APEC

**Asia-Pacific
Economic Cooperation**

Advancing Free Trade
for Asia-Pacific **Prosperity**

Facilitating Innovation and Diversity in Next Generation (5G) Network Ecosystems

APEC Telecommunications and Information Working Group

April 2016

Table of Contents

Glossary

3GPP (3rd Generation Partnership Project)	An umbrella term for a number of standards organizations which develop protocols for mobile telecommunications.
4G (Fourth Generation)	Describes technologies that fulfill the ITU's IMT-Advanced specifications such as LTE. 4G technologies have flexible channel bandwidths; peak speeds of 100 Mbit/s when mobile and 1.5 Gbit/s when fixed; high spectral efficiency; smooth handoff between different network types; and a flat, all-IP network architecture. In practice, 4G is also used to describe technologies that nearly meet these requirements such as Mobile Wimax and LTE.
5G (Fifth Generation)	Used to describe networks that use the IMT-2020 standard. 5G networks are expected to have 1-10 Gbps connections to end points in the field, as well as 1 millisecond end-to-end round trip delay (latency).
5G NR (New Radio)	Refers to the air interface that was developed to replace LTE. It is through this new radio air interface that the advances associated with 5G are achieved.
5G Non-standalone	Refers to a 5G network which is, conceptually, bridges existing air interface technologies and their core networks and 5G NR.
5G Standalone	Refers to a 5G network which "stands alone" from any prior generation mobile cellular network in that the core network technologies are entirely based on 5G NR.
Base station	Refers to the equipment that provides and manages the connection between mobile phones and the cellular network.
FDD (Frequency Division Multiplexing)	The technique of using one spectrum band for transmission and a second band for reception. This ensures that the two bands do not interfere with each other. LTE can use FDD in which case it is referred to as FD-LTE.
LTE (Long Term Evolution)	The 3GPP standard, generally branded as 4G, that uses an all-IP flat network architecture and is capable of peak downlink speeds 100 Mbit/s and uplink speeds of 50 Mbit/s when deployed in a 20 MHz channel, and even higher rates if used with MIMO to deploy LTE in multiple channels. LTE is generally FDD, but also has an TDD implementation, TD-LTE.
MIMO (Multiple-Input Multiple-Output)	A technique for using multiple transmit and receive antennas to send and receive more data
MNO (Mobile Network Operator)	An entity that provides mobile telephony and data services. The term implies that the entity "operates" a radio network, though this may not necessarily mean that it owns the infrastructure.
MEC (Mobile Edge	Network architecture concept that enables cloud computing capabilities and an IT service environment at the edge of

Computing)	the cellular network and, more in general at the edge of any network
Network (Function) Virtualization	NFV is an initiative to transfer the network functions from dedicated hardware devices to virtual machines that can run on software on standard hardware. Typically enables operators to be more flexible, cost-effective and deploy new services.
Open RAN	Refers to a new set of technologies that are about building networks using a fully programmable software-defined radio access network solution based on open interfaces that runs on commercial, off-the-shelf hardware (COTS) with open interfaces.
Radio	The equipment typically deployed on top of cell towers near the antennas that provide the analog transmission to and from mobile phones and the mobile network.
Radio Access Network	The physical radio layer at the front of each wireless network. Provides the RF connection to the end user device. Abbreviated RAN.
TDD (Time Division Multiplexing)	The technique of using one spectrum band to transmit and receive by dividing the band into alternating time slots. LTE can use TDD in which case it is referred to as TD-LTE.
V2X (Vehicle-to-everything)	A vehicular communication system that incorporates other more specific types of communication. The main motivations for V2X are road safety, traffic efficiency, and energy savings.

Executive Summary

The workshop on the Facilitating Innovation and Diversity in Next Generation (5G) Network Ecosystem was hosted by the Korea Ministry of Science and ICT (MSIT) and Korea Information Society Development Institute (KISDI). 16 APEC member economies and experts from the public and private sectors attended the workshop. Due to the Covid-19 pandemic situation, only Korean speakers and organizers attended the workshop offline and other participants attended online via Zoom.

The opening speech was given by the TEL Chair, Dr. NAM Sang-yirl, and he encouraged this workshop to be an opportunity for all the member economies to promote the rapid and inclusive supply of 5G based on convergence services for digital transformation and provide valuable insight into the future of 5G.

The theme of the first day was '5G Ecosystem', and five speakers from Korea gave the presentations. The topics were: 1) 5G+ Strategy of the Republic of Korea, 2) 5G B2B/B2C eco-system: based on Korea's experience, 3) 5G promotion from the public domain and international collaboration in Korea, 4) Overview of 3GPP Activities on 5G Standards, and 5) 5G commercialization and beyond. After all the presentations, there was a panel discussion regarding the bottle-necks of 5G B2B commercialization and the way to overcome the problem with the global collaboration, the lessons from early deployment experience of 5G, and the ways to smoothly migrate from 4G to 5G.

The second day of the workshop was to proceed with the theme of '5G Vertical Industry Use Cases'. Four speakers gave the presentations and shared each economy's 5G vertical use cases. Two presenters were from Korea, one was from Japan, and the other was from China. The topics were: 1) From Wireless Knife, Drones to Smart Factory, 2) 5G MEC (Mobile Edge Computing) Technology Use Cases in Korea to Combat Covid-19, 3) Private 5G use cases in Japan as Smart Infrastructure – Japan, and 4) 5G Applications and Ecosystems in China. At the end of the workshop, there was a panel discussion session as well. The discussions were about the bottlenecks and challenges of 5G vertical use cases and the speakers' personal opinion regarding the private 5G and the effect of 5G in the Covid-19 situation.

Background

As the fifth-generation wireless network, 5G is the essential digital infrastructure for digital transformation, and 5G promotes innovation and facilitates a prosperous digital economy as well. Since many APEC economies are ready for promoting the 5G network, this project addresses the strategies and policies to encourage business innovation based on 5G. Also, this project identifies the best practices of innovative services and business models in 5G vertical industries among APEC economies as well.

The aims of the project are highly relevant to the APEC Internet and Digital Economy Roadmap and Manila Framework. Especially, among the key focus areas of the roadmap, the project is highly related to the 'development of digital infrastructure' and 'promoting innovation and adoption of enabling technologies and services'. Therefore, the project also well aligns with APEC's digital priorities. Moreover, the project is also highly related to the APEC TEL Strategic Action Plan 2016-2020, especially for the first and the fourth priority areas which are 'develop and support ICT innovation' and 'enhance the digital economy and the internet economy.'

This project is in the form of a workshop. The first day of workshop is for sharing Korea's 5G+ Strategy and 5G B2B/B2C Ecosystem use cases and seeking the future direction of global cooperation via 5G. The second day is for sharing 5G vertical use cases.

As a result, the workshop expects to contribute to the digital transformation by promoting a rapid and inclusive supply of 5G based convergence services. Also, it would contribute to enhancement the cooperation on the 5G network of all the multi-stakeholders from industries and academies by sharing policy and experiences.

AGENDA

**Facilitating Innovation and Diversity
in Next Generation (5G) Network Ecosystems**

Date: 24-25 November 2020
Time zone: 10:30 a.m. ~ 12:30 p.m. [GMT+9]

DAY1. 24 November (Tues)
Theme: 5G ecosystem

	10:30-10:35	**Opening Speech**	Sang-yirl Nam TEL Chair
1	10:35-10:45('10)	5G⁺ Strategy of the Republic of Korea	Mr Sung-ho, Choi Program manager for Communications & Radio /The ministry of Science and ICT
2	10:45-11:05('20)	5G B2B/B2C eco-system: based on Korea's experience	Mr Dongjoo, Park Technical Director/ Ericsson
3	11:05-11:25('20)	5G promotion from public domain and international collaboration in Korea	Mr Hyun Woo, Lee Professor/ Dankook Univ.
4	11:25-11:45('20)	Overview of 3GPP Activities on 5G standards	Mr Jun Hwan, Lee Researcher / ETRI
5	11:45-12:05('20)	5G commercialization and beyond	Mr Takki Ryu Researcher / SKT
	12:05-12:30('25)	**Panel Discussion**	

DAY2. 25 November (Weds)
Theme: 5G vertical industries use cases

1	10:30-10:50('20)	From Wireless Knife, Drones to Smart Factory	Mr Seong-Lyun, Kim Professor/ Yonsei Univ.
2	10:50-11:10('20)	5G MEC(Mobile Edge Computing) technology use cases in Korea to combat Covid-19	Mr Yoon-sung, Park VP, Head of 5G MEC Business TF / KT
3	11:10-11:30('20)	Private 5G use cases in Japan as Smart Infrastructure	Ms Mitsuyo Nishioka Professional / NEC
4	11:30-11:50('20)	5G applications and ecosystem in China	Ms Shan LI Director of 5G innovation Center/ CAICT
5	11:50-12:20('30)	**Panel Discussion**	-
	12:20-12:30('10)	**Q&A**	

Workshop – Day1

1. 5G⁺ Strategy of the Republic of Korea

The first session of the workshop was presented by Mr Sung-ho Choi, the program manager for Communications & Radio at the Ministry of Science and ICT. Mr Choi started the presentation by introducing an overview of the world's first 5G commercialization experience of Korea in April 2019.

5G is one of the core infrastructures of the 4th industrial revolution, which fuels digital innovation of industries by going beyond the existing mobile communication exchanges and overcoming the limitations of the existing communication technologies. Unlike 4G that is typically restricted to B2C-based smartphones, 5G technologies will be applied to B2B based diverse industries and advanced terminal equipment devices. In that way, the 5G based advanced innovation model creates new market opportunities within the existing innovative growth sector such as autonomous vehicles, smart factories, drone, and healthcare. Therefore, the most important thing in a 5G market could be 5G convergence services including smart city, health care, smart factory, etc. In this regard, the Korean government has been proceeding with a large-scale investment to vitalize the 5G ecosystem. Since the commercialization, Korea ranked No. 1 in market share of 5G smartphones and No. 3 in market share of 5G devices in global markets. The number of 5G subscriptions and the base station has been consistently increasing as well. At the same time, Korea promotes innovative convergence services by leading the investment of the public sector and establishing infrastructures for the growth of 5G core industries through deploying testbed and encouraging 5G R&D investment. Also, Korea plans to enhance infrastructures for the world's best 5G ecosystem and to expand the investment for leading 5G industries and services through a public-private partnership.

To specify the goal regarding 5G, Korea announced 5G+ Strategy after commercializing 5G and established 5G+ Strategic Committee in June 2019. The vision of the 5G+ Strategy is realizing innovation-driven growth via 5G and reaching 150 billion dollars of industrial production based on the strategy. 5G+ Strategy is a combination of 10 core industries and 5 core services. First, the core industries include edge computing, information security, 5G V2X, robot, drone, CCTV, wearable

devices, VR/AR, smartphones, and network devices. The core services are immersive contents, smart factory, smart city, digital healthcare, and self-driving car.

With these industry and service areas, 5G+ Strategy deployed a model that the new industries and services growth together mediated by 5G. With this in mind, the Korean government proposed five action strategies. The first is to secure early market dominance and improve quality of life with leading investment by the public sector. The specific action item for the area is to verify and spread 5G+ core services, to support the public sector for creation of demand, to improve the quality of life by introducing 5G public services, and to foster a 5G based smart city. The second area is to create a testbed and pursue industrial advancement to attract private investment. The specific action item is to increase tax benefits and investment support, construct infrastructure for 5G testing-verification, acceleration of 5G technology commercialization by SMEs, support for 5G content market, and support product innovation within major industries. Third, the strategy aims to support the adoption of 5G services and user protection through institutional improvement. The specific action item is to coordinate communications plans and systems, increase radio resources and improve regulations, establish the safest environment for the use of 5G, promote regulatory innovation for 5G convergence services, and reduce the digital divide and protect users. The fourth area is to nurture companies and talent that match the global standard by establishing an industrial foundation by creating an ecosystem to lead the global market by securing leading technologies, growing the information security industry, and fostering startups and human resources to ensure a competitive advantage in the future. Finally, the last is to promote the globalization of Korea's 5g technology and services by supporting their overseas expansion. At this time, the specific action item is to promote the globalization of 5G services, lead global 5G standardization, and support overseas expansion through international cooperation.

The expected result of the 5G+ Strategy is to realize innovative growth by pursuing 5G+ technologies that transcend the world's first 5G commercialization to incorporate 'new industries', 'jobs', and 'quality of life' within 5G. To be specific, Korea will emerge as the first-mover in the global market by creating a new 180 trillion won market and achieving an export volume of 73 billion dollars by 2026 through the cultivation of 5G+ strategy businesses. Also, Korea aims to create more than 600,000 quality jobs by 2026 by nurturing an innovative service industry and new manufacturing industry based on 5G. In that way, Korea will improve people's quality

of life by creating a safer, more convenient, and happier society than before through the expansion and advancement of 5G in social systems.

2. 5G B2B/B2C eco-system: based on Korea's experience

The second session was presented by Mr Dongjoo Park, the technical director at Ericsson-LG. He shared the experiences of deploying a 5G B2B/B2C ecosystem based on Korea's experiences.

With the 5G smart phone-based commercial service and industry application trials in Korea, people can recognize the difference in the eco-system of mobile with 5G. Despite the sharp increase of subscribers of the 5G service, coverage push comes from the government and end-users in the B2C area. It's the burden of operators with poor penetration loss of mid/high band of spectrum. With 5G B2B trials under the collaboration with industries such as vehicle, factory, city, safety, and media, we find the big difference of mobile eco-system mainly caused by the diversity in services. There's a need for global collaboration for the economy of scale of the eco-system.

In Korea, a smartphone-based live 5G commercial service was launched on April 3, 2019. Three Korean operators, SKT, KT, and LGU+ start transmission of the 5G signals with a 3.5GHz spectrum of 80MHz or 100MHz BW. Three Korean operators licensed 3.5GHz of 80MHz or 100Mhz BW spectrum and 28Hz of 800MHz BW spectrum each. The number of subscribers rocketed to 9.2M in September 2020. It occupies 13.2% of Korea's mobile subscribers compared to 77.4% of LTE subscribers. During the commercialization, we can easily find increased monthly data consumptions per smartphone 25.7G bytes with 5G compared to 9.9G bytes with LTE. It's 2.6 times of LTE. When compares with monthly mobile data traffic, with 5G it reaches 226 Peta Bytes compared to 436 Peta Bytes. 5G monthly mobile data traffic occupies 34% of the total mobile data traffic in September 2020.

There's good progress in 5G B2C service penetration in Korea but the operators are under the burden of coverage expansion from the government and end-users. Currently, 5G coverage mainly focus on big cities such as Seoul, Busan, etc and major road and railways. For 5G coverage, compared to the LTE case, a larger number of install base is required for the same coverage of LTE due to the poor outdoor propagation loss of mid(3.5GHz)/high(28GHz) band of spectrum. Especially outdoor to indoor penetration loss can be reached to -20dB with 28GHz. That's the main reason why indoor coverage is poor. Korean operators have concerns about

28GHz efficiency in B2C service and currently focus on 3.5GHz coverage expansion. MSIT and three operators agree on a coverage expansion plan. It shows that major 85 cities up to sub-urban, 20 highways, all subways/KTX lines, and more than 4K major crowded facilities will be covered by 5G 3.5GHz service until the end of 2021. Major rural areas related to 85 cities, all highways, all major train lines and medium/small size of crowded facilities will be covered with 5G service until the end of 2022. In parallel with 3.5GHz spectrum band coverage expansion, 3.5GHz SA will be applied to a limited area. As for the 28GHz, B2B and B2C hotspot applications are under consideration and it will be started very soon.

From the perspective of eco-system, 5G eco-system has a difference from the one of LTE. All the networks implemented with software and the open source become important. That's the basic difference in the ecosystem. In addition to that, we can recognize major focusing area for successful 5G B2C services: MEC and indoor solution. Recently, operators treated streaming games and AR/VR services are different services from 5G B2C. SKT had a partnership with Microsoft for xCloud streaming game service and KT with Ubitus for GameBox, LGU+ with NVIDIA for GeForce Now. VR services such as SKT 5GX Jump VR, KT Super VR and LGU+ VR and AR services such as AR zoo park, mobile shopping, AR contents were provided by 3 operators and sometimes free service and free accessories are provided. MEC is considered as a key component for streaming game and AR/VR service with low latency and traffic offload features. Operators already deployed MECs at major centers up to 8 or 13. MEC with cost efficiency and open interfaces will be spread out soon with the increased use cases in B2C and B2B. To cope with poor propagation losses, in-building solution with cost efficiency, high performance is required. 5G has the advantage of high speed and in-building solution with high performance will also be required. As for the hotspot deployment of 5G antenna, securing LOS is important especially for high band of spectrum. The street level of deployment becomes important compared to the roof top level of deployment of LTE. Securing the install base for street level deployment is a pre-requisite for a high band of the antenna. Streetlamp, building outside walls, kiosks are under consideration for the level of street deployment.

5G converged with industries such as a vehicle, factory, energy, city, safety, etc., and is considered as key component for Industry 4.0 in Korea. There are many trials for the past 2 to 3 years. GIGA Korea project is a leader in this area. GIGA Korea consists of a large number of sub-projects but is categorized with driving,

manufacturing, city, safety, media, and core technology. Each category of projects consists of multiple services, driving with remote driving and Cloud sharing, safety with firefighting and BIMS, a city with CCTV and monitoring, media with hologram, high resolution and 3D, manufacturing with a robot and AR/VR, core technology with MEC and backhaul. Each service was implemented under the collaboration with industry participants and local government. The other trials recently launched are focusing on application led by the Government. Government network implementation with 5G, 5G B2B/government service development and 5G testbed with an open lab is recently launched to lead the 5G application to the industry or the government.

During the 5G B2B trials, we found the big difference between the B2C and LTE eco-system. First, the difference comes from different customers. In the B2C case, the end customers use smart phone with the offer of same services. But in B2B case, customers of operators are industry owners with different kinds of services. Wider knowledge about industry business model, stakeholders' interest, service characteristics, and varieties of requirements are pre-requisite for B2B application of 5G. Based on this knowledge, to merge the mobile with industries, mutual understanding and consulting need to be followed by system integration, equipped with mobile and industry experience. It takes time to set up this process and the time can be reduced with dissemination and public's (government) lead. The merge between mobile and industry consists of two cases of digitalization: innovation and modernization. The replacement of old technology with the new technology of 5G can contribute to the efficiency of the existing process. Innovation during the application of 5G to the industry can make a new business model with new services. To support the innovation in merging, testbed and dissemination are required to spread out the innovation environment. Diversities of services in B2B makes a big difference in the terminal eco-system. Compared to B2C cases, B2B use case has a diversity of applications with the comparatively small size of the market. In the B2B market, it is difficult to secure an economy of scale. That's the reason why the B2B terminal solution consists of multiple chips compared to the single integrated chip solution of the B2C terminal. To increase the economy of scale, global collaboration is required with the activity of standard in interfaces of terminal functions, processes, and modular-based component inter-operability.

3. 5G Promotion from Public Domain and International Collaboration in Korea

The third session was led by Professor Hyunwoo Lee from Dankook University. He is also the Chair of the TTA 5G Standard Committee and a vice chair of the executive committee at 5G Forum. In this session, Prof. Lee introduced the status of 5G ecosystem and 5G Forum focusing on the status of promoting 5G via public domain and international collaboration in Korea.

Korea actually planned to commercialize 5G in November 2020, but they started commercializing it a year earlier, April 2019. There are still many efforts going on to stimulate the massive expansion of 5G. Especially the government is funding several projects to create a new market from the public domain such as education, administration, health, and etc. In addition, global collaborations have been going among economies and regions as well as among industry fora such as 5GAA (5G Automotive Association) and 5GACIA (5G Alliance for Connected Industries and Automation).

Four months after the commercialization, the Korea Ministry of Science and ICT(MSIT) presented the result of a survey on 5G services and quality. According to the result, most of the 5G services are distributed to large cities around Seoul, the capital city of Korea, and deployed mostly in large markets, hospitals, highways, and etc. Also, the average speed of data is DL 656.56Mbps and UL 64.14Mbps. MSIT is going to present the second survey result in the first quarter of 2021.

In addition, as a part of the Giga Korea project, a core project for ICT development, Korea has proceeded businesses for advancing 5G vertical industries and services from August 2018, and 5G vertical trials are distributed all around the economy. The result of the Giga Korea project was shared at the 5G Vertical Summit which was held on November 17-18, 2020, and the technical results will be published in the third edition of 5G Forum Vertical white paper.

Moreover, the Korean government announced the Digital New Deal initiative in 2020 to utilize 5G as a catalyst for the 4th industrial revolution. The initiative mainly aims to advance the digitalization of contactless services and the public sector and to create 2 million jobs by 2025. Also, the initiative is for a digital economy that will spur economic growth and innovation. There are four main focus areas: 1) stronger integration of DNA (Data, Network, and AI) throughout the economy, 2) digitalization

of education infrastructure, 3) fostering the 'contactless' industry, and 4) digitalization of social overhead capital (SOC). First, the Korean government will promote the use and integration of data, the 5G network, and AI throughout all sectors to create new digital products and services while enhancing the productivity of the Korean economy for stronger integration of DNA. Secondly, for digitalization of education infrastructure, Korea will expand digital infrastructure and educational materials to incorporate a blend of online and offline methods into learning environments of all elementary, middle, and high schools, universities and job training institutions across the economy. Third, Korea lays the groundwork to promote and foster the 'contactless' industry by setting up the relevant infrastructure that is closely related to people's daily lives. Finally, Korea will apply ICT technologies to key SOC infrastructure for safer and more convenient lifestyles and adding 'smart' components to urban spaces, industrial complexes and logistics systems to strengthen the competitiveness of relevant industries.

To support this work from a private domain, 5G forum is doing important roles such as promotion, dissemination, and ecosystem build up. 5G Forum is a partnership consist of mobile network operators, global manufacturers, research institutes, universities and government. The vision of 5G Forum is leading the 5G and vertical convergence in the 2020's in the context of the 4th industrial revolution. They aim to mutually collaborate among all the interested stakeholders of the new mobile communications infrastructure through their regular seminar, committee, issue report and annual white paper. Specifically, 5G Forum also enhances research activities on convergence services with the core economic subjects that represent the 4th industrial revolution such as a self-driving car, smart factory, and smart city, and actively promotes the government's 5G+ Strategy in response to convergence activities of global 5G+ group in other industries. Moreover, they are planning to establish a roadmap and vision for future telecommunications in line with the plan for B5G·6G from other global organizations. With regard to their vision and goal, 5G Forum has been actively conducting various activities for realizing the 4th industrial revolution and advancing 5G by holding and participating in 5G events. Additionally, they have cooperated with 11 5G related organization from all around the world and promoted 5G related global R&D projects with them.

Lastly, in order to assist technology development and businesses, the Korean standard body established a new standard committee dedicated to 5G as TC11 in 2020 as well.

4. Overview of 3GPP Activities on 5G Standards

The fourth presentation was given by Mr JunHwan Lee, a principal researcher of Future Mobile Communication Research Division at ETRI (Electronics and Telecommunications Research Institute) and a vice chair of the Ecosystem Strategy Committee of 5G Forum. Mr Lee explained the overview of 3GPP activities regarding 5G standards called as 5G NR (New Radio).

The 5G was firstly standardized in the ITU-R with the name of IMT-2020, and it covers three representative usage scenarios like eMBB, URLLC, and mMTC which are associated with the various applications in the vertical industries. In 3GPP terminology, the 5G is named as 5G NR. Based on the usage scenarios, there have been defined as 12 deployment scenarios. Meanwhile, the 3GPP SA1 created the study item of SMARTER where 5 building blocks with 74 use cases were categorized. Regarding the overall 3GPP timeline of 5G standards, the first version of the 5G NR, Release 15, was approved in Dec. 2017. The specification was treated as an early drop supporting Non-Stand Alone (NSA) mode. The first specification supporting Stand-Alone mode was completed in June 2018 while Release 16 was delayed by 3 months till June 2020. For Release 17 the current tentative schedule is supposed to be determined at the end of the 2020. It is expected to be finished its normative works in 2022.

When it comes to 5G NR architectures, there can be two groups of NSA and SA where Option-3 and Option-2 represent for each group, respectively, and also including the variants of each option. To help understand the operations of each mode, the concepts of eNB, gNB, ng-eNB, and en-gNB should be recognized where the eNB denotes 4G base station, and the gNB stands for 5G base station. The prefix of ng- and en- to both eNB and gNB implies that eNB or gNB is interoperable with 4G or 5G. For example, ng-eNB means the 4G eNB can be connected to 5GC and gNB. Taking account of the combinations of four different nodes, there are four different types for Dual Connectivity: EN-DC, NGEN-DC, NE-DC, and NR-DC. Since the first specification of Release 15 only provides the function of NSA of Option-3, the world's first 5G launch in Korea in April 2019 operated based on NSA mode.

The 5G NR has been standardized in phase approach; Phase 1 for Release 15, and Phase 2 for Release 16. Regarding the new features in 5G NR specifications, it can be said that the new numerology takes various use cases into account and the new

spectrum band like millimeter-wave were introduced. In Release 15, the basic features of eMBB and URLLC were addressed supporting FR1(450MHz~7.125GHz) and FR2(24.25GHz~52.6GHz). The 5G NR standardization has been performed in each working group of RAN1, RAN2, and RAN3. For example, the 5G NR work items of RAN1 includes 'Initial access', 'MIMO', 'Channel coding', 'Duplexing', 'Wider bandwidth operation', 'NR-LTE co-existence, 'Uplink power control', and so on. Other than RAN1 activities, the work items of RAN2 and RAN3 cover the issues on higher layers such as MAC, RLC, interfaces between RAN and Core network.

Since the design philosophy on 5G NR specifications is forward-compatible, it is likely that the specifications completed so far will evolve further to accommodate more potential use cases and to solve societal issues. In the end, wireless communication technologies are no more limited to a single industry, but it will expand their role meeting the requirements from other vertical sectors. Finally, it is expected that it will stand as an underlying infrastructure affordable and sustainable for the society of the 4th Industrial Revolution.

5G Commercialization and Beyond

The final presentation of the first day was presented by Mr Takki Ryu, the head of the Access Network Development Team in SK Telecom Korea. Mr Ryu shared the SKT's current status of the 5G commercialization in Korea and abroad and introduced the SKT's core technologies and services.

SKT started commercializing the world's first 5G in four and a half years after the publication of the 5G white paper in October 2014. A year after, they launched the world's first 5G smartphone via SKT 5GX launching showcase. As of September 2020, SKT reached almost 46% (4 million) of 5G subscribers among all domestic carriers, and they are targeting 5 million subscribers by the end of the year and planning to expand coverage and B2B services as well. Also, SKT has been received 5G World Awards, Small Cell Awards, and Leading Lights Awards since the commercialization, which shows the technical power of SKT.

In the aspect of the speed of data, consuming 5G (25.7GB) data traffic is 2.58 times higher than 4G (9.96GB), which means 5G users consume more traffic than 4G users do. Also, it has been observed that people's lifestyle has been changed by 5G according to the data and service usage pattern comparison in SKT. For example, compared to the 4G usage pattern, 5G subscribers used 2.7 times more data, 3.3 times more games, 3.4 times more media, and 7.0 times more VR. In these 5G trends, SKT's 5GX Hyper-Connected Network has differentiated in the aspect of speed, latency, security, and stability.

First, SKT has focused on enhancing speed. SKT has secured 5G frequency with 100MHz at 3.g GHz and 800MHz at 28GHz with 5G/LTE aggregation technology. Also, they established the differentiated 5G in-building solutions for maximum capacity and coverage expansion. Second, SKT provides latency-sensitive services with 5G Mobile Edge Computing (MEC). With the economy-wide coverage, they provide interactive and immersive services such as AR/VR, multimedia, and cloud gaming in the aspect of B2C and mission-critical services such as smart healthcare, AI-Machine vision fault detection, and non-contact robot delivery in the aspect of B2B. Third, SKT has secured absolute security with an un-hackable network by quantum security. In this regard, they are planning to launch the world's first QRNG (Quantum Random Number Generation)-powered 5G smartphone that enables higher security services in authentication, payment, and e-certification in May 2022. SKT will

constantly develop and expand innovative 5GX Quantum services and applied devices through open collaboration with ecosystems based on open APIs in communication and RCS (Rich Communication Services), IoT, cloud storage, automotive, and mission-critical security era. Finally, SKT acquires the intelligent stability of 5G network through TANGO, the network management system based on AI and big data. TANGO grafts big data analysis and machine learning, and find problems of the network and solve and optimize the problem by itself. Besides, TANGO even automatically manages the quality of telecommunications via analyzing traffic information by region and time, and suggest solutions to an expert manager when detecting errors on the network. In 2017, SKT made a strategic partnership which contains transferring AI network technology skills with Bharti Airtel India, the third-best carrier in the world, and exported TANGO. Since AI network operation technology based on big data analysis is essential in the 5G era, SKT will enhance the function of TANGO to provide the best network quality to the customers.

SKT also provides differentiated 5G services such as entertainment, games, AR services, B2C/B2B through SKT's ultra-high-speed 5GX. For example, there is 5GX Cluster and Boost Park, and the ultra-high-speed of the SKT 5GX in the clusters provides 5G based fun and benefits for 5G customers. Also, 5G xCloud enables users to enjoy high-end games over high speed and stable 5G networks with the mobile edge at anytime and anywhere with any device. In addition, 5G AR using 5G MEC and AR/VR improves the users' experiences. Finally, there are the other 5G services including B2C and B2B such as immersive media, realistic game, autonomous driving, smart factory, and smart city. SKT has been collaborating with both public and private sectors including Microsoft, BMW, Nexon, Incheon Airport, T-mobile, Volvo, Severance Hospital, and etc.

SKT will continue distributing 5G-enabled innovations in various areas and lead the world towards a brighter future through SKT's 5GX.

Workshop Day – 2

1. From Wireless Knife, Drones to Smart Factory

The first presentation of the 2nd day workshop was given by Professor Seong Lyun Kim, the head of the School of Electrical and Electronic Engineering at Yonsei University. He also leads the Smart Factory Committee at 5G Forum. At this session, he covered some key technological and regulatory aspects in 5G smart factory, with special emphasis on the use cases of Korea.

The Smart Factory Committee of 5G Forum was established in May 2018, and it is composed of four working groups related to local spectrum licensing, 5G operators, 5G networks, and SMEs. The committee promotes public-private global cooperation for the realization of smart factory service based on 5G. In May 2020, 5G-ACIA (Alliance for Connected Industries and Automation) and 5G signed an MoU at 5G Vertical Summit for global cooperation such as expanding 5G based smart factory and deploying smart factory ecosystem.

As Professor Kim is the head of the Smart Factory Committee at 5G Forum, he also takes full charge of the PriMO-5G project which is an EU-Korea collaboration project studying the use of 5G technologies and unmanned aerial vehicles or drones. This project is led by both academia and industry and was first presented in May in Helsinki, Finland. KT (Korea Telecom) also participated in the PriMO-5G project and signed a business agreement with Yonsei University (Korea) for deploying '5G Open Platform' based on 5G network. '5G Open Platform' is a platform that develops and tests various 5G convergence services such as telemedicine, emergency management, and autonomous driving by connecting KT's 5G network to Yonsei Shin-chon campus and Song-do international campus. Especially, KT separated the commercial network and research network by applying network slicing technology and MEC to the 5G Open Platform. The network slicing technology provides various customized services through each slice by separating one physical core network infrastructure to a number of the independent virtual network for a form of service. Since it is possible to be virtualized under a network structure according to users' needs, it is highly cost-saving and efficient to operate, and it is drawing attention as a core technology in the 5G era due to its high utilization in various fields. Also, MEC is a technology that can manage and control big data in real-time through a distributed

server by region, and it is also regarded as a core technology in the 5G era in the aspect of stable processing of the big data with 5G.

In 2018, an end-to-end network was deployed at both Yonsei University-Shinchon and Yonsei University-Songdo through the PriMO-5G project, and the project showed a performance of sending high-resolution video which was shoot by moving drones and KT Skyship in real-time. The drone control station on the ground was 70km away from the campus, and even the shooting image was sent to a station in a vehicle through machine learning. Now, the PriMO-5G project is enhancing test bed and demonstration on the three-tier UAV system with cellular communications including 4G and 5G, and focusing on the advancement of latency and credibility of data.

Moreover, Prof Kim shared some panel discussion questions from the Smart Factory 5G Vertical Summit 2020. The questions were related to the future of 5G smart factory: 1) the key bottlenecks both in technical and regulatory aspects, 2) the promising areas in the 5G smart factory, and 3) Japan's experience in Local 5G. Professor Kim, as a moderator of the discussion, had used these same questions two years in a row since last year, and Prof. Kim was able to get improved answers from the discussants this year. It shows that the environment and technical power of 5G smart factory have been improved as well. Additionally, the concept of a smart factory has changed. For instance, in the past, the smart factory was more of "wireless" in the aspect of Korea, but now it is more of "smart." In this regard, Prof. Kim shared an example of the Daesun Corporation, a Korean liquor company, facilitating 5G-based vision camera. With the machine vision, the company is able to check and control the overall progress of producing the liquor. Also, the 5G machine vision could detect and sort out flaws.

Finally, Prof. Kim ended the presentation with introducing the requirements of 6G which are faster speed, more reliability and connectivity, lower latency, and increased energy efficiency.

2. Private 5G Use Cases in Japan as Smart Infrastructure

The second presentation was given by Ms Mitsuyo Nishioka, the head of Private 5G business in the Global Market, Cross Industry Business Unit at NEC Corporation. She introduced several private 5G use cases in Japan from NEC's experiences focusing on private 5G use cases for public sectors and public services.

Concerning the commercialization of Local 5G regulation which was announced in December 2019, NEC is providing end-to-end solutions for DX at each vertical leveraging 5G capabilities and integrating edge computing, AI analytics, managed services, and more for best service. (The meaning of "Local 5G" in Japan is same as the meaning of "Private 5G", which is generally described in English.)

The first use case is from railway industry. The representative advantages of 5G are high-speed broadband, low latency, and massive connections, and the advantages of Private 5G are uplink/downlink and other customizations, dedicated spectrum for less interference, flexible coverage design, and secure isolated network. The combination of these advantages results in positive effects on the railway industry. First, the centralized data center is able to manage and analyze data and predict risks with the efficient use of data and assets. Second, the advantages lead to enhanced controls with labor saving. Third, there are automatic ticket gates and tracking cameras with easy and flexible equipment installations. Finally, there are enhanced maintenance and operations with condition-based maintenance, drones, and train vehicles.

The second use case is the Road DX with digitalized road and mobility services. The Road DX manages traffic by adjusting signal timing for pedestrians and emergency vehicles and by reducing congestions. Also, it prevents incidents by preventing and detecting collisions from cross monitoring. Moreover, for road maintenance, Road DX can monitor conditions of roads and detect fallen objects. Finally, the enhanced transport industrial services could be used for optimizing routes and appraising insurance with the data.

The third use case is the mixed reality tourism over 5G which increases the value of tourism sites. Private 5G (Local 5G) could cover various types of tourism sites to increase attractiveness. Also, high capacity, low latency, and customization of profile give the ability for sophistication to new cultural experiences. Besides, a reliable network delivers innovative entertainment as well.

Finally, the last use case that Japan shared was natural disaster management. The Private 5G enhances and facilitates the ability to collect high capacity data. More depth and real-time analysis using high capacity data collection enhances the monitoring of natural disasters. Also, the Private 5G increases people's safety by eliminating surveillance by personnel and assisting the residents' evacuation. Finally, more bandwidth for disaster management is allocated when needed for resource utilization.

In addition to Japan's use cases, NEC also introduced Private 5G Lab which is the next-generation co-creation space. The lab experiences and verifies the Private 5G in real innovation through co-creation and tries out new use cases instantly. Also, the lab is space, facilities, and license ready place for an end to end testing using standardized 5G and for comparing with other wireless networks. Moreover, NEC has a mobility test course which is a private test center to enhance mobility solutions with traffic lights and crossings, and they obtain a private 5G network, sensors and cameras, video analytics, AI analytics, and more.

Also, NEC applies the digitalization of manufacturing using private 5G for NEC smart factories. The NEC smart factories are located in Japan and Thailand. In Kofu, Japan, the smart factory uses private 5G as infrastructure for DX and expands the know-how to other NEC factories in Japan. At the same time, the factories in Thailand is planning to use 5G for industrial use cases and expands the know-how to NEC factories located in other economies as well.

Lastly, Japan emphasizes that 5G supports new society by improving quality of life, work styles, industry ecosystem, communication, lifeline infrastructure, sustainable earth, and safer cities and public services. For this new society, Japan is working on utilizing the Private 5G as a smart infrastructure, including mobility, energy, smart city, factory, airport, construction site, railway, hospital, and education.

3. 5G MEC (Mobile Edge Computing) Technology Use Cases in Korea to Combat Covid-19

The third session was led by Yoon-sung Park, a vice president and the head of 5G MEC Business TF at KT, Korea. As he is in charge of cultivating KT's 5G B2B MEC business and AI/Digital transformation convergence business, he introduced the utilization of 5G MEC infrastructure to detect radiating heat from the body with face recognition, people counting and facility management.

The 5G⁺ Strategy enhances 5G MEC infrastructure and the MEC market is expected to expand worldwide in the future. Specifically, the experts predict that the 5G MEC market will be expanded to 35% of CAGR (compound annual growth rate) with 150K deployment by 2022. MEC linkage is required to maximize ultra-high speed and ultra-low latency characteristics of 5G. However, as 5G infrastructure is still in the initial stages, it needs to spread convergence services to various fields. Although, the world succeeded in commercializing 5G, the formation of 5G industrial ecosystem is still at the early stage. In this regard, KT has been building Korea's 5G ecosystem early by applying 5G convergence services to the public sector based on MEC technology. 5G technology secures the ICT industry with competitiveness by solidifying the preoccupation effect in 5G market, and the 5G services promote people's convenience in living by upgrading public services. Also, the 5G ecosystem expands the private sector market and creates jobs.

In addition, the 5G convergence service model provides in areas with high economy-wide sentiment and high industrial impact, especially in the case of the Covid-19 pandemic these days. 5G MEC technology could prevent infectious disease and provide health care and coaching services securely and conveniently. For example, the 5G MEC based contactless AI facial recognition services relieve public anxiety and burden on public facilities due to Covid-19. They are largely divided into 3 steps. First, MEC technology extract features of the face with facial imaging and conducts pre-examination with an AI chatbox before people enter a public place. Then, the next step is fever check through 5G MEC platform. The final step is managing monitoring with statistical information extracted from the previous steps. There is another example which is non-contact two-way coaching services that provide a safe and immersive educational environment for Covid-19 weary students. There are a number of representative MEC platforms, including real time device monitoring platforms, real time video platforms, VoD platforms, and contents development

platforms. With these MEC platforms, students are able to select and register for online courses and even participate in non-contact public sports via remote private coaching or virtual group coaching. The final example is 5G non-contact healthcare services that provide high-quality healthcare services to medically underserved communities in Jeju Island, Korea. The representative 5G MEC platform in this case is a healthcare kiosk that enables people to measure their health data and provides personalized health content to the local hospital. Also, with the UHD video call, people in the underserved area such as Jeju conduct online health consultations and diagnose their condition with remote doctors. Besides, real-time data sharing enables rapid emergency response as well. In conclusion, 5G MEC infrastructure at the network edge close to customers should be built to enhance network slicing security, to lead open-source based standardization, and localize AI semiconductors.

4. 5G Application and Ecosystem in China

The final presentation was given by Ms Shan Li, the Chair of the Industry Promotion Group of 5GAIA. In this session, she introduced 5G development of network and market in China, and 5G applications use case in China. She discussed the challenges of 5G vertical application and the ways to build a new big 5G ecosystem as well.

During the past few months, the world has witnessed the spread of Covid-19, which results in great negative impacts on the global economy. However, the rate of 5G deployment has shown a growth trend and grown rapidly in 2020. On September 30, the amount of 5G base stations reached more than 690,000. On November 7, 2020, China Telecom, the first carrier, announced a standalone (SA) 5G commercial. On September 30, 2020, the number of 5G subscribers exceeded 160 million, and the total domestic cellphone market shipment volume reached to 252 million, of which 5G cellphone shipments reached to 124 million (49.4%) in October 2020.

For the applications of 5G, there is the biggest 5G application competition in China called "Blooming Cup" which has been held since 2018. A total of 4,289 entries were received in 2020's competition, with more than 2,300 participating units, covering 30 provinces, autonomous regions and municipalities. Industrial internet projects accounted for three consecutive years of growth, accounting for 28% of all projects, becoming the hottest 5G applications. Most of the projects from the Blooming Cup Championship have already had mature solutions, and 31% of the projects from the 2020's competitive have already been implemented. Compared with 2018 and 2019, the integration level of 5G and ICT technology continues to improve. AI is still the technology with the highest degree of integration with 5G applications, and MEC technology has increased by 10% compared with the last year's and has become the key enabling technology of 5G applications.

There are largely 7 representative sectors with 5G applications in China. The first one is smart health care which has achieved the landing in practice. Remote consultation with AR/VR has been implemented in more than 60 hospitals within 19 provinces, and 5G medical robots for nursing has been implemented I more than 80 hospitals within 22 provinces. Especially, during the outbreak of the Covid-19, more than 3,000 Covid-19 cases have been diagnosed with 5G remote consultation in China, and doctors successfully controlled the ultrasonic robot and performed an ultrasound

examination for the Covid-19 patients. Secondly, 5G also applies to the entertainment area. Cloud live broadcasting business comprehensively displays the progress of the front-line epidemic prevention and control work represented by the construction of Raytheon and Vulcan Hospitals, which enhances the confidence of the Chinese people to defeat the epidemic. Also, 5G combines big data, cloud computing, VR/AR, holography, ultra HD video and other technologies to develop a new home-based cloud travel model. In addition, for smart education as the third area, 5G distance educations break the time and space limit, creates the interactive teaching model in different places, realizes the quality education under the condition of "internet +", which promotes the balanced distribution of quality education resources. Besides, the immersive classroom strengthens students' dominant position in the classroom. Through the combination of 5G, VR/AR, holographic image, and other display technologies, students get an immersive, practical, and strongly interactive classroom experience. The fourth area is V2X, and L4 level autonomous driving applications have been commercialized in the port and other industrial environments after the mature application of information services such as mobile network online navigation, congestion warning, vehicle full like cycle management, and Internet of the vehicle insurance. The next application area is the industrial internet. As the massive bandwidth provided by 5G networks is the major driving force to industrial internet, many applications supported by 5G+ industrial internet have been implemented at manufactures, ports, and mining areas. The sixth area is a port called Ma-Bay Smart Harbor, which was implemented in Shenzhen, China. These 5G smart port solutions can be copied to ports at home and abroad, driving the upgrading of the entire industry technology and bringing huge commercial benefits, which accelerates the future of 5G and vertical industry application. The final area is the virtual private network. The high-quality private virtual network based on 5G public network can meet the business and security requirements of industry users, which is the core carrier of differentiated and partially independent network service for industry users.

Even with all these 5G applications, there are still challenges to overcome such as technical standard, industrial network capacity, industrial ecology, business model, and integration policy. The industry chain of 5G applications is complex and the ecosystem has not been formed yet. Also, the connection between different industries still needs to be further strengthened. Therefore, 5G is required to establish a cross-industry ecosystem, including CT (chip, device, terminal), IT (cloud, AI, big data), vertical industry, and other fields to form an overall solution.