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Research on observation of the evolution of the new generation communications technology and the development of the regulatory policy

Executive Summary

Telecom Technology Center

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Executive Summary

Chapter 1 Introduction

The development of new-generation communication technologies not only creates opportunities for the global mobile communication industry, but also poses new challenges to the regulatory systems of competent regulators worldwide. Among the new technologies, since 5G mobile communication technology has the characteristics of higher network transmission speed, low latency, and massive machine connection, it has great potential for developing innovative applications. In other words, the use of new communication technologies will promote the transformation of the entire society in areas that are related to people's daily life, such as food, clothing, housing, transportation, education and entertainment, and play an important role in the transformation of the digital economy in Taiwan.

The new-generation communication technology, i.e., 5G communication, not only affect the traditional telecommunication industry, but also several vertically-linked industries, including manufacturing industry, transportation industry, energy industry, medical industry and entertainment industry. The changes made by the introduction of 5G communication technology also bring challenges to the planning, preparation and release of government resources, as well as the existing regulatory framework.

This research project aims to understand the evolution and development trends of the new-generation communication technologies. Through literature review, case studies, comparative analysis, interviews and conferences, specific plans to carried out for the development of new-generation communication technology by international organizations and related institutions. In addition, this research already collected the promotion measures, supervision policies and related regulations for new-generation communication technologies in major countries. The scope included the spectrum supervision specifications of various emerging

technologies adopted by major countries, the focus of the policy for promoting the country's emerging technologies, the development and release schedules of candidate band, and the specifications for the innovative application license structure. Based on the relevant policies and measures of various countries as a whole, and taking into consideration the situation of Taiwan as well as the current status of the broadcasting & communication industry and the use of spectrum, we assisted national regulator to complete the environment and ecological system for the supervision regulations of new-generation communication technologies, while adhering to the principles of fulfilling the overall business needs, technological evolution, and industrial policy development trends.

This summary report is divided into 9 Chapters. Chapter 1 is the introduction, Chapter 2 introduces the technology development trends of major international organizations, and Chapter 3 to Chapter 8 correspond to the issues of each key area. Each Chapter described the international experience first, and then propose the recommendations for the policies studied in this project after considering the current status of Taiwan. Chapter 9 is a review of the implementation results and research objectives of the project.

Chapter 2 Observation on New-Generation Communication Technology Development Trend

Section 1 ITU

The ITU started to work on the specifications of the IMT-2020 (5G) communication system in 2012, and completed the IMT (International Mobile Telecommunication system, IMT) vision in 2015; a report on the future development of the IMT framework from 2020 and beyond. In 2016, the ITU started to carry out discussions on the technical specifications and the evaluation standards as well as methods. At the end of 2017, an operation team was convened to provide information such as the template

for the IMT-2020 proposal, the minimum technical requirements, and the evaluation standards as well as methods. In addition, invitations were sent to those who are involved, requesting them to submit their self-defined 5G standards and specifications. The deadline for the submission was July of 2019. The recommendations submitted by member countries or international organizations will be reviewed and verified by an independent external assessment team to ensure that they are in compliance with the technical criteria required by the IMT-2020. The overall process is expected to be completed by the end of 2020. The milestones of the ITU's 5G technology development plan are shown in Figure 1.

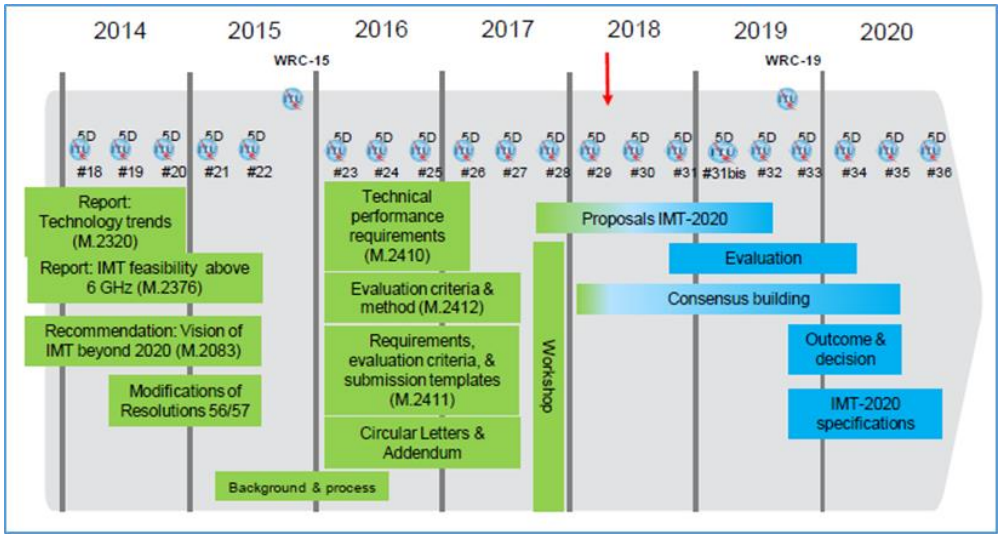

Figure 1： Overall schedule for the establishment of the IMT-2020 system specifications by ITU-R

Source：ITU-R

The International Telecommunication Union-Radio Communication Department (ITU-R) is a major unit of the ITU for developing regulations and standards for radio communication systems. The ITR-R is crucial for the management of the next-generation IMT technologies and standards. For the standardization in 2018-2019, the ITU-R is currently conducting assessments on different 5G-technology related studies and proposals, and carrying out the preparation work for the WRC-19.

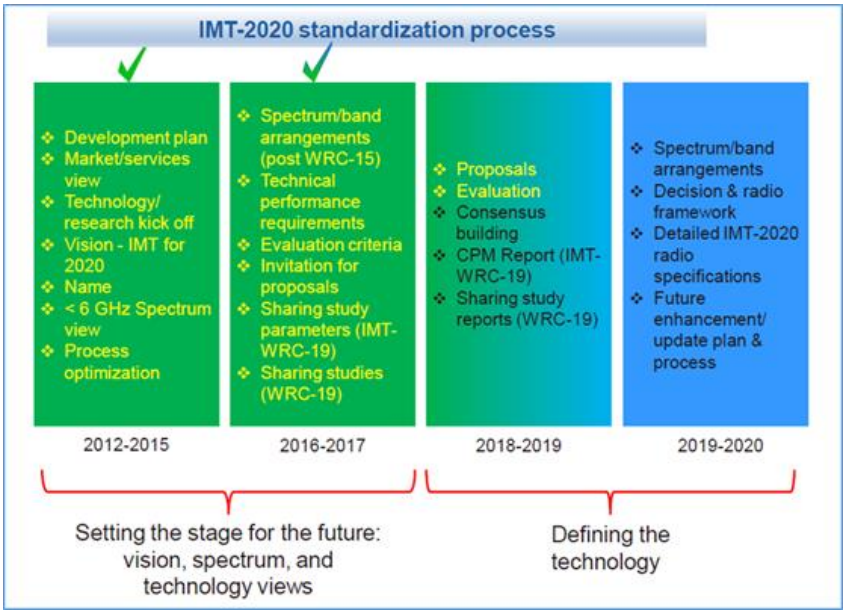

Figure 2： Standardization schedule of ITU-R for the IMT-2020

The ITU host a four-week World Radiocommunication Conference (WRC-19) in Egypt from October 28 to November 22, 2019. Besides taking into account the achievements of the WRC-15 and the report of the conference preparatory meeting, current and future needs of the involved frequency bands should also be considered. With regards to the candidate spectrum, the ITU-R agreed to study a set of global frequencies for 5G99. These frequencies will be decided at the 2019 World Radiocommunication Conference (WRC-19). The planned 5G candidate bands are shown in Figure 3, which include 24.25–27.5 GHz, 31.8–33.4 GHz, 37–40.5 GHz, 40.5–42.5 GHz, 42.5-43.5 GHz, 45.5–50.2 GHz, 50.4–52.6 GHz, 66–76 GHz, and 81–86 GHz.

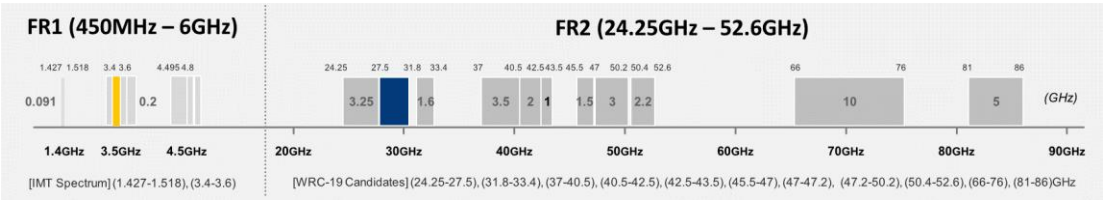

Figure 3：5G candidate bands planned by the ITU-R for the WRC19

Source：ITU。

Section 2 3GPP

Currently, the emphasis of 3GPP's work is on the establishment of the Release 16 (Rel-16) specifications. The Rel-16 is the main version of the second-phase item for the establishment of the 5G New Radio (NR) standards, particularly because it will enable 3GPP to submit the IMT-2020, offering the initial and complete 5G system.

The Rel-16 communication standards established by the 3GPP are expected to be completed in March 2020. In addition, the 3GPP also proposed the IMT-2020 Final Submission to the ITU-R in June 2019 based on the results of the Rel-16, the results of the Rel-15, and the system performance evaluation report of the combined results. The related schedule is shown in Figure 4.

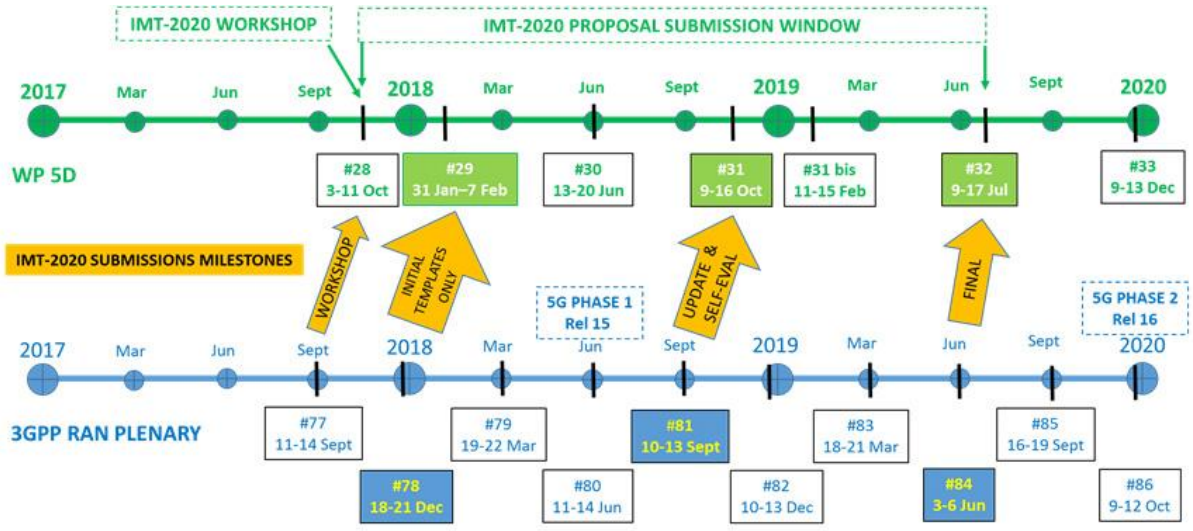

Figure 4： Schedule for the development of the Rel-16 by the 3GPP

Source：3GPP。

The frequency spectrum usage issues discussed by the 3GPP Rel-16 includes the use of the 6GHz frequency band for LTE and NR and the use of the frequency band above 52.6 GHz for NR. Regarding to the use of the 6 GHz frequency band, the 3GPP hopes that organizations around the world can provide a range of available frequency bands for reference, so

that scattered frequency bands can be used more efficiently to integrate the designs of the overall communication system. As for the use of frequency bands above 52.6 GHz, it is quite challenging. There are several difficulties in the design of radio frequency hardware alone, such as the use of power amplifiers and the noise from radio frequency circuits. In addition, such high-frequency communication will encounter significant transmission attenuation. How to design a good transmission waveform while considering the scattering conditions of the frequency band will be the major challenge for the use of the 52.6 GHz frequency band.

Here, the development of several major technologies for 5G NR is discussed. The Non-Orthogonal Multiple Access is the key technology that can be used to distinguish between 5G and 4G. In 5G communication system, in order to support a larger number of devices to carry out wireless communication at the same time, the given time-frequency resource will allow multiple users to access the resource simultaneously, which will greatly improve the spectrum utilization efficiency. Technically speaking, how to carry out appropriate coding by the transmitting end for each user and how to correctly perform decoding of the data by the receiving end for each user are the most important topics that are worth investigating based on the point of view of physical layer communication design.

The enhancement on MIMO for NR is also an important issue for 5G NR. Besides more antennas, 5G communication system also considers the use of high-frequency bands for wireless communication as compared to 4G communication system. The design of multiple-antenna system becomes more important. If the beam-forming technology formed by large number of antennas can be utilized appropriately, the characteristic of severe wave attenuation due to high-frequency bands can be overcome. In addition, the acquisition method for channel status information is also a topic of discussion which is inevitable for the multiple-antenna system. The physical layer enhancement for NR URLLC to support more vertical and real-time applications such as factory automation and transportation industries as well as their data signal format, control signals, and random access signals are all worth designing.

The discussion on the NR-based Access to Unlicensed Spectrum has increased the usage of 5G NR system. With the use of unlicensed spectrum, the connectivity of data can be enhanced. Other topics include the Two-step RACH for NR, the Integrated Access and the Backhaul for NR, the Channel Modeling for Indoor Industrial Scenarios, and the UE Power Saving for NR.

The NR V2X is an important topic discussed by various companies in the 3GPP meetings. The design of the Rel-16 with added sidelink has been widely discussed. Unlike the previous Mode 1, which relies on base stations for resource allocation, Mode 2 can only rely on the car-to-car communication protocol to carry out communication, which is one of the designs that are more difficult to achieve.

In addition, companies basically have reached some consensus on the use of the new V2X. They can be divided into four parts. Cars are lined up while driving. This not only allows cars to stay close together and improves the overall transportation efficiency, but also allows cars to save fuel because proper formation can reduce wind resistance. Furthermore, since the entire fleet is lined up to become a long line, the communication relay between cars can increase the overall transmission distance. As for the automated driving (auto pilot), cars can exchange information with each other to reduce the occurrence of traffic accidents. The exchange of information between cars allows each car to respond in advance, preventing accidents from happening and further improving the overall transportation efficiency. If some communication devices can be installed in the roadside infrastructure, they not only can provide useful information to the cars on the road, but also be used as the communication medium between cars, serving to allocate resources or increase the transmission range. These are the topics that have been discussed in the Rel-16.

Section 3 IEEE

The Institute of Electrical and Electronics Engineers (IEEE) is the world's largest technical professional organization. There is an organization under the Institute of Electrical and Electronics Engineers, IEEE 802.11. The standards developed and designed by the IEEE 802.11 cover the physical layer and data link layer of the Open System Interconnection (OSI) model. The IEEE 802.11 is the most widely used wireless computer network standards in the world. They are adopted by most home and office networks, allowing laptops, printers, and smartphones to communicate with each other and access the network without connecting wires. They are created and maintained by the Institute of Electrical and Electronics Engineers (IEEE) LAN / MAN Standards Committee (IEEE 802).

1. New-generation communication technology development timeline

The IEEE 802.11 work team was established in 1990. The first standard was released in 1997 (2.4 GHz) which supports 1 Mbps and 2 Mbps. The subsequent revisions and updates have improved radio performance and throughput by several levels. The 802.11b 11Mbps standard is the first standard to achieve commercial success. The IEEE 802.11 technology development timeline is shown in Figure 5.

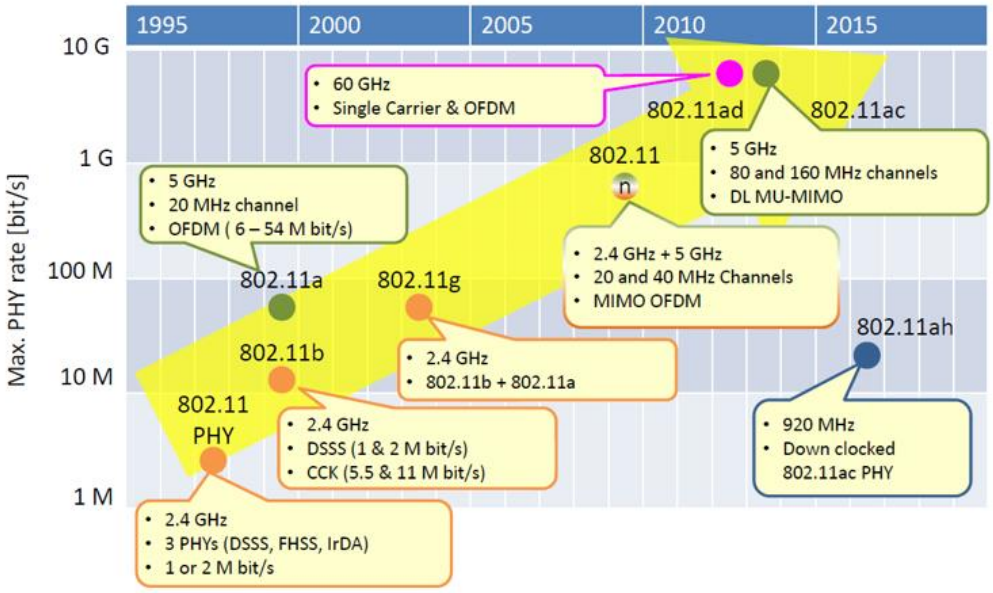

Figure 5：IEEE 802.11 Technology development timeline

Source：IEEE 802.11

2. New-Generation Communication Technology Development and Technology Standard Establishment

（1） IEEE 802.11ax technology development

The 802.11ax, also known as the "High-Efficiency Wireless" (HEW), aims to achieve an extremely challenging goal: to increase the average transmission rate per user in a user-intensive environment by 4 times or more. This new standard focuses on the implementation of the mechanism, hoping to provide a consistent and stable data stream (average transfer rate) to more users in an user-crowded environment. The 802.11ax is not applicable to indoors but outdoors as well.

（2） IEEE 802.11ay technology development

The 802.11ay technology of IEEE is expected to implement a revision in 2020 that defines the standardization modifications for the IEEE 802.11 physical layer (PHY) and IEEE 802.11 media access control layer (MAC), enabling at least one operation mode to support a maximum throughput rate of at least 20 gigabits per second (measured at the access point of the MAC data service), while maintaining or improving the power efficiency of each station. The revision also defines the operation of unlicensed

frequency bands above 45 GHz, while ensuring the backward compatibility and coexistence of traditional directional multi-gigabit base stations (defined by the IEEE 802.11ad-2012 revision) operating in the same frequency band.

The IEEE 802.11ay is a standard that supports enhanced functionality and operates in the unlicensed 60 GHz band. Through specified high-level physical layer (PHY), improved channel access, and enhanced beam-forming training, the IEEE 802.11ay supports a maximum data transmission rate of 100 Gb/s, making it an important standard for applications such as virtual reality (VR), high-density and high-throughput networks and backhauling.

The IEEE 802.11 started from Wi-Fi in the early days and gradually evolved towards diversification, transforming from the IEEE 802.11p car-to-car communication standard design to the newly developing 802.11bd. The most important 802.11ax even achieved the IMT-2020 5G standard and sent an email to the ITU to inform them of the research results via AANI SC, which is a significant breakthrough for the IEEE 802.11 team. Not only that, even though 802.11ay is still under discussion, the study of WiGig in 60 GHz standard has received considerable attention. Besides the use of the most popular devices for its applications, such as the scenario of virtual reality which exhibits short distance but high data transmission, the United States also attaches great importance to such frequency band based on the perspective of spectrum specifications. Among all countries, the United States received the most 60 GHz bandwidth. It is expected that the United States will launch its own standard next year just like 802.11ax.

Chapter 3 New-Generation Communication Candidate Spectrum Global Trend and Recommendation

Section 1 International experience

The International Telecommunication Union (ITU) will determine the requirements and application scenarios for each generation of network, and establish the IMT-2020 standards based on the needs of 5G.

In response to the future digital economy, the demand for mobile communications will increase year by year. According to the projection on mobile communication data transmission in 2020~2030 predicted by the ITU-R's "IMT traffic estimates for the years 2020 to 2030" report, the overall trend continues to grow, and the trend exhibits an exponential growth. It is expected that the pressure on communication infrastructure caused by the substantial increase in data transmission in the next 10 years will rise simultaneously.

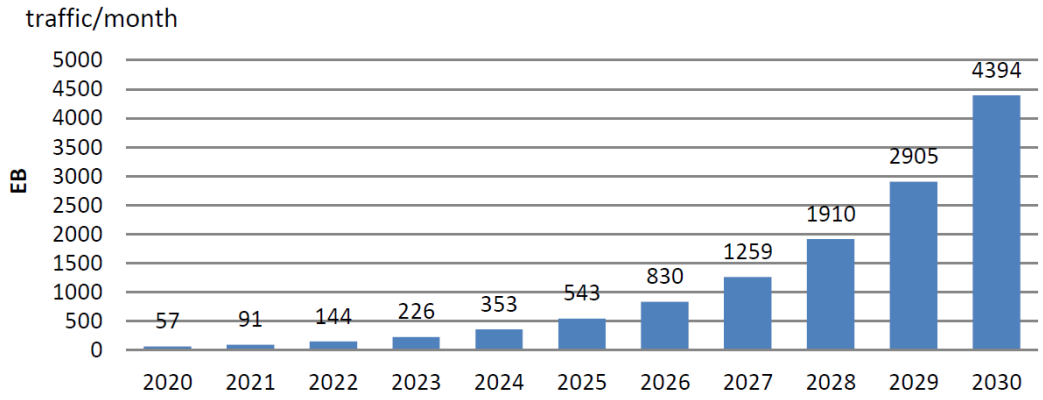

Figure 6： Global mobile communication data transmission in 2020-2030 projected by ITU

According to ITU-R’s M2410 report, the peak spectral efficiency of IMT-2020 must be under the 100 MHz bandwidth with a downlink transmission rate of 30 bit/s/Hz. The transmission rate of 5G network will be greatly increased; however, sufficient continuous bandwidth is required

to achieve the expected transmission rate. For example, when the bandwidth reaches 100 MHz, the peak rate will reach 3 Gbit/s. However, if the transmission bandwidth is 40 MHz, the peak rate will be reduced to 1.2 Gbit/s.

Table 1： 5G spectral rate of the IMT-2020

Bandwidth	(Peak data rates)	Average data rate	5th percentile data rates
40MHz	1.2 Gbit/s	0.312 Gbit/s	9 Mbit/s
100MHz	3 Gbit/s	0.78 Gbit/s	22.5 Mbit/s

Source：GSA[1]

Looking at the current schedule of release for 5G and mobile communication spectrum in the countries under studying, Korea ’s 3.5 GHz and 28 GHz auctions completed in June 2018 can be regarded as the first spectrum auction released based on 5G specifications. The UK, Australia, and Germany have completed the middle-frequency auctions in April of 2018, December of 2018 and June of 2019, respectively while Canada has completed the 600 MHz low-frequency auction in April of 2019, and the United States have completed the high-frequency actions for 28 GHz and 24 GHz in January and May, respectively. On the other hand, China and Hong Kong release their spectrum through allocation. China has completed the assignment of middle-frequency bands including 2.5-2.6 GHz, 3.4-3.5 GHz, 3.5-3.6 GHz, and 4.8-4.9 GHz in December of 2018, while Hong Kong has completed the assignment high-frequency band of 26-28 GHz in March of 2019. Japan adopts the method of review and allocation, and completed the review and assignment of the middle-frequency band of 3.7 GHz, 4.5 GHz and 28 GHz in April of 2019.

In the second half of 2019, the United States conduct a high-frequency auction (Upper 37 GHz, 39 GHz, 47 GHz) on December 10. Germany has

[1] GSA(2019), GSA VIEWS ON 5G SPECTRUM AWARDS IN 3400-3800 MHZ IN EUROPEAPRIL 2019(last visited:2019/10/23)

launched the regional license application on November 21. Japan is expected to complete the regional license system planning before the end of 2019. Hong Kong has completed the frequency auctions for the 3.5 GHz, 4.9 GHz, and 3.3 GHz from late October to early November of 2019. The UK plans to carry out the auctions for the low-frequency band in 700 MHz and the middle-frequency band in 3.6-3.8 GHz in the spring of 2020. Canada plans to carry out the auction for middle-frequency band in 3.5 GHz in 2020. Australia will conduct the auction for the low-frequency band in 850/900 MHz and the high-frequency band in 26 GHz in the first half of 2020-2021. South Korea is expected to complete the review of the high-frequency band in 28.9-29.5 GHz by 2021, and the review of the low-frequency band in 700 MHz as well as the middle-frequency band in 2.3 GHz and 2.5 GHz by 2023.

The Infocomm Media Development Authority (IMDA) of Singapore is inviting telecommunication operators to submit proposals for 5G networks. Interested parties must submit their proposals by January 21, 2020. The results are expected to be announced by the first half of 2020. This implies that, in the future, four telecommunication (mobile network) operators in Singapore-SingTel, M1, StarHub and TPG-may provide their own 5G network services.

The IMDA first carried out assessments on telecommunication operators in Singapore based on their financial capability, network security robustness, spectrum price, etc. For those operators who are interested in operating the nationwide 5G network, the operators must pay at least S$ 55 million to buy the 3.5 GHz frequency, and pay an annual fee of S$ 154,000 for an operation period of 15 years. For regional networks with relatively concentrated coverage, the 26 GHz or 28 GHz frequency will be used. However, the IMDA did not set a minimum price for these 2 frequencies, and only set an annual fee of S$ 1,232,000 with an operation period of 16 years. In the future, the IMDA also plans to provide more frequency bands in 2024 or 2025, expanding its 5G network.

The WRC-19 conference organized by ITU is an important international conference on radio-frequency related preparations and policies. This study collected the preparations and policies made by the competent authorities of various countries for the WRC-19 conference. Currently, all countries have initiated their responding measures. Most of the countries have conducted the public consultation and inventory procedure. The European Union has made preliminary conclusion on related issues, recommending member countries to support or reject such conclusion. Overall, countries are very cautious about the issues discussed at the WRC-19.

Table 2： Preparations status for the WRC-19

Country	WRC-19 preparation status	Country	WRC-19 preparation status
EU	Conduct public consultation and propose planning recommendation	**Canada**	Discuss about organizing public consultation
UK	Conduct public consultation and propose preliminary conclusion	**Korea**	Organize work team and conduct consultation
Germany	Organize work team and conduct public consultation	**China**	Establish work team
USA	Prepare work team and conduct public consultation	**Hong Kong**	Continue to follow up international trend and development
Japan	Conduct public consultation and propose preliminary recommendation	**Australia**	Continue to follow up international trend and development

Source： Organized by this project

Section 2 Domestic policy recommendation

On June 12, 2019, the research team of this project held a "Seminar on New-Generation Communication Technology Development and Spectrum Supervision Policy". Experts from industries, government agencies, and academic institutions were invited to discuss the important issues relating to the license releasing schedule of 5G communication network in Taiwan. At the meeting, opinions about the first-stage license release of the 270 MHz frequency in Taiwan at the end of 2019 were discussed and all experts agreed that the frequency of 270 MHz is difficult to meet the needs of five telecommunication operators in Taiwan for the initial deployment of 5G network. Since 5G has the characteristic of large bandwidth, a bandwidth of above 100 MHz is needed in order to fully demonstrate the performance of 5G. It is hoped that during the second-stage license release, the frequency of 4.5 GHz and 39 GHz can be included as the candidate frequency. However, since the timetable, frequency and bandwidth for the second-stage license release have not yet been determined, telecommunication operators are unable to decide how much investment they will place for the first-stage license release and the investment risk that will be generated during the implementation of the 5G network.

Currently, the pre-announcement operation of Taiwan’s first-stage license release of 5G frequency bands in 1800 MHz, 3500 MHz, and 28000 MHz have been completed, and the frequency bands is currently in the auction procedure in December of this year. According to the plan of the National Communications Commission, the first-stage license release of 5G spectrum will include 3.5G frequency band in 270 MHz, 28G high-frequency band in 2,500 MHz, and 1,800 MHz as well as 20 MHz, serving as the complementary frequency bands to enhance the coverage.

By combining the results collected in this project, it is recommended that the following low-, medium- and high-frequency bands can be released in the second stage. The middle-frequency of 4.5 GHz and the high-

frequency of 39 GHz can be considered as the top-priority frequency bands. The 5G candidate frequency bands for the second-stage license release and the comparison to those planed by the National Communications Commission are shown in Table 5.

Table 3： Comparison between the 5G candidate frequency bands for the second-stage license release recommended by this project and those planned by the National Communications Commission

	Below 1GHz	1-6 GHz	Above 6GHz	No license required
NCC plan (SRB)	● 600MHz ● 800MHz	● 4.5-5GHz	● 24.25-26GHz ● 37-40 GHz	Not announced
Candidate frequency bands for the 2nd-stage license release recommended by this project	● 600MHz	● 4.5-5GHz	● 24.25-26GHz ● 37-40 GHz	● 64-71GHz
Subsequent frequency bands recommended by this project	● 800MHz	● 3.8-4.2GHz ● 1.5GHz	Depend on the decision of the WRC-19	Depend on the decision of the WRC-19

Source： Organized by this project

Chapter 4 International Trends and Suggestions for 5G Frequency Flexible Application Measures

Section 1 International experience

The competent authorities of all countries agree that the principle of flexible spectrum management should be applied, and the frequency usage efficiency should be improved. After analyzing the international trends, it was found from this project that most countries adopt the pre-regulating measure of setting the upper limit of frequency acquisition during auction. However, some countries have adopted the regulatory measure of setting the upper limit specification or canceling the upper limit after the second transaction of the frequency. For instance, the telecommunication operators in the United States have been required that the total bandwidth obtained after the transaction of five millimeter wave frequency bands (24 GHz, 28 GHz, 37 GHz, 39 GHz, and 47 GHz) must not exceed 1,850 MHz, accounting for approximately 37.3% of the total bandwidth of 4,950 MHz for the five frequency bands released. The UK did not set an upper limit for specific frequency band; the bandwidth possessed by telecommunication operators must not exceed 37% of the total bandwidth released for mobile communication.

As for the trading and leasing of frequency bands among the countries studies, they can be divided into three types: implementation of spectrum trading system through precise regulations, allowing spectrum trading without clear regulations, and not allowing spectrum trading. Among them, possible transactions for the implementation of spectrum trading system with clear regulations include: full or partial spectrum transfer, with/without liberalized transactions (service neutrality), performing license transaction with or without technology neutrality, lease permits, allowing currency transaction to compensate for biased transactions, pre-approved requirements by regulatory authorities, the use of competition law to resolve possible anti-competitive practices, etc.

Currently, there are still some countries that do not allow spectrum trading or leasing. For example, Germany has not yet allowed frequency trading and leasing. The UK is reviewing whether to allow the leasing of the 700 MHz and 3.6 GHz frequency bands (currently is not allowed). Many countries in Asia, such as Japan, Korea and China, do not allow frequency band leasing. Hong Kong implemented the lock-up period; those acquired the frequency band and fulfilled the obligations prescribed by the competent authority shall not perform trading within the next five years.

Section 2 Domestic policy recommendation

The release of frequency for the mobile broadband services in Taiwan before 4G is carried out in accordance with the Telecommunications Act. The use of frequencies is exclusive and only allows the transfer of the frequency usage right when the telecommunication operators are merged. Based on such regulation, telecommunication operator only obtains the right to use the frequency through bidding. Therefore, based on the principle of trust protection, it is not appropriate to allow frequency leasing, lending and trading.

Although the release of 5G frequency still has to be carried out in compliance with the Telecommunication Act, the Telecommunication Administration Act has been passed by the Legislation Yuan at this time. Besides permitting frequency sharing, the new Administration Act also allows secondary transactions such as leasing, lending and trading. Telecommunication operators will receive sufficient information during the bidding process. Therefore, it is recommended to allow 5G frequencies for flexible use in the early stage to ensure fair competition among the winning bidders.

There have been major changes in the supervision of the Telecommunication Administration Act. The obtaining of the qualification for telecommunication business operation has been changed from permit-

or license-based based system to voluntary registration-based system in order to lower the market entry requirements and activate the communications & broadcasting industry. Therefore, in addition to the telecommunication businesses that have traditional telecommunication infrastructures, the targets who may acquire 5G frequencies that can be leased, lent, or traded through auctions also include any industry with a communication need such as vertical field vendors under digital convergence. . However, the telecommunications business under the original Telecommunication Act can only be transferred to the Telecommunication Administration Act after changing the business plan and obtaining a license.

In order to promote the effective use of spectrum resources, the Telecommunication Administration Act has substantially relaxed the restrictions on frequency use. In Article 58, Paragraph 1 of the Telecommunication Administration Act, it allows telecommunication operators to lease, lend or otherwise allocate a portion of their allocated radio frequency to other telecommunication operators by means of frequency division, time division, or area division, etc. On the other hand, Article 59, Paragraph 1 of the Telecommunication Administration Act allows all or a part of the frequency obtained by the telecommunication operators via auction or public bidding to be used by other telecommunication operators once the application is approved by the competent authorities. The former frequency leasing and lending are regarded as commercial negotiation between the telecommunication operators, and the frequency license usage right is not transferred, while the latter frequency secondary transaction must transfer the frequency license usage right. In order to ensure the quality of service and the operation of the public telecommunication network after the frequency transfer, and protect the rights of consumers, frequency transfer processes need to be reviewed by the competent authorities before they can be implemented by other telecommunication operators.

Although the nature of frequency leasing, lending, and trading are all different, the regulatory principles should be consistent in consideration of the purposes of efficient use of spectrum resources, fair market competition, and protection of consumer rights. Items such as the bandwidth upper limit (maximum bandwidth limit), the lock-up period, the bid winning amount issue, tax issue, and frequency management, will be explained in the following section：

(1) Maximum bandwidth limit

Since the use of frequency is exclusive, most of the release of international frequencies is coupled with a maximum bandwidth limit to avoid over-concentration or hoarding of spectrum resources, maximizing the utilization of resources. However, there are different international practices for the specification of the bandwidth upper limit, including (1) setting an upper limit on the released frequency band (such as Australia, Japan, Korea, Germany, and Hong Kong); (2) setting an upper limit on the total bandwidth (such as the UK has about 37 %); (3) setting the upper limit for the bandwidth obtained after the trading (such as the US has about 37%) (see Table 8).

Table 4： Maximum bandwidth limit of various countries

Type	Setting maximum bandwidth limit while bidding/releasing		Set upper limit of bandwidth obtained after the trading
	Set upper limit on released frequency bands	Set upper limit on total bandwidth	
Country	Australia, Japan, Korea, Germany, and Hong Kong	UK （~37%）	USA （~37%）

Source：Organized by this project

Due to the economies of scale in the telecommunications industry which makes it easy to form a monopoly market and the fact that frequency band below 1GHz is a popular band because of its advantages in transmission distance or penetration rate, it is recommended to maintain the current mobile broadband service management regulations; setting an upper limit of 1/3 of the total bandwidth below 1GHz. As for the upper limit of the secondary transaction, according to the provisions of the Telecommunication Administration Act, only part of the owned bandwidth can be used for frequency leasing and lending while all or part of the owned bandwidth can be traded. However, after the transaction, the total bandwidth owned below 1GHz must meet the 1/3 upper limit requirement in order to reduce spectrum concentration and promote market competition.

However, considering the large-bandwidth, high-speed, and low-latency communication characteristics of 5G technology applications, besides removing the restrictions on frequency leasing, lending, and trading, Taiwan's Telecommunication Administration Act also allows telecommunication operators to share frequency bands, promoting the utilization of spectrum resources. In addition, by observing the recent international 5G spectrum release and corporate network planning, they are mostly based on the release of middle- and high-frequency spectrum. With regards to the current regulation of setting an upper limit of 1/3 for the total bandwidth owned, it is recommended to competent authorities may adopt flexible reviewing system in order to comply with international trends and maintain fair competition in the domestic market.

(2) Lock-up period

In order to prevent telecommunication operators from selling the obtained frequency band at a higher price after the bidding, and failing to fulfill the obligations of setting up the network, a lock-up period can be set to avoid such intended frequency selling. Internationally, Hong Kong currently has implemented the lock-up period, which inhibits telecommunication operators to perform any transaction five years from the date when spectrum allocation is approved. The lock-up period can be

applied until the telecommunication operators have completed the network construction obligations for the obtained frequency (such as the number of base stations constructed and the number of people covered by the frequency). Once the obligations have been fulfilled, frequency leasing, lending, or trading can be operated to fully utilize the spectrum resources.

(3) Bid winning amount issue

According to the provisions of Article 36 of the Regulations for Administration of Mobile Broadband Businesses implemented on September 3, 2019, winning bidders are allowed to pay the bid winning amount in one payment or in installments over the next two to five years. In order to prevent the telecommunication operators from leasing, lending or trading the obtained frequency bands at higher prices, the bid winning amount should be paid first to stabilize market development and protect consumer rights.

(4) Tax issue

Although Article 62 of the Telecommunication Administration Act requires frequency users to pay for the use of the frequency, since the right to use the license for leasing or lending of frequencies has not been transferred, it is recommended that usage fee is paid by the telecommunication operators with the license in order to facilitate administrative management. On the other hand, for frequency secondary transaction, the right to use the license has transferred; therefore, the frequency usage fee should be paid by other telecommunication operators with the license.

(5) Frequency management

As the restrictions on frequency usage under the Telecommunication Management Act become more and more relaxed, allowing frequency leasing or lending by means of frequency division, time division, or area division, it is expected that frequency users will change more frequently in the future; as a result, systematic management will become more important. As the authorities for frequency allocation and use, it is recommended that

the National Communications Commission (NCC) should establish a frequency management system to achieve the goal of effective spectrum management.

Chapter 5 5G International Trends and Recommendation for the Harmonious Sharing of 5G Candidate Frequency Bands

Section 1 International experience

This study collects international measures for harmonious sharing of 5G candidate bands and existing services, including the following types：

- Set technical specifications and transmit power limits；
- Set interference protection zone / prohibited zone / coordination zone；
- Adopt a spectrum sharing mechanism；
- Frequency shifting, frequency shifting subsidy may be involved.

Measures for harmonious sharing have been implemented in various countries. For example, the competent authorities in Korea adopt the practice of negotiation between telecommunication operators if interferes occur while using the 3.5 GHz frequency band. When the competent authorities of Hong Kong are handling the spectrum preparation operations for the release of 5G from 3.4 to 3.7GHz, they first check the status of satellite service and then perform interference assessment to set 100 MHz as the protection frequency, and set up interference protection zones around the satellite tracking and telemetry (remote monitoring) stations. The United States also adopted the interference coordination zone for part of the millimeter wave frequency bands. Part of the frequency bands has adopted the spectrum sharing mechanism to handle the harmonious sharing of frequency bands.

Table 5： Frequency harmonious sharing measures in various countries

Country	Frequency harmonious sharing	Country	Frequency harmonious sharing
EU	Consider sharing conditions case by case	**Canada**	Allow sharing
UK	Adopt frequency sharing or frequency shifting depending on the frequency band variation	**Korea**	Frequency shifting or negotiation between telecommunication operators
Germany	Allow frequency sharing under certain conditions	**China**	Regulate 5G and negotiation between existing telecommunication operators
USA	Design interference coordination zone or adopt frequency sharing	**Hong Kong**	Set up protection zone for satellite telemetry (remote monitoring) stations
Japan	Conduct interference assessment and regulate transmit power	**Australia**	Adopt frequency sharing or frequency shifting depending on the frequency band variation

This study collects measures for the harmonious sharing of frequencies in the 5G bands of various countries. Some countries set interference assessment standards and regulate the transmit power to allow different services to coexist harmoniously in the frequency band. Some countries designed protection zone to avoid new services interfering with the existing services. Other countries adopt frequency shifting for the

existing telecommunication operators and give appropriate compensation for any loss due to such frequency shift. In general, harmonious sharing measures need to be accurately considered depending on the characteristics of each frequency band and the operation status of the existing services.

There are currently three types of frequency sharing mechanisms: the CBRS (Citizens Broadband Radio Service) in the US, the innovative application frequency sharing in the UK, and the Licensed Shared Access (LSA) in the EU. The CBRS mainly uses the 3.5GHz frequency band and assigns spectrum resources by an active method. The so-called active method refers to the mechanism with a spectrum access database and environment sensing equipment. When the sensing equipment detects an existing user (military radar) who is going to access the frequency band resources, the originally shared spectrum resource is retrieved for the existing user through the spectrum access system. As for the UK's innovative application frequency sharing and the LSA mechanism used by the EU, they are similar, both adopting a passive operation manner. Before sharing, check the time and area of operation. The telecommunication operators who want to access the shared spectrum resources must submit application to the competent authorities. Once the application is approved, operators must meet certain operation restrictions and conditions and must not interfere with the existing users.

Table 6： Frequency sharing mechanisms in various countries

Country	USA	UK	EU
Frequency sharing mechanism	Citizens Broadband Radio Service（CBRS）	Innovative application frequency sharing	Licensed Shared Access（LSA）
Applicable frequency band	3.5GHz	1.8GHz (part of the frequency), 2.3 GHz and 3.8-4.2 GHz	2.3GHz

Sharing method	Active: When the sensing equipment detects an existing user (military radar) who is going to access the frequency band resources, the originally shared spectrum resource is retrieved for the existing user through the spectrum access system	Passive: check the time and area of operation before sharing	Passive: check the time and area of operation before sharing

Section 2 Domestic policy recommendation

The existing satellite services and the feasibility of harmonious sharing of 5G depends on various factors, including the 5G business model, i.e., large-scale deployment of eMBB or regional industrial application, the types of services used by the existing operators and the extent and location of its use, and whether the sharing is common frequency sharing or adjacent frequency sharing. To investigate the harmonious sharing measures of the major 5G services in the middle-frequency bands from 3.4GHz to 4.2 GHz, one must first understand the applications of the fixed satellite (FSS space to earth) in this frequency band：

- Large satellite ground station used to transmit and receive trunk or network traffic (feeder link) between a communication gateway and a satellite space station
- Telemetry, Tracking and Command (TT & C) station for communication between spacecraft and ground.
- VSAT (Very Small Aperture Terminal) is mainly used in enterprises, but also in military and government applications.

- Satellite Master Antenna Television (SMATV), a system that uses multiple satellite and broadcast signals integrated into a single cable TV signal to distribute the signal to building's wiring network (such as apartments, buildings, hospitals, etc.).
- TV Receive Only (TVRO) for receiving broadcast signals, such as free broadcast television.
- Other applications include: radiolocation (3.3GHz ~ 3.4 GHz) and fixed services (3.4GHz ~ 4.2 GHz)

Currently, there are more than 200 satellite receiving sites in Taiwan. The empirical measurement for checking whether satellites interfere by 5G services is carried out by the method in which the height of 5G base station is lower than the height of the satellite ground station receiving antenna. The methods for reducing the interference may have different cost-effectiveness depending on the implementation time and costs. According to the results of the cost-benefit evaluation and taking into consideration the number of satellite ground stations in Taiwan, this study proposed three methods that can achieve the best efficiency. They are “Setting up Satellite Ground Station Restriction Areas", "Installing Wave Filters on Satellite Ground Stations" and "Determining the location of 5G Base Stations and Antenna Pointing Direction Based on the Location of the Existing Satellite Ground Stations". These are effective methods for reducing interference before setting up 5G.

"Setting up Satellite Ground Station Restriction Areas" is a method with relatively low cost and construction time. However, if seamless large-scale satellite ground station protection is required, the size of the restriction area will be too large, making it difficult to achieve. The same applies to the method of "Installing Wave Filters on Satellite Ground Stations ". There are 200 satellite ground stations in Taiwan; hence, installing wave filters is an affordable and efficient method. In addition, by taking Hong Kong as the worst-case scenario to design the protection frequency band, the protection frequency band of 100 MHz was decided.

After reviewing the current international middle-frequency band as well as the harmonious frequency sharing policies, and taking into consideration the fact that Taiwan is also facing the situation of C-Band harmonious sharing and high population density, recommendation on the preparation of harmonious sharing measures are proposed in this project, serving as the reference for future studies. They can be summarized into three key points and implementation stages, namely the planning evaluation, the communication and coordination, and frequency assignment：

- Stage 1-- Planning and decision announcement: At this stage, a comprehensive review of the frequency band usage should be conducted, including assessing potential frequency sharing models, i.e., common-frequency sharing or adjacent-frequency sharing, evaluating feasible solutions, and conducting cost-benefit analysis. Only then can the right decision be made. The whole process will take approximately 12 months.

- Stage 2-- Implementation of spectrum preparation and related measures: For common-frequency sharing, the existing operators should be informed of the relevant measures and schedules to be carried out. For the adjacent-frequency sharing, the existing operator should be informed of the measures to reduce interference. In addition, cross-border coordination of potential interference is also required. At this stage, depending on the degree of difficulty and different time requirements for the measures, the whole process may take several months or more than one year.

- Stage 3-- Frequency assignment: The work at this stage includes determining the technical conditions required for the frequency band, designing an appropriate licensing method based on national objectives, and implementing the tasks related to frequency assignment.

Chapter 6 International Trends and Recommendation on the Supervision System of Innovative Technology License

Section 1 International experience

This study summarizes the spectrum resources and license system of innovative technologies such as Internet of Things (IoT), Internet of Vehicles, drones, and intelligent medical care, in European Union, the UK, the United States, Japan, Australia, Korea, and Japan.

With regards to the Internet of Things (IoT), most countries currently provide spectrum of the IoT through licensed spectrum and unlicensed spectrum. Countries around the world continue to check whether there are spectrum resources appropriate for the IoT application. Moreover, providing IoT services through spectrum resources of the mobile network is also commonly seen. The IoT frequency bands collected in this study are summarized as follows：

Table 7： The IoT frequency bands in various countries

Country	Released frequency bands
EU	● Licensed spectrum: spectrum resources for mobile networks (2G, 3G, 4G or even 5G), dedicated telecommunications, fixed communications or satellite communications services ● Unlicensed spectrum: 169 MHz, 433 MHz, 863-870 MHz, 2400-2483.5 MHz, 5150-5350 MHz, and 5470-5725 MHz.
UK	● New BR licenses (55.75625-60 MHz, 62.75625-64.8 MHz, 64.8875-66.2 MHz, 70.5-71.5 MHz and 80.0-81.5 MHz) ● Unlicensed spectrum
USA	● Licensed spectrum: mobile network, licensed spectrum for 5G, such as 28GHz, 24GHz and 37GHz

	● Unlicensed spectrum: 5.15-5.35GHz, 5.47-5.725GHz and 5.725-5.85GHz, 902-928MHz and 2.4GHz, 54-71GHz
Japan	● Unlicensed frequency band（920MHz）
Australia	● Licensed spectrum: 700MHz, 850MHz, 900MHz, 1800MHz, 2.1GHz, 2.3GHz, 2.6GHz and 3.4-3.6GHz, 433 / 434MHz and 915-928MHz ● Unlicensed spectrum: 915-928MHz, 2.4GHz and 5GHz
Korea	● 917-923.5 MHz, 940-946 MHz, 1788-1792 MHz ● Unlicensed frequency bands: 2,400 ~ 2,483.5MHz, 5,150-5,350MHz, 5,470-5,650MHz, 5,650-5,725MHz, 5,725-5,825MHz, 5,825-5,850MHz
China	● Mainly licensed frequency bands: 5G frequency bands (3.4 GHz -3.5 GHz, 3.5 GHz -3.6 GHz, 2515-2675MHz, 4.8 GHz -4.9 GHz, 700MHz)

The Internet of Vehicles shows a slightly different pattern. All the countries in this study have clearly specified the dedicated spectrum for the Internet of Vehicles, with slightly different frequency positions. It is obvious that for the spectrum resources used by the Internet of Vehicles, most of them use dedicated spectrum. However, in terms of the license structure, there are two major types; one is similar to the US regulated authorization license, the Australian class license or the UK lightly authorized license, and the other one is the unlicensed structure adopted by Japan and Korea. For the unlicensed structure, even though a license is not required, restrictions such as the transmit power specified by the competent authorities must be complied.

For the licensing structure of the Internet of Vehicles among all countries, regardless of adopting the regulated authorization license, the class license or the unlicensed structure, a specific license will not be issued to a single operator. However, a practice similar to the regulated transmit power will be used to provide the operator who is qualified for the services to carry out the operation complying with the relevant technical

specifications. The frequency bands of the Internet of Vehicles collected in this study are as follows：

Table 8： The Internet of Vehicles frequency bands in various countries

Country	**Released frequency bands**	**Country**	**Released frequency bands**
EU	5855-5925 MHz	**Australia**	5855-5925 MHz
UK	5855-5925 MHz	**Korea**	433MHz, 5855-5925MHz
USA	5850-5925 MHz	**China**	5905-5925MHz
Japan	5770-5850 MHz and 755.5-764.5 MHz		

With regards to the spectrum resources and license structure for drones, countries in this study have adopted the unlicensed structure. Currently, drone operations mainly use unlicensed spectrum. Although the European Union and other countries have begun to investigate whether it is necessary to allocate dedicated spectrum for drone operation, at this point, most drones are still operated by unlicensed spectrum or mobile network license spectrum, and there is no case of dedicated spectrum for drone operation worldwide. The frequency bands of the drone operation collected in this study are as follows：

Table 9：Drone operation frequency bands in various countries

Country	Released frequency bands	Country	Released frequency bands
EU	Unlicensed frequency band（2.4GHz and 5.8GHz）	**Australia**	Unlicensed frequency band（2.4GHz and 5.8GHz）
UK	Unlicensed frequency band（35MHz, 2.4GHz, and 5.8GHz）	**Korea**	Unlicensed frequency band（2.4GHz）、5030-5091MHz、5091-5150MHz、5650-5850 MHz
USA	Unlicensed frequency band and requesting for 5030-5091 MHz	**China**	840.5-845MHz、1430-1444MHz、2408-2440MHz
Japan	73MHz、920MHz、2.4GHz、1.2GHz、169MHz and 5.7GHz		

With regards to the spectrum resources and license structure for intelligent medical care services around the world, there are unlicensed frequency bands, as well as dedicated frequency bands for wireless medical equipment. However, in general, they are mostly used for low-power medical equipment. In the future, if intelligent medical applications that require extremely low network latency, such as long-distance surgery, are demanded, 5G network is still needed. As a result, dedicated spectrum for intelligent medical care services is rarely seen internationally. The frequency bands for intelligent medical applications collected in this study are as follows：

Table 10：Intelligent medical application frequency bands in various countries

Country	Released frequency bands	Country	Released frequency bands
EU	SRD frequency band（30.0-37.5 MHz, 401-406MHz and 2.483-2.5 GHz）	**Australia**	Frequency band used by medical equipment
UK	Unlicensed frequency band and SRD frequency band（401-402 MHz）	**Korea**	2.36-2.4GHz
USA	Wireless medical telemetry（608-614 MHz, 1395-1400MHz and 1427-1432 MHz） and medical equipment frequency band（401-406MHz）	**China**	401-402 MHz、402-405 MHz、405-406 MHz
Japan	410-430 MHz, 440-470 MHz and unlicensed frequency band（900MHz, 2.4GHz and 5.7GHz）		

Section 2 Domestic policy recommendation

With regards to the spectrum resources for various innovative technologies such as the Internet of Things, the Internet of Vehicles, drones and intelligent medical care, some countries currently have dedicated spectrum for the Internet of Things, while most countries have delineated spectrum for the Internet of Vehicles. Moreover, there is no dedicated

spectrum for drones yet, but some countries have dedicated spectrum for intelligent medical care services.

In this study, a seminar on innovative applications and spectrum supervision was held in October. During the seminar, experts mentioned that through methods such as the regulatory sandbox, room for innovative technology development can be created. Other experts mentioned that flexible spectrum management tools such as sharing spectrum and unlicensed spectrum can further expand the development of innovative technologies. Regarding whether innovative technologies and applications require dedicated spectrum, experts pointed out that if the application involves public interest or security, dedicated spectrum should then be considered. Through the implementation of flexible spectrum management systems such as the 5G licensed spectrum, the unlicensed spectrum, or the sharing spectrum, the needs for innovative technology development can then be better fulfilled.

In response to international trends and the suggestions of domestic experts and scholars, a consensus on adopting flexible spectrum management structure for innovative technologies and applications can be reached. The spectrum management structure can be divided into licensed spectrum for 4G and 5G networks, unlicensed spectrum and shared spectrum. In addition, some countries currently provide room for commercial or technical verification of innovative applications by increasing the spectrum for experimental license or increasing the experimental areas. Therefore, it is recommended in this study that for the innovative technology applications, there is no need to use a single licensed spectrum or to divide a dedicated spectrum, but to continue to review the possibilities of experimental spectrum, shared spectrum, and unlicensed spectrum with flexible and diverse spectrum management structure.

This study suggests that for the license system of innovative technology applications, a flexible spectrum management structure should be adopted to create room for the development of innovative technology

applications through ways such as licensed spectrum, unlicensed spectrum, shared spectrum and experimental spectrum. It is suggested in this study to implement supporting measures to promote the development of innovative technologies. These measures include：

(1) Regularly check or study the spectrum resources demand for innovative technologies

This study suggests that the competent authorities can regularly check and monitor the development trend of innovative technologies and applications, and continue to follow up the spectrum resources demand for innovative technologies through public consultation meetings or industry surveys. If, after the investigation, there is a clear spectrum resources demand for specific services, dedicated frequency bands can then be specified based on the international trend.

(2) Set appropriate license structure

Currently, in some countries, the license structure for the Internet of Things is based on class license or regulated authorization license under the dedicated license system, which is used by a large number of IoT devices with the same businesses and operation conditions.

After the passing of Taiwan’s Telecommunication Administration Act, the competent authorities have more flexible frequency management structure. If there are specific innovative technologies that have high demand for spectrum resources, large number of equipment, and specific businesses or similar power, it is recommended to refer to other countries and set the license structure to class license or regulated authorization license in order to reduce the administration work of base stations for the competent authorities.

Chapter 7 International trends and recommendation on 5G network establishment obligations and supervision regulations

Section 1 International experience

Looking at the status of 5G network establishment worldwide, some countries have set certain goals and obligations. The status of establishment for various countries is summarized in Table 17.

Table 11： Establishment of 5G network in various countries

Country	Obligations	Population (household) coverage	Basic establishment quantity	Facility construction rate	Key area	Others (including service quality, PPDR, etc.)
EU	Member countries' establishment types: general establishment, major roads (key areas), rural areas, specific areas, regional coverage, etc.				✓	✓
UK	· Mobile service coverage should reach at least 90% (vary slightly in different regions)	✓	✓			✓
USA	· First 5G millimeter wave establishment in 2016: population coverage 40% · Second 5G millimeter wave establishment in 2017: geographic coverage 25%	✓				✓

Japan	・Establishment rate: varies by operators (56.1% ~ 97.0%) ・Establishment quantity (3.7, 4.5GHz): varies by operators (8,001-30,107 stations) ・Establishment quantity (28GHz): varies by operators (5,001-12,756 stations)		✓	✓		
Korea	・Establishment standard quantity ・Obligated establishment quantity for different frequency bands in 3 to 5 years		✓			
Germany	・Household coverage：98% ・Key area establishment ・Quantity of establishment (1000 stations) and quantity of establishment for non-hot areas (500 stations) by 2022	✓	✓		✓	
Canada	・Population coverage reaches different rates by year ・24 Tier-4 service areas provide 95% service coverage	✓			✓	
Hong Kong	・Number of required establishment for the specified frequency band ・Population coverage for specified frequency bands ・Yearly requested establishment rate	✓	✓	✓		

Section 2 Domestic policy recommendation

The establishment of 5G network is indispensable in the development of 5G new-generation communication technology. The completeness of 5G network infrastructure will determine whether or not the development of 5G technology in Taiwan is successful. Therefore, the establishment of 5G network and related obligations become significantly important. The main regulations on 5G network establishment obligations are stated in Article 66, paragraphs 2 to 5, of the "Regulations for Administration of Mobile Broadband Businesses", which was newly revised on September 3, 2019. It requires the winner of the bid for the released 5G frequency to fulfill establishment related obligations including population coverage and the number of base stations, etc.

Based on the international status of network establishment, there are two suggestions proposed in this study for Taiwan's 5G network establishment obligations：

1. To increase 5G network installation in specific areas

Comparing with other countries, it was found that some countries, such the European Union and Germany, have required certain establishment obligations for specific areas such as rural areas or domestic roads to strengthen the completeness of domestic network infrastructure. In contrast, the competent authorities in Taiwan mainly require the operator to fulfill the obligation of "the wave coverage of the fifth-generation mobile communication base station of the high-speed base station should reach 50% of the population in the operated area." It does not require which areas should carry out the establishment, which may lead to uneven 5G network distribution, affecting the popularization of 5G communication technology. It is suggested that the competent authorities should check the 5G network establishment status of various operators on a regular basis and issue administrative guidance in a timely manner to guide the operators in carrying out 5G network establishment in specific regions in order to strengthen the development of 5G network in various parts of Taiwan.

2. Establishment of 5G network can be shared with public facilities such as utility poles

In order to popularize 5G network establishment, some countries, such as the United States and Japan, have begun to build 5G networks in the form of small base stations, including the use of utility poles, traffic lights, and smart street lights to increase the coverage of 5G networks. It is recommended that the competent authorities can apply regulation relaxation or cross-department (cross-ministry) coordination, so that the establishment of 5G network can also be shared with the existing public facilities such as utility poles, traffic lights, street lights, etc. to speed up the schedule for the establishment of 5G network.

Chapter 8 International Trends and Recommendation on Enterprise Private Network Planning and Management System

Section 1 International experience

This project studied the current status of countries and regions such as the European Union, the United Kingdom, the United States, Australia, Japan, Korea, Germany, Hong Kong, China, and Canada, and added information from France, Sweden, and Singapore in this Section, with a total of thirteen regions and countries. However, most countries are still in the consultation stage (the UK, Australia, Canada, Sweden, and Singapore). In terms of corporate private network policies, Japan, Germany, Hong Kong and France have relatively clear policy objectives, systems and regulations. However, France is still based on its existing dedicated telecommunication policy.

Table 12： Status of enterprise private network in various countries

Policy stage	Country or region
System planning	Japan, Germany, Hong Kong, France (based on the existing dedicated mobile communications policies)
Consultation stage	Sweden, Singapore, the United Kingdom
No plan	The European Union, the United States, Korea, China, Canada, Australia (Consulting but no follow-up development)

Source：Organized by this project

In summary, enterprise private network policies are still in the preliminary research and development stage. Most countries focus on policy consulting and system planning, while some countries at this moment do not have plans on enterprise private network policy. In addition, the UK and the EU have promoted the development of vertical applications through experiments (EU 5GPPP project) and shared spectrum (UK). Therefore, vertical applications and even enterprise private network policies will still vary significantly. It is worth watching closely on the latest international trend.

Section 2 Domestic policy recommendation

This project reviewed and summarized the vertical application and enterprise private network policies in various key countries. Based on the summary results, suggestions on Taiwan’s enterprise private networks are proposed. These suggestions include: experimental verification, encouragement of cooperation, use of unlicensed frequency bands, and private network frequency band evaluation plans.

Table 13： Suggestions on Taiwan's enterprise private networks

Suggestion	Content
Experimental verification	● Encourage experiments such as PoC and PoB. ● Without interfering with the existing users, special requirements for the experimental spectrum can be reduced. However, it is necessary to pay attention to the extensive use of the experimental equipment. For example, the application of the experimental network is mainly based on the first-stage license release of 5G frequency bands. After the release of license, negotiate with the spectrum winning bidders to continue the experiment, or adjust the frequency band to the adjacent band to continue the experiment.
Encouragement of cross-industry cooperation	● Provide incentives such as cooperation subsidies and reduction of frequency usage fees; and build a communication and interaction platform between the two parties to promote cooperation between telecommunication operators and vertical application operators. ● Or use flexible measures such as Network Slicing, MVNO, or leasing frequencies from telecommunication operators to assist the cooperation between the two parties.
Use of unlicensed frequency bands or shared spectrum	● Unlicensed frequency bands can also meet some vertical application requirements. It is recommended to use the 5.8GHz frequency bands (5.15-5.35GHz, 5.47-5.875GHz) or to prepare the millimeter-wave unlicensed frequency bands in the future to meet the requirements and support unlicensed vertical innovative applications. ● Taking the practices of the UK as examples, in order to encourage the development of domestic innovative applications, 1.8GHz, 2.3GHz and 3.8-4.2GHz are selected as shared spectrum, and the spectrum resources are provided to innovative applications in a shared manner in areas or periods that are not used by the existing users. This will improve the efficiency of frequency use and

	increase the opportunities for innovative applications to acquire spectrum resources.
Private network frequency band evaluation plan	● Continue to pay attention to the development trend of vertical-field applications in various countries, explore domestic demand, and study the feasibility of potential spectrum based on the cooperation between the telecommunication operators and vertical application operators after the first-stage license release of 5G, and the empirical measurement results of potential interference in the frequency band. For example： ■ 26.5-27GHz： Currently, there is no existing user, which can be included based on the demand. ■ 2.3GHz frequency band： It has been included in the consideration of 4G open frequency bands in 2017 (open bandwidth 35MHz). Although 35MHz bandwidth cannot meet the needs of 5G large-bandwidth services, it can meet the needs of 4G enterprise private networks and public sector private networks.

Enterprise private networks exhibit great development potential; however, there is still no clear development trend, and the "private frequency requirements" are still unclear. In addition, the necessity of private frequency is still worth studying (for example, the UK plans to use shared frequency bands). The planning of enterprise private network frequency bands in various countries lacks consistency. Therefore, it is recommended to apply the strategy of "experiment first" and "encouraging cross-industry cooperation" in the early stage.

As for the medium and long-term planning recommendations, it is suggested to adopt the rolling-type analysis method to review the feasibility of potential frequency bands based on the results of domestic PoB and PoC experiments, the development trends of vertical applications in various countries, the effectiveness of cooperation between vertical application operators and telecommunication operators after the first-stage

license release 5G, and the measurement results of potential frequency band (26.5-27GHz, 2.3GHz) interference, and then incorporate the results into the frequency supply plan. Based on whether public interest is directly involved, a reasonable frequency use cost is formulated to reflect the true value of the frequency spectrum, avoiding the free-rider problem which may hinder the development of 5G vertical applications.

Chapter 9 Conclusion

The objective of this study is to propose a spectrum monitoring policy for the use of 5G new-generation communications and emerging technologies that meet the needs of the market in Taiwan, collecting and analyzing the latest international trends while considering the status of Taiwan's actual systems and technology development status to propose recommendations for the preparation of future policies in Taiwan.

During the implementation of this project, three major research goals were completed: The first one is to understand the latest development trends of global new-generation communication technologies and summarize the development of new-generation communication technologies in 3 important international organizations, including the International Telecom Union (ITU), the 3rd Generation Partnership Project (3GPP), and the Institute of Electrical and Electronics Engineers (IEEE) in the development status of new-generation communication technology, including technical standard development schedule, technical standard development content, etc., in order to grasp the development progress of new-generation communication technologies promoted by the international organizations.

The second one is to collect the new-generation mobile communications and various emerging technologies as well as spectrum development trends in advanced countries, and understand the spectrum preparation systems and regulatory policies for 5G, the Internet of Things, the Internet of Vehicles, drones and intelligent medical care, including

focus of policy promotion, the development and release of candidate frequency bands, spectrum preparation measures in response to WRC-19, harmonious sharing measures for the existing services and the candidate frequency bands, and the related license regulatory framework.

The third one is to collect the research results of the new-generation communication technology spectrum supervision policies of various countries, and apply the results as reference to prepare the spectrum and regulatory systems suitable for 5G and emerging technology applications in Taiwan. Related topics include the suggested target of 5G candidate frequency bands and the release schedule, the flexible use of frequency release, the harmonious sharing of frequency bands for new technologies and the existing services, and the license systems as well as the supervision supporting measures for innovative technologies.