Telecommunication Environment

	3G	4G	5G predictions
Devices	Rise of smartphones	Universalization of Smartphones and tablets	Variety of devices
Major changes	Beginning of Internet access Start of data services	Increase of data transmission speed Universalization of video call	Massive connectivity and increase of speed, low latency
Global services	Smartphone platform rival • Android, iOS Beginning of SNS using low data text PC webhard disk (not mobile yet)	Streaming platform rival • Netflix, YouTube Change of SNS paradigm (photos and videos) Mobile cloud service (mobile webhard disk)	Core service platform • autonomous driving, VR contents High quality video based SNS Universalization of cloud (storage, calculation)
Major national services	Messenger services based on 3G	Variety of messengers services	Same as above

Source: NIA (2019).

to discuss and design technical specification for mobile telecommunication. When 3GPP submits the results to ITU, ITU will approve them as international standards. In other words, ITU first defines the concept and performance of 5G, and 3GPP develops and specifies detailed technologies to meet the requirements defined by ITU. ITU then examines the proposed specification and approves it once it meets the performance standards. The following is a description of major detailed technologies introduced by 3GPP that are designed to provide 5G's high-speed (eMBB), URLLC, and ultra-connectivity (mMTC) services.

- Beamforming: A technology that allows the beam of an antenna to concentrate radio transmission in a specific direction or, conversely, ad-

just radio transmission energy to contribute to securing coverage and enhancing reliability of millimeter-wave bandwidth frequencies.

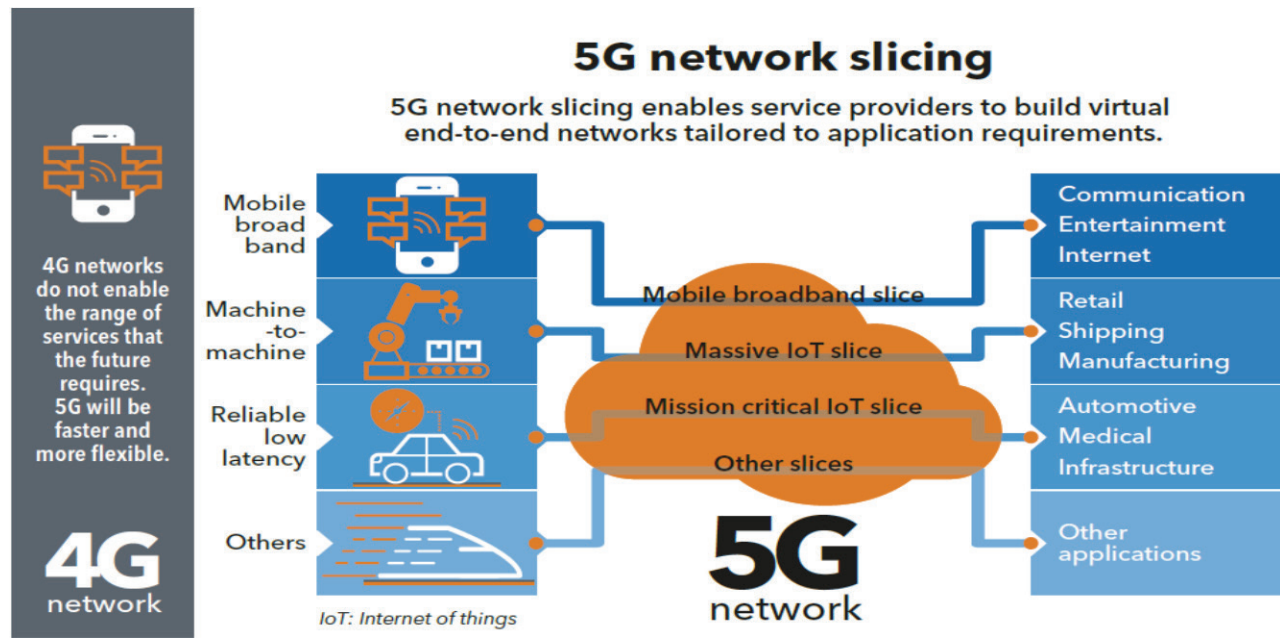
- MIMO: A method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation. Although MIMO technology was also used in 4G, the beam was not sharp enough so that there were limitations in user classifications (e.g., 4X4). In 5G, however, more than a few dozen antennas can be used to support more multiple users (e.g., 64X64).
- Network Slicing: A technology that creates multiple logical networks with different speeds, capacities, and coverage, with a single 5G physical network, providing dedicated networks

FIGURE 1.4 Beamforming and Massive MIMO



Source: Samsung (2018).

FIGURE 1.5 5G Network Slicing



Source: ITU News (2017).

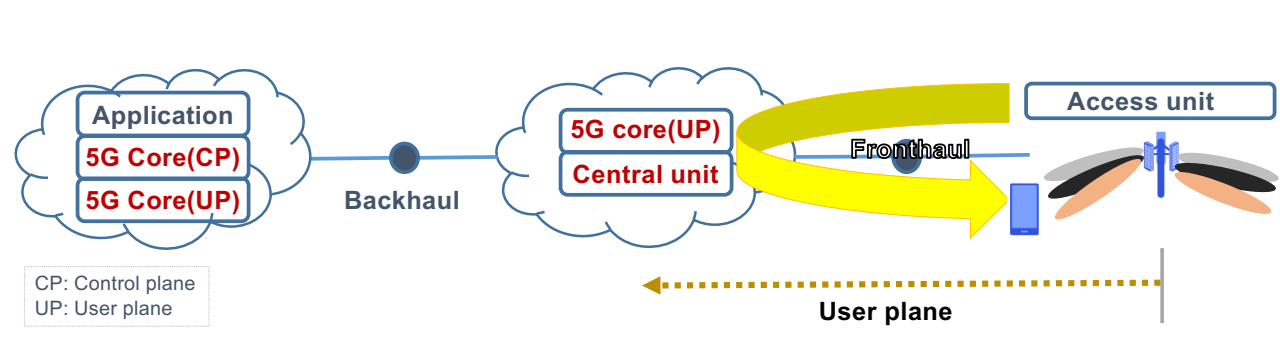
specialized for various services with different characteristics. In 4G, it was not possible to differentiate between individual services because all data services shared one resource. But in 5G, each data service can also be allocated independent network resources to ensure the quality of each service without being affected by other services. This independent allocation of network resources can ensure the quality of mission-critical services such as autonomous vehicles, which require ultra-low latency characteristics.

- **Mobile Edge Computing:** While data must be processed through a core network located at a remote location in the 4G network, the 5G network makes low-latency service implementation possible by distributing the core functions so that data can be processed at a closer distance to the user.

5G Spectrum

Because of interference, frequency band cannot in principle be used for multiple purposes at the same

FIGURE 1.6 Mobile Edge Computing



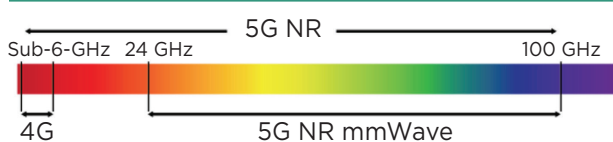
Source: Author's elaboration.

place at the same time. It also applies to the spectrum for 5G. A specific band cannot be used for 5G if it is already being used for other purposes, even though the band is intended to be used for 5G.

What frequency band is suitable for 5G? First, 5G band requires wide contiguous spectrum to provide a high-speed transfer rate. Additionally, it should be internationally harmonized to achieve economies of scale. 3GPP, which practically determines 5G standards, standardizes frequency bands for 5G in two major bands, namely sub-6GHz bands Frequency Range 1 (FR1) and millimeter-wave bands (FR2), based on the location of the bands. So, why are 5G frequencies divided into two bands?⁶

In general, the transmission speed of a wireless network is proportional to the bandwidth it uses. To accomplish 20Gbps high-speed, the aim of the 5G network, GHz-width class broadband is required. However, it was impossible to secure spectrum for 5G in 2GHz or lower bands, which are being of use in networks up to 4G, since the spectrum is being used for other purposes in most countries. Therefore, millimeter-wave spectrum in the 24GHz band or higher⁷ was chosen for 5G since broad contiguous millimeter-wave spectrum was securable in most countries. However, despite the fact that millimeter-wave band had the advantage of acquiring broad contiguous bandwidth, the coverage of one base station was much smaller than the base station coverage of the low-frequency band due to its characteristics of heavy attenuation and difficulty in penetrating obstacles, resulting in very high deployment costs for millimeter-wave bands. For this reason, millimeter-wave band is suitable for securing transmission capacity in hotspot areas where users are concentrated, such as urban centers, stadiums, stations, and airports, but it is not appropriate for nation-wide 5G networks.

FIGURE 1.7 5G NR



Source: Microwaves & RF (2018).

To acquire broad coverage at reasonable cost, 3GPP adopted sub-6GHz bands as 5G standard bands in addition to millimeter-wave bands. This is because sub-6GHz can provide broader coverage than millimeter-wave, as it is less attenuated and penetrates obstacles easier. Although it was difficult to secure GHz-class broad contiguous spectrum in sub-6GHz band like millimeter-wave, many countries had some broad contiguous spectrum available—more than 100MHz contiguous spectrum—in sub-6GHz. In short, sub-6GHz band is necessary for high-speed data transmission and capacity acquisition to achieve an appropriate level of speed and wide-area coverage at the same time.

Countries and MNOs currently deploying or planning to deploy 5G network are choosing between sub-6GHz bands and millimeter-wave bands, considering the country's spectrum availability and business models. Countries that have difficulty in securing sub-6GHz could start to implement 5G network with millimeter-wave in the first place, while countries forecasting low demand in millimeter-wave could focus on sub-6GHz preferentially. Asian countries such as China, Japan, and South Korea, which seek faster speed and broader coverage simultaneously, are allocating both bands to 5G. Eventually, most countries are expected to establish 5G networks in both bands to secure coverage along with the provision of super-fast and large-capacity services.

Societal Change and Economic Contributions

Societal Change

The emergence of 5G is expected to create new convergence services and innovative changes in various

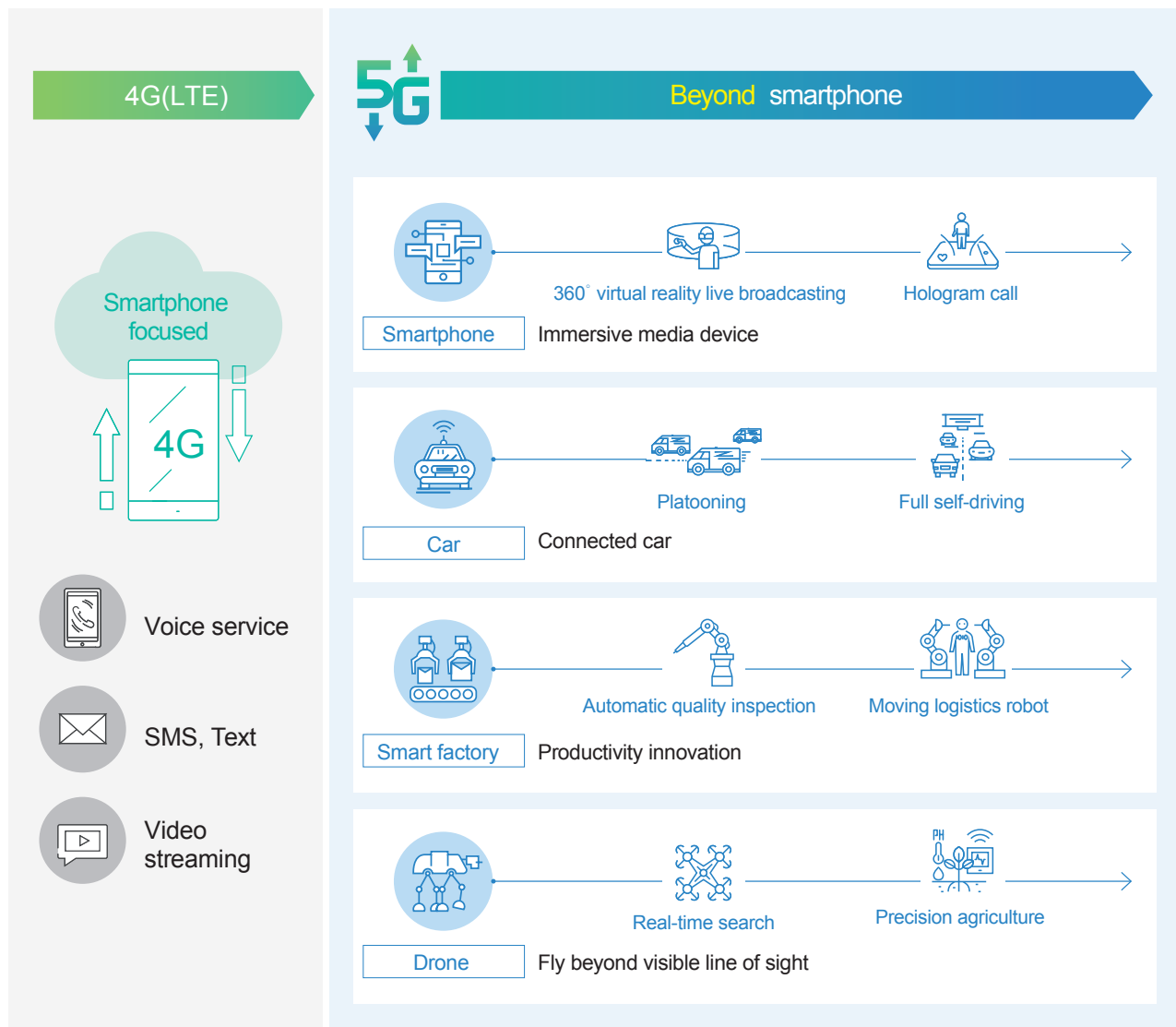
⁶ Some institutes, such as the GSMA and the FCC, divide sub-6GHz band into sub-1GHz band and 1-6GHz band. Sub-1GHz band is expected to be widely used for IoT services because of its excellent propagation characteristics and wide-area coverage.

⁷ Because spectra between 6GHz and 24 GHz are being used for other purposes, such as satellite and microwave relay, it will be difficult to use them immediately for 5G in many countries.

aspects by combining with existing industries. While 4G's application usages were limited to smartphones (B2C), 5G is expected to be fully applied to a variety of industries (B2B) and high-tech devices. Based on 5G, innovative areas involving information and communication technology (ICT), such as self-driving cars, smart factories, healthcare, and drones, will bring new service paradigms and new business opportunities. For example, in 4G environments, self-driving services were limited to guaranteed

location verification and other convenience services. However, the fast speed and real-time characteristics of 5G technology enable blind-spot detection and real-time updating of long-distance traffic information. Smart factories can now use 5G wireless connections instead of 4G fixed-wired production lines since 5G offers real-time guaranteed services. Drones in 5G can be controlled outside of the viewing area, and large-capacity high-definition images such as 4K/8K can be transmitted in real-time.

FIGURE 1.8 Change in Services Based on the Evolution of Mobile Communications Technology (4G->5G)



Source: MSIT (Ministry of Science and ICT) (2019).

TABLE 1.2 Top 10 Industries where 5G is Applicable

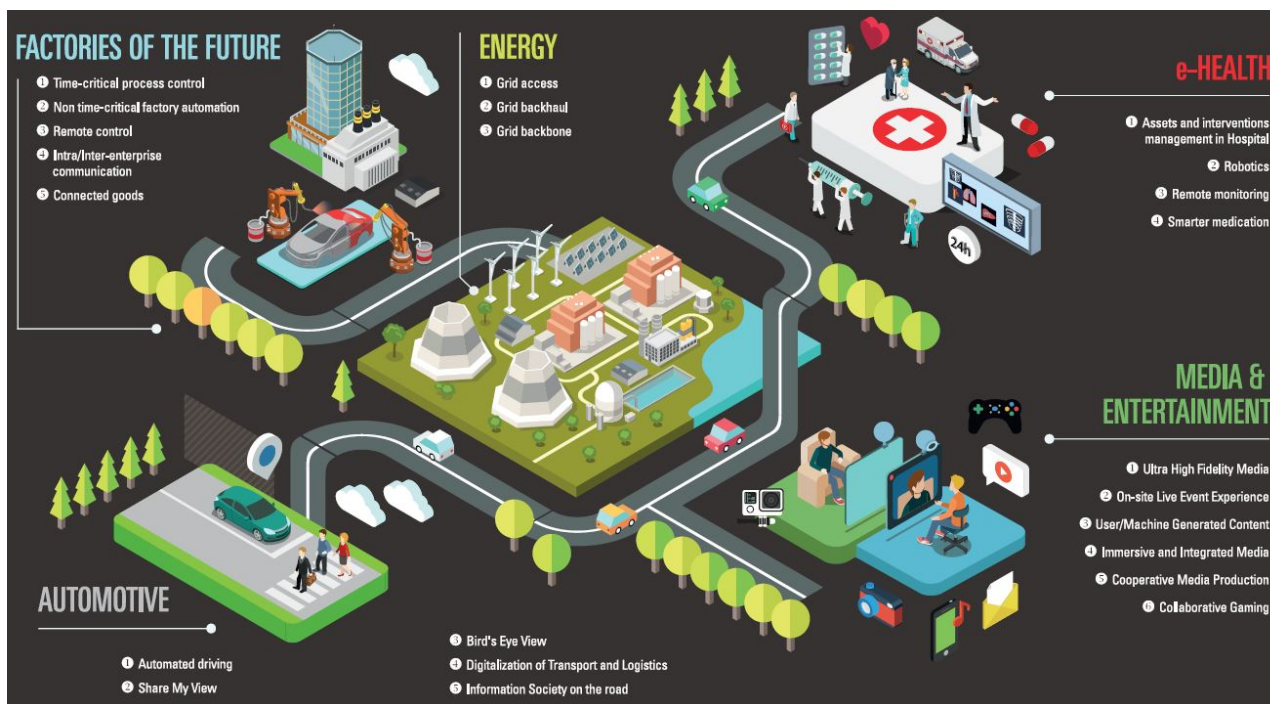
Industry	Content
Smart mobility	• Real-time information about demand and supply and active sharing can support searching best routing and eventually the realization of Automatic driving
Smart factory	• Wireless factory, wireless maintenance, VR service for efficiency of factory using 5G's high-speed and low latency
Energy	• 5G's Super-connected characteristic can analyze water, power, gas using smart meter and offer energy efficiency
Disaster management	• In emergency, 3D design transmission, wireless CCTV, real-time data transmission can be used
Health care	• Telemedicine can be offered to rural areas where there are no hospitals
Smart farm	• Temperature, Humidity, Sunshine can be measured, analyzed and managed automatically
Smart distribution	• Distribution process can be shared in real-time, new application services can be developed
Entertainment	• High-quality streaming service and VR contents will be developed
Education	• VR education contents can be developed to help students
Tourism	• VR sports, intelligent room service, entertainments for the tourists can be applied

Source: Author's elaboration.

5G will be combined with various existing sectors, such as manufacturing, agriculture, finance, and distribution, to drastically upgrade them. It will also bring about breakthroughs in e-health, education, public transport, and transportation. Additionally, it is expected to contribute to the improvement of

public safety measures, such as real-time disaster and safety responses, and to the resolution of the medical and educational gap between regions through realistic and high-immersion remote education. It is expected to further accelerate the 4th Industrial Revolution, in which all objects are connected to the

FIGURE 1.9 Challenges Arising as Different Areas Converge through 5G Services



Source: 3GPP (2016).

network. This will cause data to explode, with everything connected provided in real-time, and with AI making decisions from the data generated.

5G is a key means of promoting the production, distribution, and utilization of data. It will be a catalyst for the revitalization of the data economy. The commercialization of 5G will usher in a super-connected era of numerous sensors and devices, and data production will surge throughout the economy and society. High-speed transmission through 5G will enable the distribution of large-capacity data, such as streaming of high-resolution 4K/8K images, which was impossible in the past. In addition, the combination of 5G's ultra-fast, ultra-low

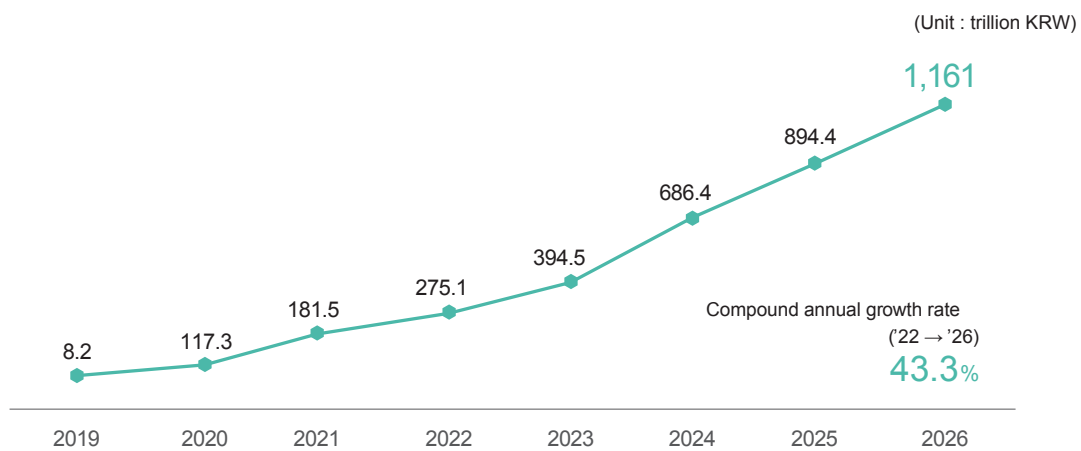
latency, super-connectivity characteristics merging with AI and cloud technologies will significantly contribute to the utilization of data and productivity at industrial sites.

Economic Contributions

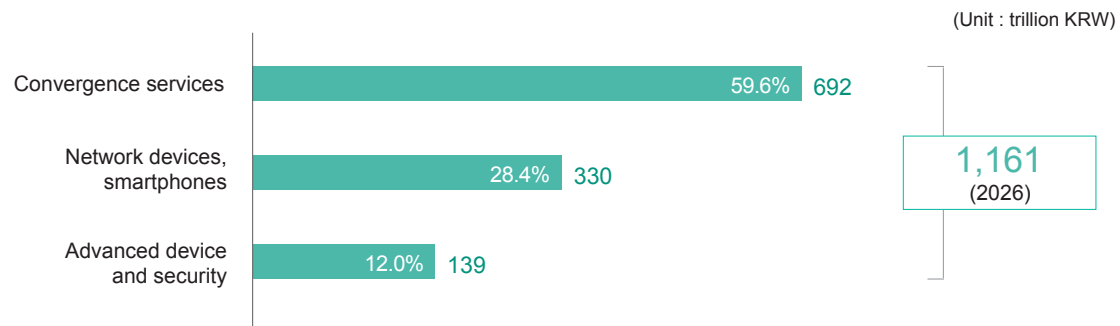
It is predicted that convergence between 5G and all industries will create co-growth in front-office and back-office industries and will add value to large-scale future markets. KISDI, Korea's leading state-run ICT think-tank, predicted that 5G will add US\$967.5 billion to the world economy by 2026, growing at an annual average rate of 43.3 percent (2022–2026)

FIGURE 1.10 Global Market Forecast

By year (2019–2026)

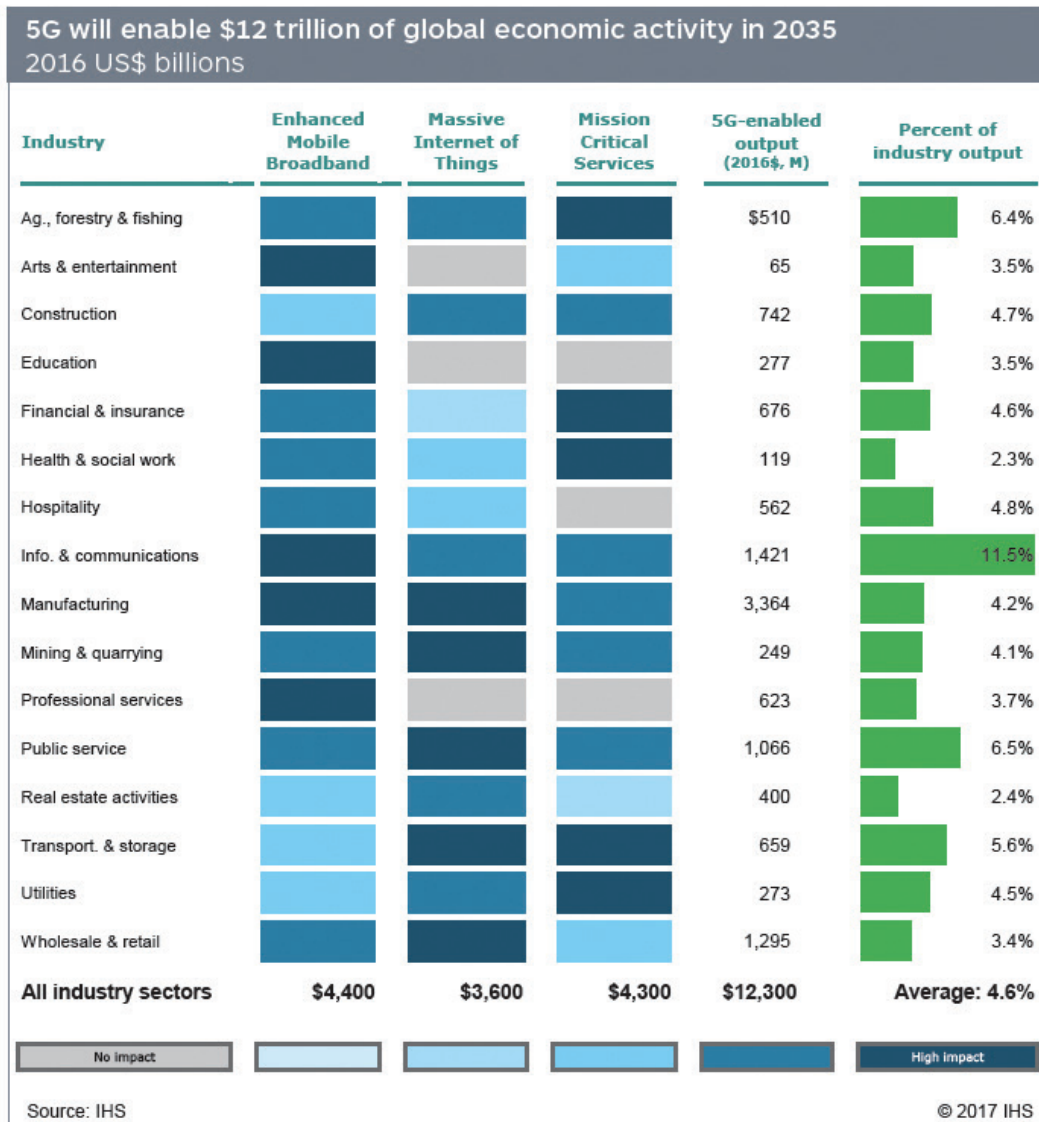


By sector (2026)



Source: KISDI.

FIGURE 1.11 5G Value Chain Outlooks



Source: IHS (2017).

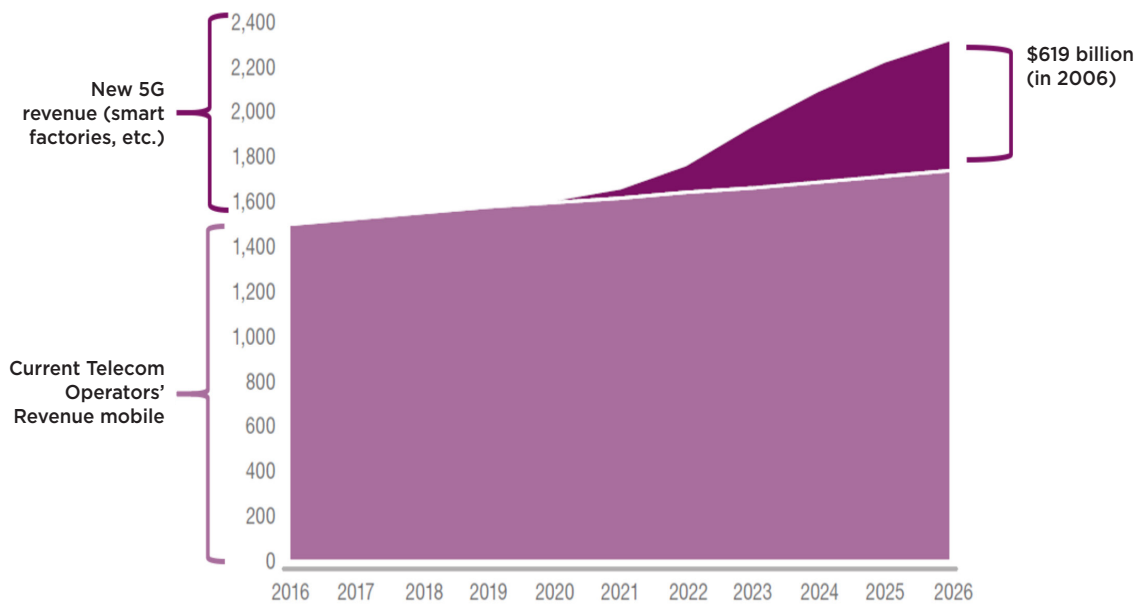
in major 5G-related industries. The forecast that the market for convergence services will account for about 60 percent of the total market means that 5G will shift from telecommunication manufacturing businesses such as mobile devices and equipment to a core infrastructure for the economy and society by accelerating convergence among industries.

To understand the impact of 5G on the global economy, IHS Markit, a global market research firm, measured the contribution of 5G by industry after developing an economic model for potential global

operating activities in various industrial sectors. The results show that 5G has a positive effect on most industries, with industry-specific effects varying from 2.3 to 11.5 percent, as shown in Figure 1.11. It is estimated that US\$12.3 trillion⁸ in global value

⁸ This is the sum of the total amount of products and services to be generated by 5G in 16 major industries, including agriculture, forestry, art, entertainment, construction, education, finance, insurance, healthcare, information and communication, manufacturing, mining, public services, real estate, transportation, logistics, utilities, wholesale, and retail.

FIGURE 1.12 Current and 5G-addressable revenues (global)



Source: Ericsson (2017) "The 5G Business Potential".

could be generated by 2035, which is 4.6 percent of the world's total output.

Despite the introduction of 4G LTE services to the world, the growth of subscribers has slowed due to market saturation. However, it is predicted that 5G will create new demands through the introduction of new 5G services, such as self-driving and smart factories, thus becoming a growth engine for the stagnant telecommunication services market. Ericsson predicted that global 5G network coverage will reach 40 percent, subscribers will reach 1.5 billion by 2024, and total revenue generated by the introduction of 5G will reach US\$619 billion, or 36 percent of total sales, in 2026.

Conclusions

This chapter discusses the definition and performance of 5G technology. It also explores the existing generation of communications and social value and economic contributions of this new technology. 5G is not just another telecommunication generation that provides faster mobile communication speeds; this innovation will radically change industries such as manufacturing, distribution, and agriculture. Nationwide 5G distribution will build a new foundation for national economic growth.

South Korea: Home of the World's First 5G Commercialization

Contribution of Information and Communication Technology to the Development of South Korea

Since the establishment of the Comprehensive Promotion Plan for the Construction of High-Speed Information and Communication in 1995, the government of South Korea has successfully implemented the plan and established a high-speed information communication infrastructure (fixed-line network) across the country. As a result, Korea increased productivity and efficiency across all sectors of industry, strengthening its national competitiveness and developing high-tech technologies through the establishment of high-speed ICT infrastructure. Moreover, through the informatization of administration, government services have been improved, and private companies' investment has been activated through deregulation. The high-speed Internet service provided to elementary and high schools nationwide provides a great educational environment for young students, making it the cornerstone for investment in the future and cultivating professional manpower. Korea is the best example of how a nationwide high-speed information communication network affects the competitiveness of the country as a whole. In particular, many of the challenges of the nation overcome by Korea's deployment of high-speed information and com-

munication networks are similar to those that most LAC countries face. Thus, Korea is a good reference for LAC countries.

Several explicit indicators confirm the development of ICT in Korea over the last two decades. As Table 2.1 shows, in the OECD wired broadband penetration rate and the ITU ICT Development Index, Korea have reached the world's highest level since 2010, and the coverage of Giga Internet in Korea is more than 98% of households.

Thanks to the rapid development of information technology and technological innovation in the information and communication field, the proportion of ICT industry in the Korean economy has been expanding rapidly. The total output of the ICT industry increased almost fourfold, from 3.3 percent in 1995 to 13.0 percent in 2009, and the export proportion of the ICT industry increased from 9.8 percent in 1995 to 33.6 percent in 2009 (Table 2.2). In addition, the rapid growth of the ICT industry has steadily expanded its contribution to the overall economic growth. The total output growth contribution of the entire ICT industry rose from 18.4 percent in the late 1990s to 21.6 percent in the early 2000s and to 28.4 percent in the late 2000s (Figure 2.1).

This chapter introduces South Korea's case as a reference model for commercialization and utilization of 5G. In April 2019, Korea commercialized mobile handset-based 5G service for the first time

TABLE 2.1 Major Statistics

<Giga Internet deployment status>								
	2013	2014	2015	2016	2017			
Coverage	16.8%	36.15%	60.01%	91.82%	98.0%			
Household subscriber	17,000	34,000	1,982,000	4,410,000	6,480,000			
<OECD broadband statistics>								
	2009	2010	2011	2012				
FTTH user %	16.220%	19.265%	20.892%	22.328%				
Global ranking	1 st	1 st	1 st	1 st				
Broadband user %	33.241%	34.799%	35.878%	36.502%				
Global ranking	6 th	5 th	5 th	6 th				
<ITU measuring the information society 2015>								
	2010	2011	2012	2013	2014	2015	2016	2017
Ranking	1 (out of 150)	1 (out of 150)	1 (out of 150)	1 (out of 150)	2 (out of 150)	1 (out of 150)	1 (out of 150)	2 (out of 150)
Score	7.80	8.45	8.51	8.81	8.85	8.78	8.84	8.85

Source: NIA (2018).

in the world. It was achieved more than a year earlier than initially planned. As of December 2019, the penetration rate of 5G network is now the highest in the world, with the 5G network being built and serviced in 85 local governments where 93 percent of the Korean population lives. As shown in Figure 2.2, Arthur D. Little's 5G Leadership Index ranked South Korea at the world's highest level in

terms of infrastructure availability and commercialization tendency, beating the United States and Australia.

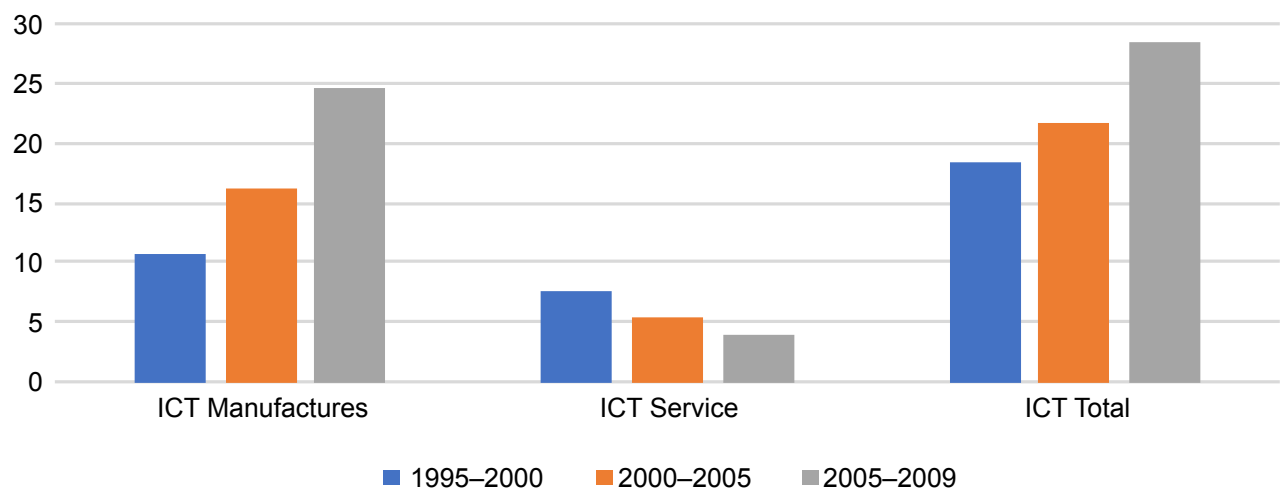
Behind this world's first and best 5G performance, there were preparations and efforts by the public and private sectors in South Korea over the last decade. South Korea predicted the economic and industrial value of 5G and proactively

TABLE 2.2 Change of ICT Industry Proportion

		1995	2000	2005	2009	2011
Total output	ICT manufacture	2.1	4.2	7.1	9.5	7.4
	ICT service	1.2	2.8	3.4	3.5	2.7
	ICT total	3.3	6.9	10.5	13.0	10.2
Added value	ICT manufacture	..	0.4	4.2	6.4	4.2
	ICT service	1.8	3.7	4.1	4.2	3.5
	ICT total	..	4.1	8.3	10.6	7.7
Export	ICT manufacture	9.5	15.3	28.2	33.1	20.3
	ICT service	0.3	0.4	0.4	0.5	0.5
	ICT total	9.8	15.6	28.6	33.6	20.8
Employment	ICT manufacture	2.1	2.4	2.4	2.0	2.2
	ICT service	1.1	1.7	2.1	1.9	1.9
	ICT total	3.2	4.0	4.6	3.9	4.0

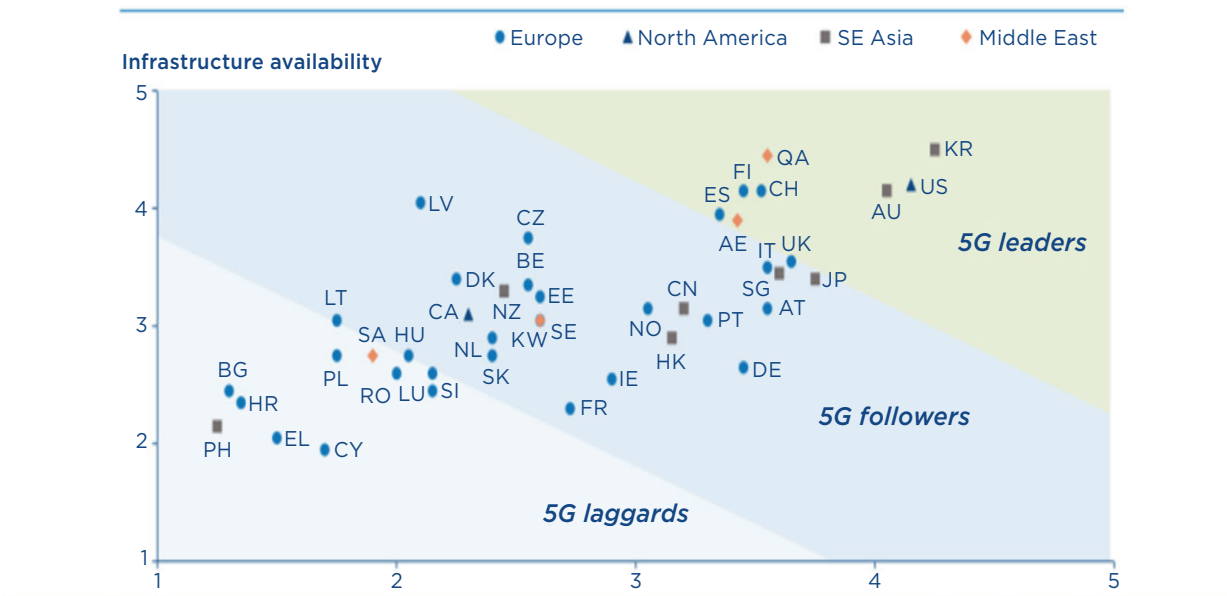
Source: KIET (Korea Institute for Industrial Economics & Trade) (2015).

FIGURE 2.1 Total Output of the ICT Industry Growth Rate



Source: KIET (2015).

FIGURE 2.2 5G Leadership Index



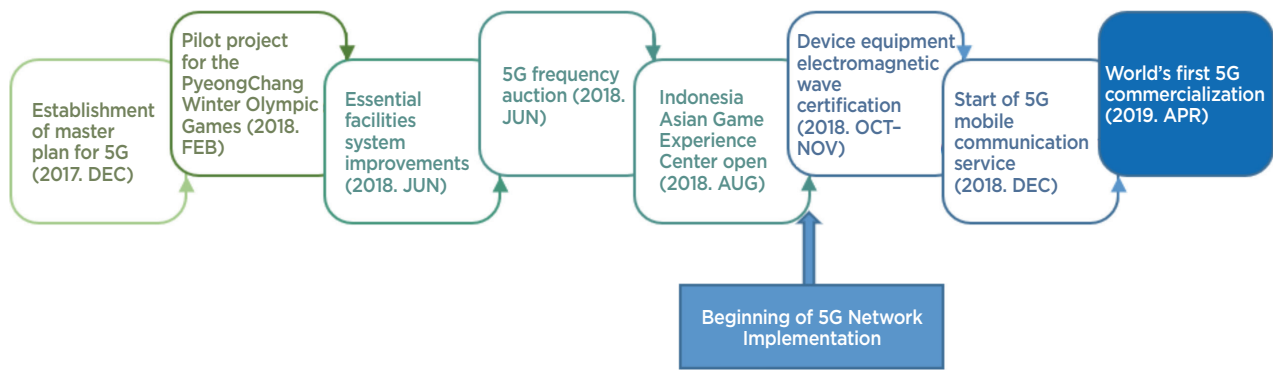
Source: Arthur D. Little (2019).

responded with technological innovation, as well as role sharing and cooperation between the public and private sectors.

This chapter explains the process of South Korea’s implementation of the 5G network, including the establishment of a master plan for 5G, the pilot project for the PyeongChang Winter Olympic

Games (February 2018), the auction of 5G frequencies (June 2018), and the certification of base station equipment (October 2018). It also examines the “5G+ plan,” the 5G utilization plan established by the MSIT (Ministry of Science and ICT) to maximize the economic and industrial effects of the 5G network in the future.

FIGURE 2.3 Timeline of 5G Implementation in South Korea



Source: Authors' elaboration.

National 5G Deployment Plan

South Korea became an ICT powerhouse because of its leadership in developing next-generation networks. By commercializing code division multiple access (CDMA) in 1996 and high-speed Internet in 1998, South Korea established a platform to lead the global mobile device market, and by utilizing the world's best wired and wireless networks, new network-based services such as online games and Internet banking were widely activated. Based on the experience, South Korea recognized the economic and social values and benefits of 5G network as a core infrastructure for the society of the future. When discussions of 5G technology began, it responded actively by drawing up a promotion system and plan.

Discussions of global 5G standardization and implementation activities began in the early 2010s, led mainly by ITU and 3GPP. In line with the global 5G discussion, South Korea founded the private sector-led 5G Forum in May 2013 to establish strategies for innovation of 5G technologies, support national and international standardization, and provide a platform for active communication between experts and academics, industry, and government. In addition, the MSIT launched the 5G Strategy Promotion Committee in January 2015, where MNOs, manufacturers, small and medium sized businesses, 5G forums, and experts gathered to examine the state of 5G preparation at the national level and to provide a platform for active

communication and cooperation for the successful deployment and activation of 5G.

The Korean government also supported 5G technology and standardization development projects. Particularly, the MSIT established the Giga Korea Business Group in 2013 to support and manage the development of GHz-level mobile technologies for 5G. The group supported the development of key technologies related to 5G, including GHz-level wireless networks, high-capacity content processing platforms, holographic and super-realistic terminals, and large-scale super-realistic terminals.

In addition, a national blueprint for Korea's implementation of 5G was presented. In 2014, the first national-level plan that presented a long-term vision and supported measures for 5G, called the Creative 5G Mobile Strategy, was established. With the vision of becoming a 5G powerhouse, the plan decided to invest US\$1.4 billion over the next seven years in developing world-class R&D, facilitating key 5G services early, strengthening global cooperation, and creating a smart mobile new ecosystem. In 2017, MSIT announced the creation of the Super-connected Intelligent Network Strategy, in which detailed schedules for implementation of 5G and measures for implementation were presented in greater detail. The plan proposed a roadmap to achieve commercialization by March 2019, a year ahead of the original schedule for launching 5G service in the first half of 2020, and to complete the deployment of 5G nationwide network by 2022. Moreover, the MSIT

FIGURE 2.4 PyeongChang Winter Olympics with 5G



Source: Authors' elaboration.

announced a policy to facilitate the joint use of 5G essential facilities, including the sharing of conduits, poles, and other telecommunication facilities among service providers, to reduce the cost of 5G deployment and to ensure efficient deployment of the 5G network. The MSIT revised the criteria for calculating the cost for 5G spectrum to reflect characteristics of 5G spectrum, which were different from those of the existing spectrum up to 4G.

In parallel with the government's establishment of the national master plan for 5G, the private sector made efforts to preempt the 5G global market. Korean manufacturers such as Samsung and LG actively promoted patent-acquisition and standardization activities by developing core 5G technologies, and Korean MNOs such as SKT, KT, and LGU+ worked with their global partners on equipment, mobile devices, chips, and application companies, to develop 5G network and killer applications.

Korea's efforts in 5G became explicitly known to the world through the 5G pilot service⁹ for the PyeongChang Winter Olympics. KT, the official

partner of the PyeongChang Winter Olympics, has developed items for 5G demonstration service performance since 2016 and showcased them at the venue in February 2018. Using the ultra-low latency and massive connectivity of the 5G network, the company successfully implemented 5G drone torch relay and LED performance at the opening ceremony. It established a 5G network in various areas of the stadium and provided a viewing experience from specific points in real time in long-distance events such as biathlons.

Securing and Allocating/Assigning the 5G Spectrum

To implement 5G networks, it is essential to secure spectrum that is suitable for 5G. Even though all other conditions necessary for 5G deployment are

⁹ KT's pilot services for Pyeongchang Winter Olympics were provided with equipment and terminals that implemented the own technical specification (KT SIG specs) rather than the 3GPP standard.

prepared such as strong political will and funds for deployment, 5G network cannot be implemented if each nation does not have a frequency spectrum suitable for the network.

Since the early 2010s, when 5G was actively discussed, the MSIT attempted to secure 5G spectrum by paying attention to trends in international standardization of 5G frequency bands. First, it established the K-ICT Spectrum Plan in January 2017 to announce a schedule for auction of 5G in the first half of 2019, along with a plan to secure 4,300MHz of bandwidth, including 3.5GHz and 28GHz bands, to guarantee the speed and coverage of 5G network at the same time. However, as the global movement for 5G was accelerated, the MSIT advanced the initial auction schedule by almost one year from the first half of 2019 to the first half of 2018. It also revised the legal framework by early 2018, and performed the auction of the 5G spectrum in June 2018.

5G Frequency Band

The spectrum required to deploy the 5G network is divided into sub-6GHz bands (FR1) and millimeter-wave bands (FR2). Sub-6GHz bands are needed to secure coverage along with Gbps-class transfer rates. Millimeter-wave bands are necessary for hotspot areas such as urban centers, stadiums, and stations, where high speed and capacity are required, although it is difficult for them to provide wide-area coverage due to their poor propagation characteristics.

The MSIT chose 3.4 to 3.7 GHz band for sub-6GHz band and started to secure it. The reason why the band was chosen as sub-6GHz in South Korea was because many countries around the world were paying attention to it as an internationally harmonized sub-6GHz band, and it was relatively easy for South Korea to secure hundreds of MHz broad contiguous bands. Previously, the band was used by the three South Korean terrestrial broadcasters and by 22 wireless stations for mobile television services. The MSIT started to withdraw and relocate the band in early 2016 by moving the wireless stations

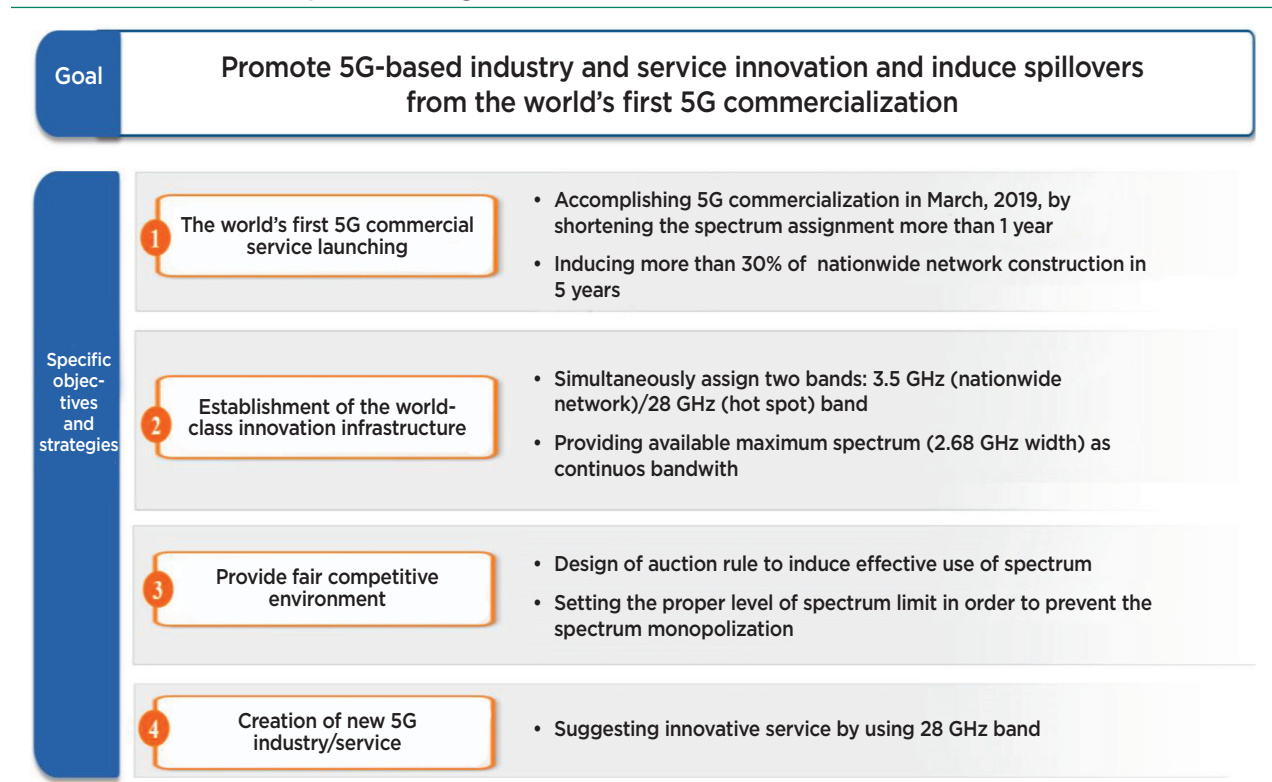
for mobile TV to other frequency bands. The MSIT provided US\$1.0 million to the broadcasters as compensation and finally secured a 300MHz width spectrum as a sub-6GHz band at the end of 2017.

The MSIT chose 28GHz band (26.5 to 29.5GHz) as 5G millimeter-wave band. Several 5G millimeter-wave bands were being globally discussed as 5G standard spectrum, including 26GHz and 28GHz. The MSIT chose 28GHz because it is easier to secure than the 26GHz band already used for other purposes in South Korea. However, since some countries that used 28GHz band for satellite purposes opposed to using the band for 5G service because it could interfere with their satellite network, it was necessary to expand standardization allies for utilizing 28GHz bandwidth for 5G use. Thus, the MSIT held a 28GHz Frontier International Workshop with the participation of countries such as Canada, Japan, and the United States, MNOs, manufacturers, and institutions that prefer the 28GHz band as a 5G millimeter-wave band. Finally, the 28GHz band was standardized as a 5G millimeter-wave band in 3GPP.

5G Spectrum Auction

With respect to 4th generation mobile telecommunications, South Korea held a 4G spectrum auction, referencing examples of countries who had already auctioned and commercialized a 4G network. However, the MSIT had difficulty preparing the 5G spectrum auction, because Korea was one of the first countries in the world to hold a 5G spectrum auction. First, it collected opinions from various stakeholders on how to conduct the 5G spectrum auction. It stood up a Frequency Policy Advisory Committee consisting of experts from industry and academia, which reviewed and commented on the draft auction plan prepared by the MSIT. In addition, the opinions of communication service MNOs, global equipment manufacturers, and chip and device manufacturers were collected several times and were appropriately reflected in the auction plan. In addition, public hearings were held to open the government's draft auction plan to the general public for public consultation.

FIGURE 2.5 Goal for 5G Spectrum Assignment Plan



Source: Authors' elaboration.

The policy goal of the 5G spectrum auction was to maximize the economic and social effects of the 5G mobile network. One of its main objectives was to commercialize the 5G mobile network for the first time in the world so that Korean companies could take the lead in the 5G industry and 5G-based services. Another main objective was to enable people to improve their quality of life through 5G without undue burden.

The spectrum subject to the auction is 2,680 MHz of bandwidth in total, including 280 MHz in the 3.5 GHz band (3,420 to 3,700 MHz), and 2,400 MHz in the 28 GHz band (26.5 to 28.9 GHz). The available bandwidth for 5G was 300MHz in 3.5GHz band (3,400 to 3,700MHz) and 3GHz in 28GHz band (26.5 to 29.5GHz). However, for the 3.5 GHz band, interference with the adjacent 3.3 GHz band that was being used for public use was not clearly identified, so that the adjacent 20 MHz band was excluded from the auction bands. For the 28GHz band, it has decided

to auction off 2.4GHz of bandwidth, which is maximum demand by South Korea's three MNOs, as the 28GHz band base station equipment could not support more than 800MHz width at that time. By supplying the 5G spectrum at the maximum contiguous bandwidth that could be supplied at that time, the Korean government helped MNOs to reduce the cost of 5G deployment significantly compared to that of 4G deployments, where multiple redundant equipment investments were required.¹⁰

In general, the spectrum cap—the maximum amount of spectrum that an individual MNO can secure—is limited in spectrum auctions. The reason that spectrum caps are set is to prevent a single MNO from obtaining excessive spectrum, which can result in unbalanced market competition

¹⁰ In the case of 4G, 4 separate auctions in the 380MHz band (100, 50, 90, 140) caused multiple redundant equipment investments.

arising from large deviations between MNOs in the amount of spectrum secured. South Korea's 5G auction imposed the spectrum cap of 100MHz in 3.5GHz band and 1,000MHz in 28GHz band. As mentioned earlier, there was practically no need to set spectrum cap for the 28GHz band because the demand for the band was up to 800MHz per MNO. On the contrary, the nation's three telecom MNOs wanted to secure as much bandwidth in 3.5GHz band as possible, because the amount of secured 3.5GHz band with which a nationwide network is supposed to be deployed was expected to directly affect the quality and the competitiveness of the 5G service market. The leading MNO in South Korea called for raising the spectrum cap so that it could secure as much spectrum as possible in 3.5 GHz band, noting it has nearly 50 percent of the market share. The other MNOs insisted that excessive deviation between MNOs in the 3.5GHz band, which can be brought about by a high spectrum cap, should be avoided, so that the playing field in the 5G service market will not become too unlevel. Under these circumstances, the MSIT presented three options on the spectrum cap—100MHz width, 110MHz width, and 120MHz width—and collected opinions from related experts and institutions, and it finally decided to set the cap at 100MHz width. In the spectrum cap of 100MHz per MNO, the maximum deviation between the three MNOs in the 3.5 GHz band is only 20MHz. The reason why the Korean government set such a low deviation was to prevent unbalanced competition at the start of the 5G network, providing opportunities for all MNOs to attempt to innovate 5G in a similar environment, thus expediting 5G innovation and maximizing the social benefit from it. Instead, the MSIT announced that the spectrum caps in the following 5G spectrum auctions are going to be eased, so that each MNO can secure enough spectrum to respond to the increase in demand in the spectrum.

The reserve price, that is, the minimum price for the auction, was set at US\$2.41 billion for the 3.5GHz band (280MHz width, 10-year service period) and US\$0.57 billion for the 28GHz band (2400MHz width, five-year service period). It is important to

set the reserve price in an auction carefully. An overly low reserve price can cause MNOs to take excess profits coming from exclusively utilizing spectrum, which is a scarce public resource. On the other hand, if the reserve price is too high, it can deter MNOs from investing in the deployment of the network and can induce them to charge subscribers a high rate, substantially lowering the affordability of the service. In setting the reserve price for the 5G spectrum, the MSIT reflected various factors such as past auction results, the ultra-wide contiguous spectrum supply, the future 5G spectrum supply expected, and the 5G market outlook. In particular, the reserve price for the 28GHz millimeter-wave band, which was the first to be auctioned in the world, was difficult to determine because the potential of the 28GHz band is expected to be large in the future. However, there were also uncertainties in terms of technical and economic efficiency of its service at the time. Reflecting these circumstances and the results of extensive discussion, the reserve price of the 28GHz band was drastically lowered to reduce MNOs' investment risk.

A clock auction was selected as the rule for auctioning 5G spectrum. Clock auction is suitable among the existing spectrum auction methods for distributing broad consecutive spectrum to multiple MNOs. It is a two-step auction rule that determines amounts of spectrum taken by each MNO in the first stage and then the location of spectrum in the second stage. The first stage can proceed up to 50 rounds until demand is less than or equal to supply, with a maximum 1 percent bid increment per round to prevent overheated competition and prevent winner's curse. In the second stage, the sealed bid auction method is used.

In most spectrum auctions, network deployment obligations are imposed on service providers that are given spectrum to encourage them to invest to network deployment. In the case of the 3.5 GHz band in Korea, more than 15 percent of the total number of base stations in the nationwide network were imposed as the obligation within three years, and more than 30 percent within five years. In the 28 GHz band, 15 percent or more within three

years were obligated to deploy. This obligation is somewhat lower than that of the existing 4G LTE. That is because it is intended to alleviate the burden of initial 5G investments and mitigate the risk of investment. In addition, small equipment such as repeaters were recognized as base stations so that the relevant small and medium-sized businesses that produce small 5G equipment can have opportunities for growth in the 5G market.

South Korea's auction of 5G spectrum, held in June 2018, ended two days after its launch. The total winning bid was US\$3.29 billion, which is US\$311 million over the reserve price of US\$2.98 billion. There was some bidding competition in the 3.5 GHz band, as all three MNOs wanted 100 MHz, the spectrum cap. There was little competition in the 28 GHz band, because there was enough bandwidth to fulfill the MNOs' demand. The first stage of the 3.5 GHz band auction, which determines the amount of spectrum (number of blocks¹¹), saw a nine-round total increase, from US\$2.41 billion to US\$2.46 billion, which was US\$50.9 million up from the starting price. The second stage, which decided the location, rose to US\$2.49 billion. The first stage of the 28GHz band auction ended in the first round and increased by US\$0.6 million in the second stage to be finally confirmed at US\$0.52 billion. SKT and KT, the No. 1 and No. 2 MNOs, respectively, secured the 100 MHz in 3.5 GHz band, while LG U+, the No. 3 MNO, secured 80 MHz. In the 28GHz, 800MHz were assigned equally to the three MNOs.

The auction results show that each MNO developed an auction strategy focused on becoming a market leader rather than beating out their

competitors. That is because the MNOs intended to lead global competition in the 5th generation mobile communications era by avoiding excessive competition and not fighting to secure more spectrum than the other MNOs. With the assignment of the 5G spectrum described above, Korea became the first country to assign both sub-6GHz band (3.5GHz) and millimeter-wave band (28GHz), which are essential for a fast and wide-coverage 5G network. Since all of the MNOs secured contiguous spectrum for broadband required by 5G, the stage was set for them to become the global leaders in 5G mobile communication. They are tackling innovation challenges such as self-driving cars, smart cities, and smart factories, based on early-established 5G networks.

Institutional Improvement

After the 5G spectrum auction, the MSIT began making the institutional improvements needed to establish the 5G network more effectively. To mitigate the cost of deploying the 5G network, the government cut taxes on investment in 5G deployment and facilitated joint utilization of essential facilities. In addition, the MSIT approved the 5G fee for SKT, the market-dominant MNO, for the activation of 5G service use at an appropriate price and prepared a new certification system for 5G equipment and devices.

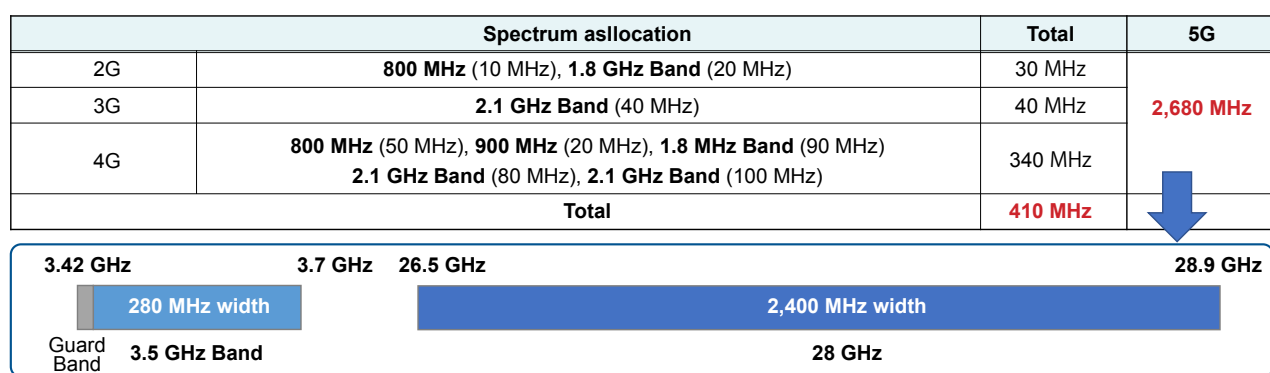
¹¹ In the 3.5GHz band auction, 280MHz contiguous band was divided into 28 10MHz-blocks. In the 28GHz band auction, 2400MHz contiguous band was divided into 24 100MHz-blocks.

TABLE 2.3 5GHz / 28GHz Band Spectrum Auction Results

Band	Bandwidth	Reserve price	Usage Period	Winning bid	Auction details
3.5 GHz	3420–3700MHz (280MHz bandwidth)	US\$2.20 billion	10 years	US\$2.49 billion	<ul style="list-style-type: none"> • SKT 100MHz (3600–3700MHz) • KT 100MHz (3500–3600MHz) • LGU+ 800MHz (3420–3500MHz)
28 GHz	26.5–28.9GHz (2400MHz bandwidth)	US\$0.52 billion	5 years	US\$0.52 billion	<ul style="list-style-type: none"> • SKT 800MHz (28.1–28.9GHz) • KT 800MHz (26.5–27.3GHz) • LGU+ 800MHz (27.3–28.1GHz)

Source: Authors' elaboration.

FIGURE 2.6 Spectrum Allocation in Korea



Source: Authors' elaboration.

Tax Cut

Although 5G networks are expected to provide a core foundation for the 4th Industrial Revolution, the high cost of deployment is an obstacle to active investment by network MNOs. In response, the Korean government and Congress amended the Restriction on Special Taxation Act, which provides tax deductions for investment in 5G network facilities, to accelerate the development of the 5G network, promoting 5G investment and leading global markets. In this act, corporate taxes can be deducted at a rate of less than 3 percent for investments in 5G base stations in areas other than metropolitan areas. Such corporate tax deductions are expected to allow MNOs to receive corporate tax cuts worth between US\$61 million and US\$127 million per year.

Joint Construction of Essential 5G Facilities

The MSIT announced an Improvement Plan for Joint Construction of Facilities to support early introduction of 5G and efficient infrastructure deployment. In this plan, the range for joint deployment was expanded from wired facilities such as conduits and poles to wireless facilities such as antenna and sites of base stations. Through this improvement, the government expects to reduce capital investment by eliminating the possibility of overlapping investments and shortening the investment period.

MNOs and Internet service providers in Korea have announced that, through the plan, the costs for the creation of a 5G infrastructure will be distributed. They anticipate a reduction in costs over the next ten years of up to US\$1 billion.

Tariff Approval Regulation

The Korean government has had a tariff approval regulation since 1991 under which market-leading MNOs with the highest market share are required to get approval from the MSIT for service rate changes and other terms and conditions. The regulation was introduced to protect latecomers and keep market-leading MNOs in check. Rates for leading MNO have a significant impact on other MNOs' rates, which in turn have a significant impact on mobile service charges. Some experts say that the regulation should be abolished to reduce government regulation. However, the regulation persists in South Korea to prevent MNOs from setting service rates arbitrarily high.

SKT, the leading MNO in South Korea, initially proposed the lowest 5G plan rate above US\$58 per month to the government, but the government rejected it and encouraged the launch of a lower-cost plan to allow more users to receive 5G services, eventually bringing the cost down to US\$42 per month. Also, KT launched a 5G unlimited data plan at US\$67 per month, which is lower than the 4G LTE unlimited data plan set at US\$73 per month.

With the tariff approval regulation, the prices of 5G service plans have been set at up to 50 percent cheaper than 4G LTE in terms of data usage.

Prepare 5G Equipment and Device Certification System

Wireless stations that use radio waves should be inspected to determine whether they meet the requirements of appropriate frequency bands and outputs allowed by the government, and they should be certified before emitting radio waves. 5G equipment and devices of 5G network require new certification methods, as they use different frequencies and technologies than the previous generations.

The MSIT has newly established technical standards and testing methods for radio frequency (RF), electromagnetic compatibility (EMC), and specific absorption rate/electric and magnetic field (SAR/EMF) based on 3GPP international standards. In addition, the standards and procedures for the joint use of 5G wireless facilities and environmentally friendly installation were simplified. The notice concerning the establishment of wireless stations was revised to simplify the 5G deployment process.

5G Network Utilization Plan: 5G+ Strategy

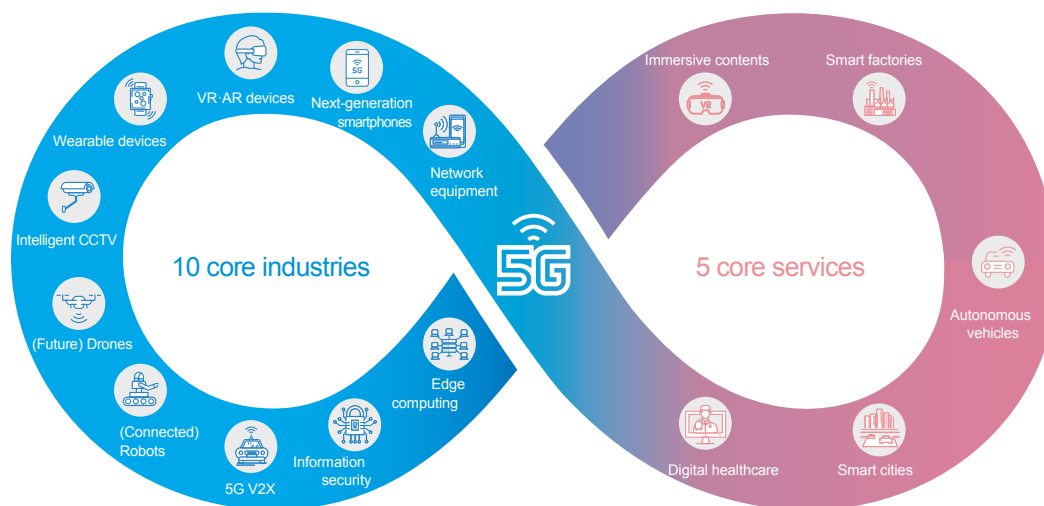
Korea's 5G+ strategy was developed with the aim of maximizing innovative growth and providing a roadmap for industrial development by activating the use of 5G network following its commercialization. It is designed to nurture 5G+ Strategy industries and fully converge 5G across the economy and society. In this way, Korea will secure global leadership of new 5G-based industries and realize its goal of becoming the leading country in the 4th Industrial Revolution. The 5G+ strategy proposes 10 core industries and five core services. The 10 core industries are network equipment, next-generation (5G) smartphones, VR/AR devices, wearable devices, intelligent CCTV, drones, connected robots, 5G V2X, information security, and edge computing. The five core services

are immersive content, smart factories, autonomous vehicles, smart cities, and digital healthcare.

To foster the 5G strategy industries and improve quality of life through 5G, the government plans to set up 52 detailed tasks in five major strategic areas: 1) public sector-led investment, 2) expansion of private investment, 3) institutional improvement, 4) creation of an industrial foundation and 5) support for overseas expansion. Through the public sector-led investment strategy, the government supports the demonstration of killer services and the expansion of supply of the five core services, such as smart factories and autonomous vehicles, and supports the creation of public demand through the application of 5G in public sectors such as social overhead capital, housing facilities, and aging nuclear power plants. To expand private investment, 2 to 3 percent of taxes received from investment in the network this year and next year will be deducted, and 13 5G testbeds will be established. The institutional improvement strategy includes improvement of 5G tariffs to support the activation of B2B services and doubling of the 5G spectrum by 2026. To create an industrial foundation, the government will strengthen investment to secure leading global technologies and push for the development of source proprietary technologies. The government will also support entry into foreign markets by helping small and medium-sized enterprises expand to foreign markets and establish partnerships with leading global businesses.

The government of South Korean will form a joint 5G+ Strategy Committee in a public-private partnership (PPP) to promote the 5G+ strategy nationwide. The MSIT is planning to hold a 5G+ Strategy Check Conference to examine the progress of the 5G+ strategy periodically and designate responsible managers and project managers in strategic industries. Through the 5G+ strategy, South Korea is set to accelerate innovative growth and will push hard to create public markets, facilitating corporate investment and improving institutions in the near future.

FIGURE 2.7 Nurturing 5G+ Strategy Industries



Source: MSIT (2019).

Conclusions

Several policies to introduce 5G in Korea have been developed. Considering the astronomical value of 5G infrastructure, careful policy development and implementation are essential in the early stage of its introduction. That is because some policies, such as frequency policies and auctions, cannot be

undone once they are executed, and government policies in the early stages of network adoption can have a significant influence on various important variables, such as fair competition among telecommunication companies and the stimulation of private investment. It is also an opportunity to make the market sound and fair without being caught up in the market economy logic of private MNOs.

3

Future Challenges and Policy Implications

Global 5G network deployments are accelerating. As indicated in the name of IMT-2020, 5G was initially intended to be commercialized in approximately 2020, a few years earlier than 5G would be made available worldwide. By July 2019, 54 MNOs in 31 countries, including Finland, South Korea, Switzerland, the United Kingdom, and the United States, had established 5G networks.

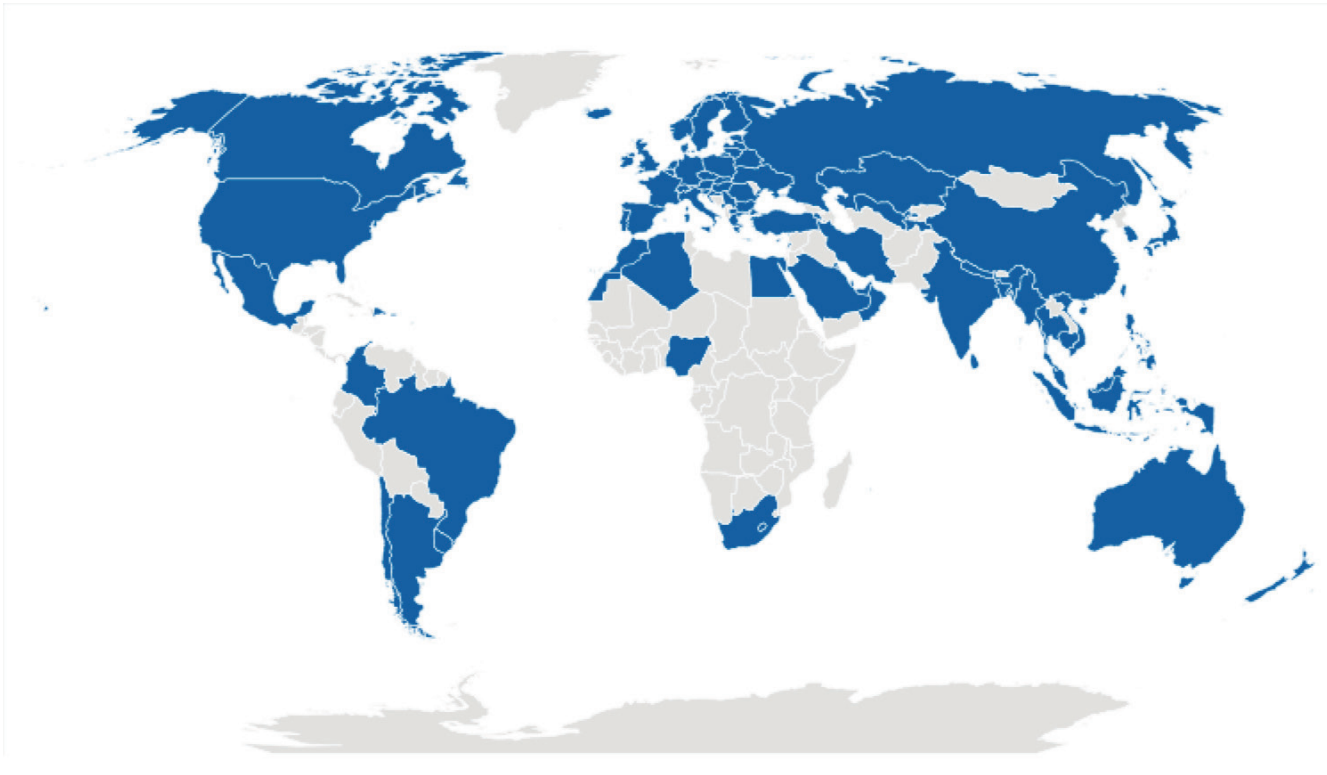
Thirty-five have already begun 5G services, according to GSA announcement (GSA, 2019). Another 293 MNOs in 98 countries are investing in 5G in many forms (Figure 3.1).¹² Many countries around the world are rushing to introduce 5G so that they may soon enjoy its significant economic and social benefits.

Developing countries, including those in the LAC region, must not be left behind in being able to take advantage of the numerous opportunities that 5G will bring. The innovations of 5G could significantly raise economic growth in the LAC region and improve the quality of people's lives in various ways. 5G is not merely an advanced communications infrastructure; it is a core foundation of rapid economic and social development. In particular, social problems like public safety, drug trafficking in developing countries can be resolved through 5G applications such as high-resolution CCTV and AI-based face detection system. A recent report by Intel (2016) cites a number of sector-specific examples of the importance of 5G in developing countries:

- e-health: 5G will reduce delays in conducting remotely assisted surgery. Specialists are not available in many hospitals and could join a local surgeon remotely to perform procedures that require expert skills. (The latency of 5G transmission is around one millisecond—imperceptible to the human eye and about 50 times faster than 4G).
- Smart Learning: 5G will enter the classroom and bring new ways of learning to students. Augmented reality, virtual reality, and virtual presence will immerse students in a more visual and interactive learning experience where students and teachers may not necessarily be in the same location.
- Water Management and Agriculture: 5G will also facilitate smart water management and smart agriculture systems in developing countries. For example, sensors with wireless connectivity for crop fields can help optimize growing and minimize the use of water and fertilizers through targeted applications.
- Smart Transportation Systems: According to the World Health Organization, 90 percent of the world's traffic fatalities occur in low-and

¹² These countries have demonstrated, are testing, or have been licensed to conduct field trials of 5G technologies, have acquired licenses enabling them to launch 5G, are deploying 5G networks, or have announced service launches.

FIGURE 3.1 Countries with MNOs Investing in 5G Networks



Source: GSA (2019).

middle-income countries, even though these countries have only half of the world's vehicles. Road accidents cost Egypt EGP 30.5 billion in 2015, and the death or injury of around 25,500 people.

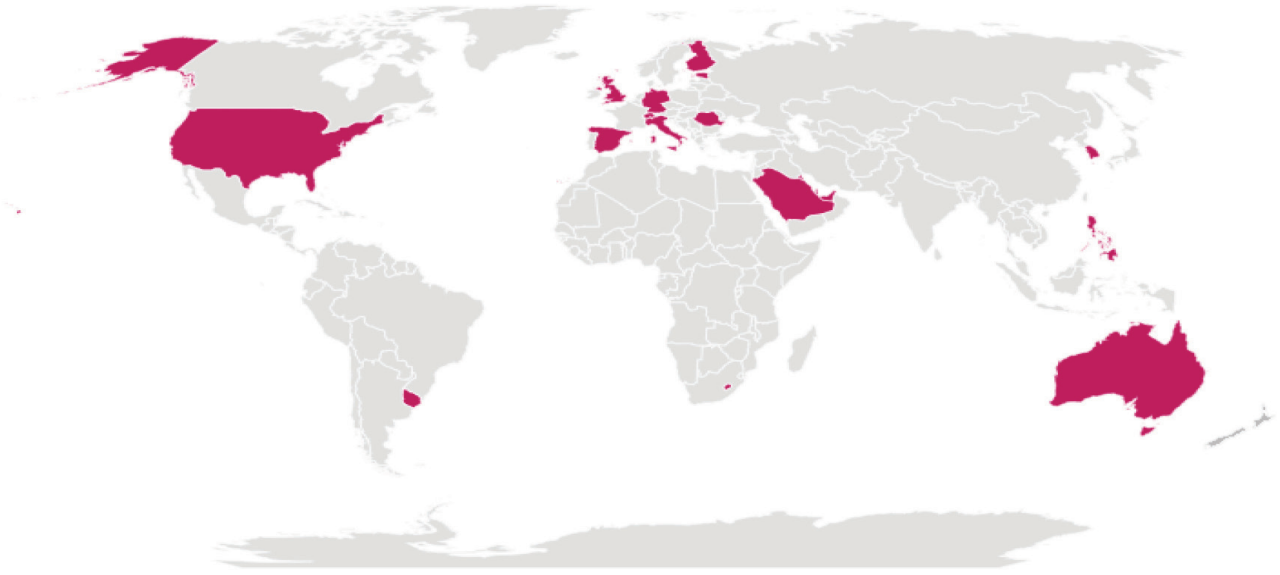
Plans are already underway to introduce 5G in LAC countries. ANTEL, the Uruguayan state-owned telecommunications MNO, made the first 5G call on a commercial network in the LAC region in the 28GHz band. Telebrasil, the Brazilian mobile telecoms company, signed an agreement with China, the European Union, South Korea, and the United States on 5G technology support. The Brazilian government is also laying the foundation for introducing 5G by establishing the Internet of Things (IoT) Innovation Center with Ericsson. Telcel, a Mexican MNO, announced a plan to distribute 5G in 2020. Argentina has also conducted tests in cooperation with Ericsson, and Colombia is planning to

conduct a 5G network test. Chile has been testing 5G with Nokia, and Huawei and Claro are continuing their cooperation on IoT.

Thus, the race for 5G deployment has already begun in the LAC region. However, the region faces many challenges. There are many places where fixed-line networks are not in service, and many people still do not have access to 3G and 4G mobile broadband services,¹³ which makes it difficult to build 5G infrastructure immediately. Several of the main challenges in building 5G—high implementation cost, securing spectrum, strengthening institutions, and activating 5G services—are presented below, along with suggested solutions for each one.

¹³ According to GSMA (2016), only 33 percent of the population in the LAC region uses 3G and 4G mobile broadband services; 10 percent are not covered by a mobile broadband network, and 57 percent are covered but do not subscribe to mobile broadband.

FIGURE 3.2 5G Leadership Index



Country	Operator	Country	Operator
Australia	Optus, Telstra	Qatar	Ooredoo, Vodafone
Bahrain	Bateico, Viva	Republic of Korea	KT, LGU+, SKT
Estonia	Elisa	Romania	RCS&RDS, Vodafone
Finland	Elisa	Saudi Arabia	STC
Germany	Deutsche Telekom	Spain	Vodafone
Italy	TIM, Vodafone	Switzerland	Sunrise, Swisscom
Kuwait	Ooredoo, Viva, Zain	UK	EE, Vodafone
Lesotho	Vodacom	UAE	Du, Etisalat
Monaco	Monaco Telecom	Uruguay	Antel
Philippines	Globe	United States	AT&T, Sprint, T-mobile, Verizon

Source: GSA (2019).

High Implementation Cost

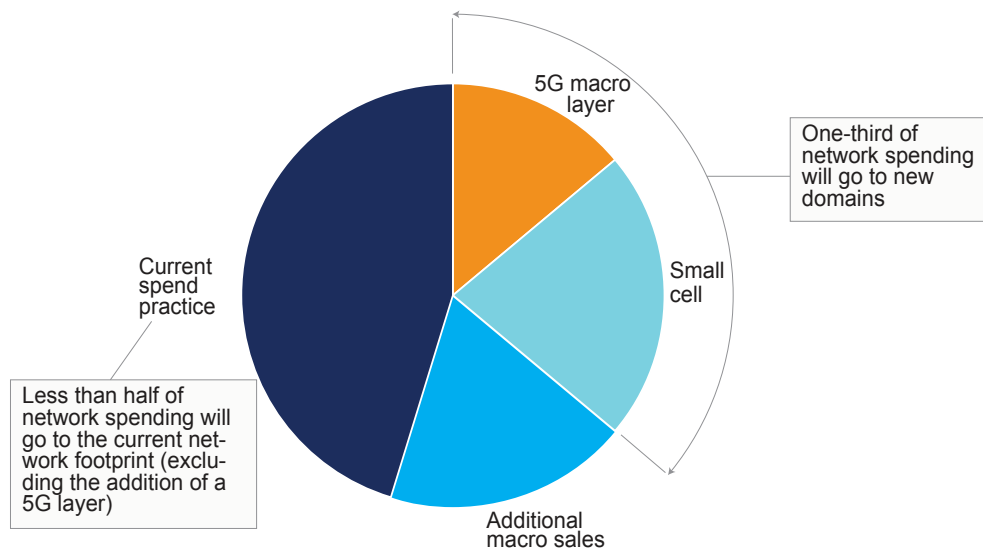
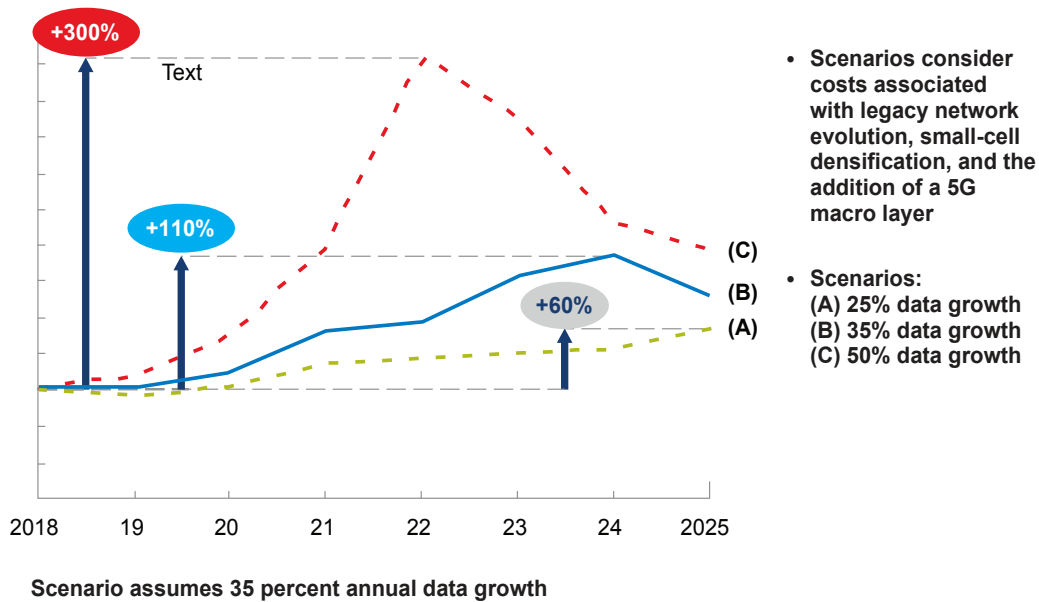
Challenges

Deploying 5G networks is costly. New 5G base stations and core networks must be established to provide 5G service. Because of poor propagation characteristics of the high frequencies used in 5G, the number of base stations needed to cover the same area is greater than those needed for 3G and 4G. In addition, the unit price per 5G equipment is currently higher than that of 4G equipment. The cost of renting and managing many base station sites

because of the introduction of small cells cannot be ignored. Backhaul networks need to be extended into high-capacity fiber networks to accommodate the vast amount of data traffic generated by 5G. Fixed-line Internet networks and IXT connected to 5G network may also require additional capacity to accommodate increasing 5G traffic.

According to a report by McKinsey & Company (2018a), which analyzes the cost of deploying and operating mobile networks from 2018 to 2025, the annual capital and operating cost of 5G networks will increase by 110 percent at most from the current level. Moreover, the total cost of the 5G network

FIGURE 3.3 Growth of Infrastructure Cost



Source: McKinsey & Company (2018a).

will be about one-third of the total cost, assuming an annual data growth of 35 percent (Figure 3.3).

In an internal report issued by a South Korean MNO, the number of 3.5GHz 5G base stations is predicted to be 2.7 to 3.5 times more than that of existing 4G base stations, considering relatively weak radio propagation characteristics in the 3.5GHz band used for nationwide 5G networks. Because of the 5G technology characteristics of beam forming and multiple input, multiple output (MIMO), it is

necessary to introduce antenna integral base station equipment to increase the number of 5G base stations at the LTE antenna branch level. Additionally, the reduction of radio coverage in the 3.5 GHz band and the reduction of coverage due to the introduction of TDD symbolic ratio raise the number of base stations needed in 5G networks.

Millimeter-wave bandwidth frequency characteristics make it difficult to penetrate obstacles such as buildings. As shown in Figure 3.4, for example,

TABLE 3.1 Factors Increasing Number of 3.5GHz Base Stations in 5G Network (Compared to LTE)

Factors	Reasons	Level
The number of antenna branch	The increase of the number of base stations in a cell	2.3 times
Degree of radio attenuation	To compensate the coverage reduction resulting from high frequency characteristic of 3.5 GHz	1.2 times
Changes of the symbolic ratio	To compensate the coverage reduction resulting from the introduction of TDD symbol ratio	1~1.3 times
Total cost (3.5 GHz nationwide network)		2.7~3.5 times

Source: Authors' elaboration.

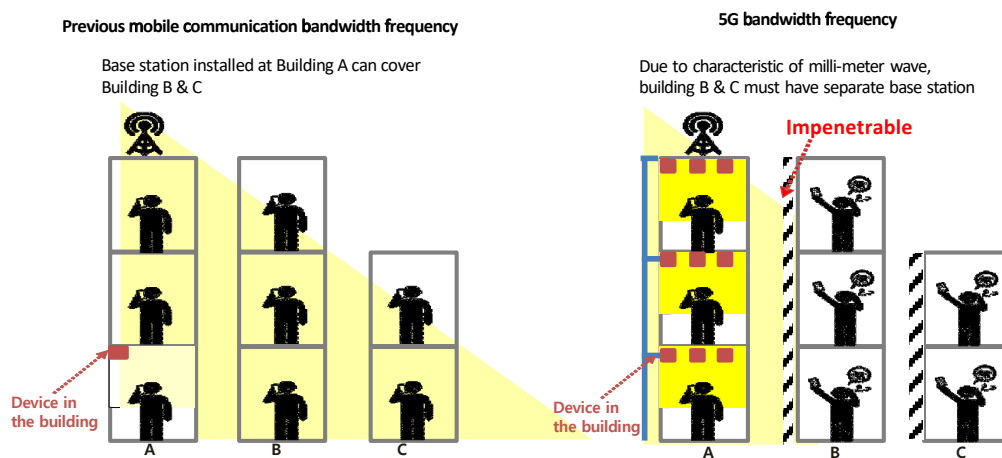
base stations should be increased in proportion to the number of buildings to eliminate shaded service areas within buildings. The high probability of attenuation of millimeter waves caused by obstacles such as trees and rainfall can also significantly increase the number of base stations needed.

Recommendations

The high cost of introducing 5G may pose a major obstacle to 5G expansion by discouraging MNOs from investing. Even after completing the deployment, MNOs may significantly impede 5G user affordability by raising service rates to recover their substantial investment costs. To minimize 5G deployment costs, various types of PPPs in which the government supports private 5G deployment or partially participates in 5G deployment should be considered.

Various government policies could be developed to reduce costs. First, infrastructure sharing, in which networks are shared by various providers, could reduce costs. Infrastructure sharing involves not only sharing passive elements such as physical sites, conduits, and street lamps, but also active sharing methods that share electronic components, such as base stations and cables. McKinsey proposed an infrastructure-sharing approach as a major way to reduce 5G costs, predicting that it would save more than 40 percent of the cost of deploying 5G small cells and the 5G macro layer. In addition to reducing costs, infrastructure sharing can address possible social problems caused by the separate installation of 5G equipment and underground optical cable lines, collisions with existing urban facilities, and visual pollution and public hazards.

FIGURE 3.4 Countries with OMNOs Investing in 5G Networks



Source: Authors' elaboration.

FIGURE 3.5 5G Cost Reduction due to Network Sharing



Network sharing is a lever that can reduce ~40% the cost of 5G related access network domains (small cells and 5G macro layer)

Source: McKinsey & Company (2018b).

The government could create a public investment fund to stimulate private 5G investment. In 2016, the government of the United Kingdom established the National Productivity Investment Fund (NPIF), contributing 0.74 billion pounds to support the deployment of 5G and optical networks. The Chinese government plans to invest around US\$411 billion to build 5G between 2020 and 2030. However, it will not be easy for governments in developing countries with limited fiscal space to create large public funds for 5G. Thus, part of a fund's creation plan could involve using the proceeds from a 5G spectrum auction. For example, Korea prepared the legal basis for introducing a spectrum auction system by revising the Radio Frequency Act in 2010 and secured US\$8.2 billion in revenue from the auction through three 4G LTE spectrum auctions in 2011, 2013, and 2016

and one 5G spectrum auction in 2018. In this way, it raised sufficient public funds for 5G proliferation.

Another possibility is introducing tax cuts to stimulate 5G deployment. As explained in Chapter 2, the Korean government passed a bill in 2018 to reduce corporate taxes by up to 3 percent of its investment in 5G base stations to encourage MNOs to build 5G networks. In addition, some cost savings can be expected by lowering inspection costs imposed by the government on base station installations.

Securing and Allocating/Assigning the 5G Spectrum

Challenges

To establish a 5G network, it is necessary to secure spectrum for that purpose in advance. However, not

TABLE 3.2 Definition of Frequency Ranges

Frequency range designation	Corresponding frequency range
FR1	410 MHz – 7125 MHz
FR2	24250 MHz – 52600 MHz

all frequency bands can be used for 5G. Only bands that 3GPP designates as 5G standard bands can be used for 5G. The reason why standard bands are designated is to lower the development and production costs of chips, devices, equipment in the band. If a 5G network is deployed in a band other than the 5G standard band, it may not be profitable because the market for the band would be small.

Broad and contiguous spectrum is essential for providing high-speed 5G services. To that end, global MNO group GSMA (GSMA, 2019) recommends securing 80 to 100 MHz contiguous spectrum in sub-6GHz bands and 1GHz in millimeter-wave bands. Considering the initial worldwide demand for 5G spectrum, GSMA recommends 3.3

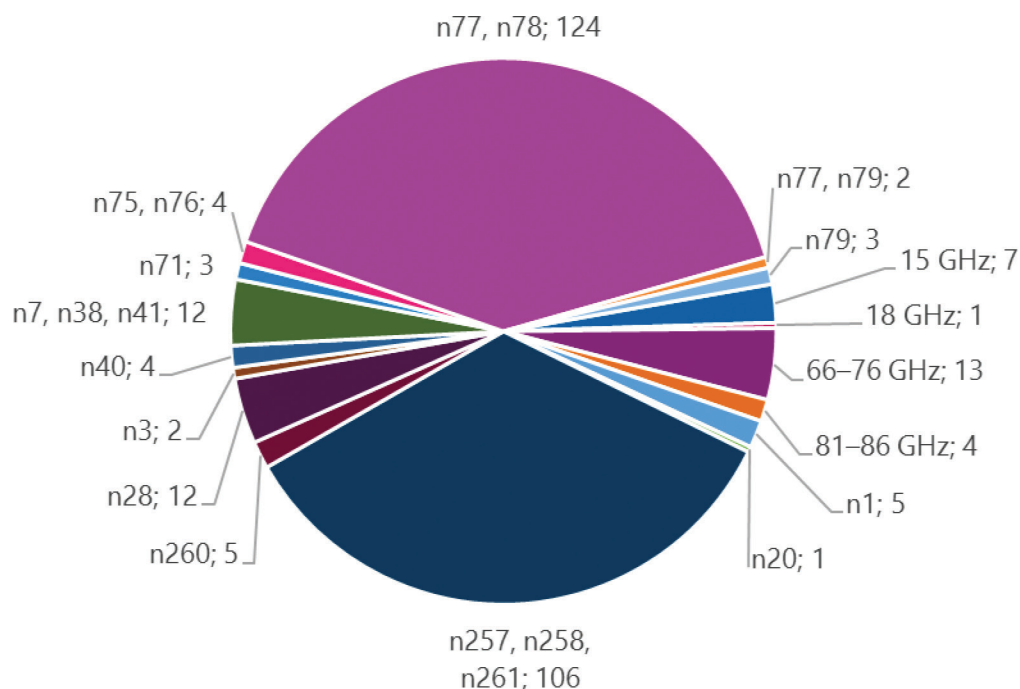
to 3.8 GHz (n77, n78) bands¹⁴ for sub-6GHz bands and 26GHz (n258) and 28GHz (n257, n261) bands for millimeter-wave bands. Figure 3.6 shows a spectrum band in which MNOs around the world have invested. Many MNOs have selected the n77, n78, n257, n258, n261 bands recommended by GSMA for 5G bands.

It may not be easy to get the broad standard bands that 5G networks require in some countries. In principle, spectrum cannot be used for multiple purposes¹⁵ at the same time and at the same place due to interference. Therefore, if all the 5G standard bands are already being used for other purposes in a specific country, 5G networks cannot be deployed even if they enjoy strong political will and enough funding. In addition, if 5G candidate bands

¹⁴ GSMA mentions 1.8GHz, 2.3GHz, and 2.6GHz bands as an alternative to 3.3–3.8 GHz band.

¹⁵ Spectrum can be used for multiple uses if its uses are divided into time, geography and space, but in principle, spectrum is used for only a single use in a single time and an area.

FIGURE 3.6 Count of MNOs' 5G Investments by Spectrum Band; Number of MNOs Investing in Each Band



Source: GSA (2019) Global Progress to 5G – Trials, Deployments and Launches.
 Note: Includes MNOs paying for licenses, testing/trialing, deploying, and those with launched services.

TABLE 3.3 New Radio (NR) Operating Bands in FR1

NR operating band	Uplink (UL) operating band BS receive / UE transmit FUL_low – FUL_high	Downlink (DL) operating band BS transmit / UE receive FDL_low – FDL_high	Duplex mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
n18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n30 ³	2305 MHz – 2315 MHz	2350 MHz – 2360 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n48	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD ¹
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD ⁴
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780 MHz	N/A	SUL
[n90]	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD ⁵

TABLE 3.4 NR Operating Bands in FR1

NR operating band	Uplink (UL) operating band BS receive / UE transmit FUL_low – FUL_high	Downlink (DL) operating band BS transmit / UE receive FDL_low – FDL_high	Duplex mode
N257	26.5 GHz – 29.5 GHz	26.5 GHz – 29.5 GHz	TDD
n258	24.250 GHz – 27.5 GHz	24.250 GHz – 27.5 GHz	TDD
n260	37 – 40 GHz	37 – 40 GHz	TDD
N261	27.5 MHz – 28.350 GHz	27.5 MHz – 28.350 GHz	TDD

Source: 3GPP TS 38.101-1 v16.0.0 (2019).

are being used for other purposes, it may take a long time and may even be impossible to withdraw and reallocate them for 5G use. That is why 5G spectrum should be secured as soon as possible before establishing 5G networks.

Once 5G frequency is secured, sophisticated auction¹⁶ method of 5G spectrum should be prepared. Because of high frequency and broadband characteristics of 5G spectrum unlike 3G and 4G spectrum, all the specifications related to the 5G spectrum auction, such as auction rules, reserve price, and network construction obligations, are different from those of the 3G and 4G spectrum auction. Auctions in which the characteristics of 5G spectrum are not reflected adequately can cause serious problems later on, such as an excessive or small winning price, the occurrence of unbid spectrum, and unbalanced 5G market competitiveness.

Recommendations

The most widely used solution for acquiring broad contiguous 5G spectrum where it is not currently available is the withdrawal and relocation of spectrum. To acquire a new 5G band through withdrawal and relocation, it is necessary to identify the status of 5G standard bands and select a band that is easy to abolish or move existing wireless stations in the band. However, vacating the spectrum bands that are being used for other purposes could create a backlash from existing users or could be costly and time-consuming. Korea invested around US\$10 million over two years to transfer wireless stations to other bands to secure spectrum for 5G with the 300 MHz bandwidth in the 3.5 GHz band.

As a prerequisite for withdrawal and relocation, accurate data on the use of radio stations is essential, and radio wave monitoring systems that can identify and resolve illegal spectrum utilization are also required.

Another way to acquire 5G broadband spectrum is to standardize a country's available spectrum that is not a 3GPP standard band at the time. This method, however, would not work if the market size for the band is not large enough. Even after the band is standardized, if the market for it is not promising, it is likely that manufacturers of the chips, handsets, and equipment would not produce the products. For these reasons, this method requires efforts to establish sufficient market size by securing allies for bands that are to be standardized, such as cooperation with other countries, manufacturers, and MNOs.

To establish an effective 5G spectrum auction plan, some factors should be considered, such as supply and demand of 5G spectrum, the effect of spectrum auction results on 5G investment, and the impact of the spectrum on market competitiveness. When setting the reserve price and auction rules, it is necessary to secure the economic value of the spectrum, while not discouraging MNOs

¹⁶ Auction methodology can be considered an effective way of assignment if there is a competitive demand from multiple operators. Compared to the beauty contest which was applied widely in the past, auction is adopted as a universal assignment methodology because it can provide efficient assignment of spectrum which is a limited national resource, realizing the maximum value of spectrum, maximizing social benefits, and expanding the fairness and financial income.

from building networks. In other words, setting too high a reserve price and inducing excessive bidding competition could lead to excessive auction prices that would subsequently discourage investment and lead to ‘winner’s curse.’ Conversely, auction rules that have too low a reserve price can lower the value of scarce public resources and result in losses of fiscal revenue. When determining the spectrum cap, which is the maximum bandwidth an MNO can take, the difference in market competitiveness due to deviations in the amount of spectrum available among MNOs should be taken into account. A high spectrum cap may activate bidding competition in an auction, but competition in the 5G market will likely be unbalanced in the future as there will be significant deviations in the amount of spectrum among MNOs. When imposing network deployment obligations on MNOs in many countries to activate network development, the impact of the deployment obligation should also be reviewed. In the case of 5G spectrum with high network deployment costs, especially for millimeter-wave bands, imposing overly high deployment obligations may place an unaffordable burden on MNOs, while a low duty may widen the digital divide between urban and rural areas.

Institutional Issues

Challenges

When establishing a 5G network, many institutional problems, which arise from the differences between 5G network and previous generation mobile networks, must be solved. First, 5G small cells may not be allowed under current power density regulations in many countries. Unlike previous generation networks, where base stations were located on high-rise buildings and power transmission towers around highlands, quite far from homes and workplaces, massive numbers of small cell base stations in 5G will be deployed on poles and streetlights adjacent to homes and workplaces. This can increase the power density of mobile base stations, seriously threatening human health.

FIGURE 3.7 Small Cell Deployment



Source: Crown Castle (2017).

The environmental impact of 5G is another challenge that must be tackled. The construction of new facilities for 5G, such as base stations and conduits, may violate current regulations for the preservation of the environment and historical sites, which may be an obstacle to the deployment of 5G networks.

Another potential institutional problem resulting from the introduction of 5G is network slicing. Network slicing provides multiple logical networks over a single physical network, which can support applications with different requirements, including different latencies, reliability, and speed, over the same physical network. Despite the advantages of network slicing techniques, there is the possibility of undermining network neutrality if a network MNO unfairly discriminates against or blocks users by using network slicing.

5G is enormously important as social infrastructure that will change industries, economies, and societies of the future. Because of its centrality, however, the potential collapse of the 5G network would bring about enormous social and economic threats and losses. For example, if self-driving cars or smart cities lose control of 5G-connected facilities and devices due to external hacking or breakdowns, the damage would not be limited to information leakage and financial damage; it could be catastrophic throughout society. Thus, maintaining and enhancing the security and stability of

5G networks is an essential task that must be undertaken with great diligence.

Recommendations

To facilitate the establishment of 5G networks, telecommunication policies must be updated to meet the needs of changing telecommunications markets. Regulations that protect public health and preserve the environment as well as historic sites must be adopted after adequate research and consultations have been conducted. Against this backdrop, regulators in various European countries are discussing the elements of revised power density-related regulations so that all EU members can establish 5G networks in time. The U.S. Federal Communications Commission FCC is also revising existing environmental laws and historic preservation-related bills to accommodate the coming roll-out of 5G networks.

It is difficult to predict at this stage whether network slicing would violate network neutrality in the future, because network neutrality depends not only on technical performance, but also on market demand, competition, regulation, and other factors. Appropriate measures must be adopted in advance to confront any institutional problems that may arise in the area of network neutrality issues.

The most effective approach to securing 5G infrastructure is to require MNOs to introduce reliable and secured equipment. A 5G certification management system should be established that allows safe equipment to be introduced and continuously inspected and managed, and that sets security standards so that only securely certified (ISO or any global security certification) 5G equipment and devices can be adopted. However, even if equipment is designed with security in mind, it could be vulnerable to unforeseen security issues. Since 5G is a key foundation for the societies of the future, it is also necessary to develop comprehensive countermeasures and response systems to confront unexpected future 5G security threats.

Expansion of 5G Specialized Services and Applications

Challenges

The significance of 5G is not just about establishing networks; its main value is in the social and economic benefits that will accrue to society through the use of its functions and capabilities. It is therefore important to plan how 5G will be used once the network is established. To maximize the benefits of 5G, new industries should be intensively developed that enable 5G to be integrated into the economy and society, enhancing people's quality of life. In addition, 5G accessibility should be increased so that people can enjoy its benefits regardless of their location, socioeconomic status, or age.

Recommendations

To increase the benefits of 5G to the economy and society, governments can develop related public projects to create proactive demand for 5G. Real-time monitoring systems can be established at major social overhead capital, such as roads, ports, airports, hazardous facilities such as nuclear power plants and gas facilities, and educational and cultural facilities, to provide safe and efficient management. Incorporating 5G into projects related to education, health care, agriculture, and the environment will not only improve the quality of people's lives but will also stimulate development of the 5G market. Policy support can be helpful in distributing key 5G services. For example, supporting demonstration projects, creating test beds, and fostering startup companies will encourage the development of new 5G industries, such as immersive contents, smart factories, self-driving cars, smart cities, and digital health.

To narrow the 5G accessibility gap between urban and rural areas, there may be ways for the government to invest directly in network deployment, or to induce or enforce private MNOs to deploy 5G networks in rural areas. These methods include

requiring MNOs to deploy the network in rural areas when assigning spectrum.

To encourage more people to use 5G services regardless of their economic status, 5G rates must be affordable. However, it is unreasonable to expect private MNOs to voluntarily lower rates for 5G network services. Therefore, the government should make 5G service more affordable by stimulating competition among MNOs. The South Korean government controls the service rates by approving the service tariffs charged by leading MNOs. In this way, the overall telecommunication service rates remain at a level that is accessible to all.

To provide access to 5G the poor, the elderly, the disabled, and people in rural areas, separate funds should be created. Many countries are currently establishing universal service funds for this purpose.

5G National Master Plan

Challenges

The challenges and recommendations described thus far are related to the construction and utilization of the 5G network. These issues have general solutions common to every country. But to maximize the benefits of 5G network, a sophisticated plan that is specific to each country's situation should be developed, based on a long-term vision and stakeholders' interests. Even for developing countries that lack the economic capacity to build a 5G network, it is not too early to develop a 5G master plan, given the importance of 5G to the economies and societies of the future. Especially, it is not too soon to draw up detailed plans for securing 5G spectrum and financing, which can take a long time to prepare.

Recommendations

Developing countries, including those in the LAC region, which have little experience and know-how in mobile network deployment, can receive outside assistance to establish a 5G master plan. The Inter-American Development Bank uses the Korean Trust Fund (KTF), the Korean government's grant, to support various projects in LAC countries, including the establishment of telecoms networks. These projects are useful in benchmarking best practices from countries that have already deployed and are utilizing 5G networks, such as Korea, several European countries, and the United States. They also provide LAC countries with the technologies, policies, regulations, and legal frameworks required to deploy 5G networks and receive customized recommendations.

In addition, establishing and implementing a 5G master plan requires whole-of-government 5G governance with a strong central command. Individual ministries are limited in their ability to handle all the issues surrounding 5G, because 5G is applied in every sector. In the United Kingdom, a Commission was established at the Department of Culture, Media, and Sport (DCMS) to grant the authority and responsibility to build 5G infrastructure with DCMS, and digital infrastructure groups were organized to promote the exchange of views and cooperation among ministries.

Conclusions

This chapter identifies a number of challenges, such as the high cost of deploying 5G, the need to readjust existing use of frequencies and revise relevant policies, the need to develop applications, and the establishment of a government-wide master plan.

4

Roadmap to 5G in Latin America and the Caribbean

Like previous generation mobile network, it is predicted that multiple MNOs—mainly private businesses—will establish and operate 5G networks. With the large initial investments required to establish 5G networks, private MNOs are not likely to make investments in 5G networks voluntarily if their profitability is not guaranteed. It is unreasonable to expect the private sector in the LAC region to invest in 5G networks when the investment costs of recent LTE infrastructure have not yet been recovered. Thus, early deployment and widespread use of 5G networks in the LAC region will require the participation of private MNOs. Governments should encourage their involvement through regulatory reform, the introduction of 5G supporting institutions, and financial incentives.

This chapter presents a three-step roadmap for the entire process of building and utilizing 5G networks. The first phase consists of a status analysis and preparation of the 5G master plan; the

network deployment plan is implemented in the second phase; and in the third phase, utilization of the deployed network is maximized.

Phase 1: Preparation

The preparation phase is to establish the national 5G master plan, which includes network deployment and utilization plans. To establish a network deployment plan, a relevant status analysis is carried out first. It identifies the demand for the 5G network, potential network builders, institutional and financial difficulties in investment in the network, the status of securing 5G spectrum, and stakeholder positions.

Based on the results of the status analysis, the national 5G master plan should include specific relevant topics, such as spectrum supply, system improvement, investment incentives, financial support, and joint implementation measures MNO.

TABLE 4.1 Roadmap to 5G

	Phase 1	Phase 2	Phase 3
Main activities	<ul style="list-style-type: none"> Establish national 5G master plan Network deployment Utilization plans 	<ul style="list-style-type: none"> Activities prior to the building networks <ul style="list-style-type: none"> Allocate/assign spectrum Improve certification system Keep monitoring 	<ul style="list-style-type: none"> Implement 5G new services, integrate with existing industries, and expand 5G public services Enhance accessibility, affordability Strengthen security and securing stability
Duration	With 2 years	Years	Years
IDB support	Technical cooperation project	Loan project	Loan project

Source: Authors' elaboration.

The 5G network utilization plan is designed to maximize utilization of the 5G network that has been established. It includes developing and applying various new 5G application services, such as smart cities, smart factories, self-driving cars, and digital healthcare, which use 5G's ultra-fast and real-time characteristics. In addition, productivity improvement and industrial innovation are promoted through integration with other industries, such as machinery, chemicals, electronics, energy, and biotechnology. Measures to apply to the public sector, such as social overhead capital, education, administration, welfare, health care and civil service, are also proposed to enhance quality of life.

The duration of the preparatory phase will vary depending on the situation of each country but is expected to be completed in two years. As in the case of the Republic of Korea, the utilization plan may be set up separately at the beginning of the second phase. Leveraging the IDB's Korea Trust Fund will help LAC countries develop a national 5G master plan.

Phase 2: Deployment

After each government's commitment to building and utilizing is clearly expressed through its national 5G master plan, incentives must be created for MNOs to deploy 5G networks. If the MNOs express their intention to deploy them, 5G network deployment can be initiated under the leadership of MNOs. However, the government must play a proactive role in helping MNOs to build 5G networks, as described below.

First, the government allocate/assign spectrum. As explained in Chapters 1 and 2, spectrum auctioning should take diverse aspects into account. A reasonable level of deviation of the spectrum supply between MNOs to induce market competition should be considered. Also, a reasonable price of spectrum should be set not only to maintain their willingness to invest in networks but also to eliminate the possibility of MNOs' passing the cost to customers due to the excessive cost of spectrum. Appropriate network deployment obligation level—not too high nor too low—should be assigned not to

give MNOs too much burden, but to induce MNOs to deploy 5G networks throughout the country, thus provide 5G service to more people. In addition, a certification system suitable for new 5G equipment, new base station permits, and inspection systems should be prepared to appropriately respond to requests from manufacturers and businesses.

Once these activities are completed, such as the allocation/assignment of spectrum and certification system, MNOs will be able to establish networks. The government should monitor the network deployment and resolve problems that may arise during the deployment process, such as the need for system improvements, differences over joint deployment, and others. In addition, appropriate measures should be taken to ensure that MNOs properly perform their obligation to build networks and to correct them in the event of non-compliance.

The deployment phase can begin immediately after the first phase of preparation, or it may take years depending on the MNO's ability and intention to deploy. The actual 5G network deployment period takes years, as it is first built around the city center and then expanded nationwide. Direct investment or financial support by governments may be required to provide 5G services in rural areas where MNOs will not deploy the network due to its low profitability. In this case, an IDB loan is a good alternative to finance the deployment.

Phase 3: Utilization

Once the 5G network is established, it should be widely used. The government should lead the implementation of new 5G services, their integration with existing industries, and expansion of public services to enhance people's quality of life.

During the utilization phase, continuous improvement of related institutions is required to expand the uses of 5G. Measures to enhance accessibility and efficiency and tax incentives to increase private investment should also be considered.

Finally, the government should strengthen cyber security in response to hacking, viruses, and other threats to the system, and should prepare

countermeasures to secure continuous operation and use of the networks in the event of natural or man-made disasters.

5G utilization can be initiated as soon as the service is initiated—months after the completion of deployment—even if Phase 2 is not yet complete. As with Phase 2, budgets for expanding utilization can be funded through the IDB.

Conclusions

There is no “one size fits all” in information and communication technology policy. It is not feasible to provide a single roadmap for every LAC country,

given their diverse socio-economic situations and institutional cultures. Therefore, a 5G plan that is tailored to a specific country should be devised. If governments are proactive in considering policies and seek solutions that are tailored to their environment, building 5G infrastructure can be far easier. Policies should be developed considering the tasks mentioned in Chapter 3. The IDB supports technical cooperation (TC) projects that provide research on optimal national policies. Through these projects, financed by the Korea Trust Fund, LAC countries can obtain technical and financial assistance to support the planning and deployment of 5G networks.

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