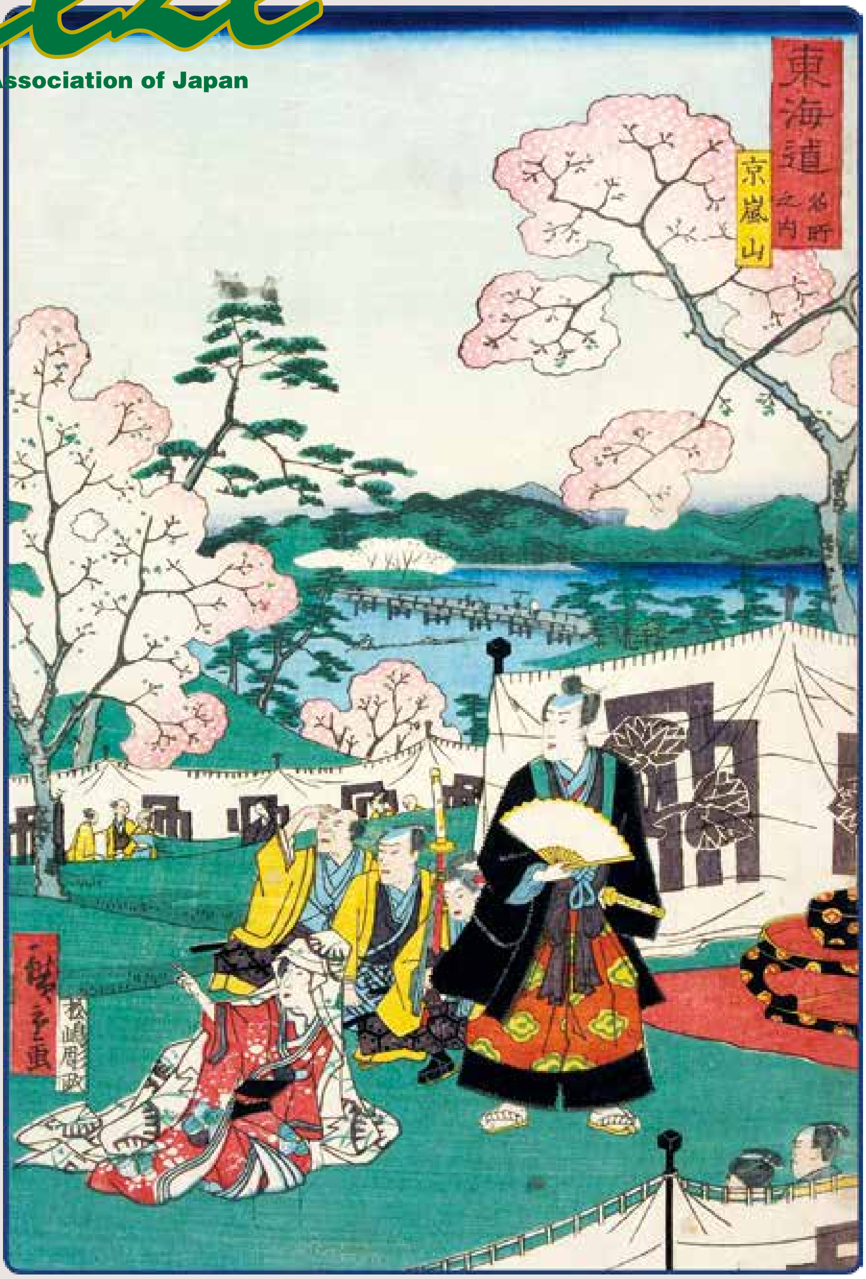
ISSN 0915-3160

平成二十九年四月十日発行（年四回一、四、七、十月の十日発行）通巻百十四号　New Breeze

New Breeze

Quarterly of The ITU Association of Japan

No. 2
Vol. 29 April 2017
Spring



Special Feature

Future Vision of 5G Mobile Communications

Domestic and International Trends

Fifth Generation Mobile Communications Promotion Forum (5GMF) White Paper

NTT DOCOMO Outlook for 5G Deployment

KDDI's Perspectives Towards 5G

New Breeze ISSN 0915-3160
Quarterly of The ITU Association of Japan
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Tokyo 160-0022 Japan
Tel: +81-3-5357-7610 Fax: +81-3-3356-8170
https://www.ituaj.jp/?page_id=310

Publisher: Michiaki Ogasawara

Editors: Yuzo Mori
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Letters to *New Breeze*

New Breeze welcomes readers' opinions. Please send comments with your name, address, and nationality by e-mail, fax, or post to the editor.

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Subscription forms are available on the ITU-AJ website:
http://www.ituaj.jp/english/subscription_form.pdf

Subscription Fee:

Single issue:	¥1,500
Annual subscription (4 issues):	¥6,000

C O N T E N T S

About ITU-AJ

The ITU Association of Japan (ITU-AJ) was founded on September 1, 1971, to coordinate Japanese activities in the telecommunication and broadcasting sectors with international activities. Today, the principle activities of the ITU-AJ are to cooperate in various activities of international organizations such as the ITU and to disseminate information about them. The Association also aims to help developing countries by supporting technical assistance, as well as by taking part in general international cooperation, mainly through the Asia-Pacific Telecommunity (APT), so as to contribute to the advance of the telecommunications and broadcasting throughout the world.

Domestic and International Trends

— *Japan's cooperation with the efforts of other countries and key points of the Radio Policy 2020 Study Group Final Report* —

New-Generation Mobile Communications Office,
Land Mobile Communications Division,
Radio Department, Telecommunications Bureau
Ministry of Internal Affairs and Communications

1. Introduction

Nowadays, the use of radio waves is expanding into a wide variety of fields that are essential for our daily lives, including not only communication networks such as mobile phones and wireless LANs, but also robotics, medicine and the environment. It is also expected that the Internet of Things (IoT), where everything is connected to a network, will soon be in full swing.

On the other hand, there are demands for the provision of new mobile services that can handle the increased traffic levels resulting from the evolution of mobile broadband networks. In response to this situation, the Ministry of Internal Affairs and Communications has been promoting efforts aimed at delivering fifth generation mobile communication systems (5G) in time for the Tokyo 2020 Olympic and Paralympic Games. These include joint R&D projects between industry, academia and government institutions with the aim of delivering enhanced Mobile Broadband (eMBB) while supporting massive Machine Type Communications (mMTC), international cooperation involving stronger ties with governments and 5G promotion organizations worldwide, comprehensive trials that are scheduled to begin in 2017, and discussions of frequency allocations for 5G networks.

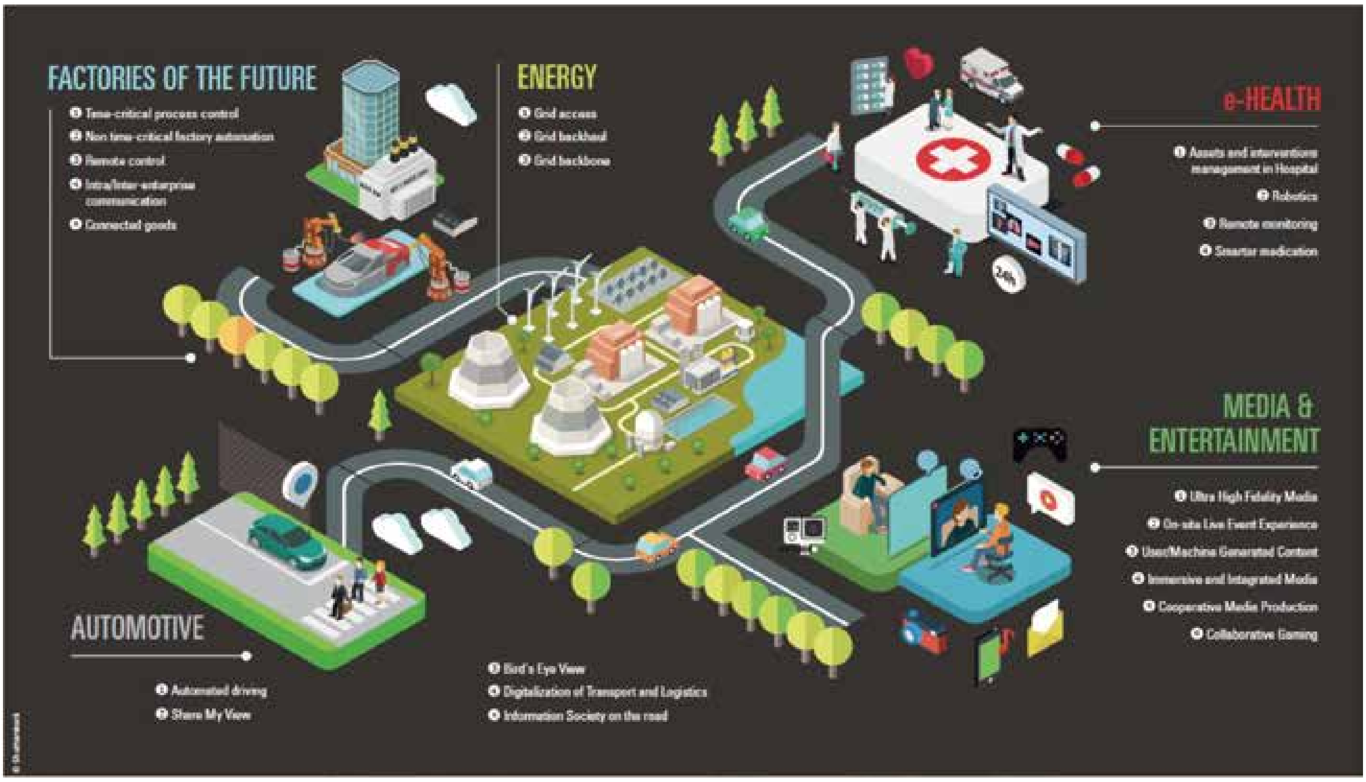
This article introduces the efforts being made to realize 5G, particularly regarding Japan's cooperation with the efforts of other countries, and the Radio Policy 2020 Study Group that was opened by the Senior Vice-Minister for Internal Affairs and Communications between January and July 2016.

2. Foreign initiatives

2.1 Europe

Through the Horizon2020 framework for the promotion of research and innovation throughout the EU, the European Commission plans to invest €700 million over the 7-year period from 2014 through 2020, with an additional €3 billion or more to be invested by the private sector. Since 2015, further R&D projects such as METIS II have been set up to make use of this program under the 5GPPP R&D project.

■ Figure 1: Fields of 5G utilization in Europe



Source: 5GPPP, 5G empowering vertical industries(Feb 2016)

In September 2016, a 5G action plan was published to summarize the details of demonstration experiments and standardization policies in preparation for the launch of commercial 5G services by 2020. Candidate frequency bands for 5G were announced in November 2016. These include the 3.4–3.8 GHz, 24.5–27.5 GHz and 700 MHz bands.

Regarding the use of 5G, the 5GPPP has identified five key fields with "Vertical" connections (automobiles, factories/manufacturing, energy, health/medicine, and media), and is holding specialized workshops and other events to develop stronger ties with the fields where 5G will be used.

In the UK, a 5G Innovation Centre (5GIC) has been set up at Surrey University with the cooperation of the industrial sector, and trials using a 5G radio technology testbed were started in 2015.

Communication equipment vendors including Ericsson and Nokia have also been cooperating with communication providers in various countries, and are leading the way in 5G joint R&D initiatives and standardization efforts including the 3GPP.

2.2 United States

On 14th July 2016, the FCC (Federal Communications Commission) announced that it would reserve frequencies for 5G services. In particular, it was made clear that the 27.5–28.35 GHz and 37–40 GHz bands would be licensed, while the 64–71 GHz band would be made available for unlicensed use. The unlicensed 64–71 GHz band is to be combined with the 57–64 GHz band, which is already unlicensed, resulting in the availability of a continuous unlicensed band of 14 GHz. There are also plans to introduce a mechanism for dynamically sharing bandwidth between commercial applications and other commercial or public applications in the 37–37.6 GHz band.

In the private sector, the Verizon 5G Technology Forum was established in September 2015 by Verizon together with other participants including Alcatel-Lucent, Ericsson, Nokia, Qualcomm and Samsung, and since 2016 it has been actively involved in carrying out field tests. Verizon has announced that it will begin 5G commercial services using the 28 GHz band from 2017. AT&T is also planning to introduce 5G at an early stage, and is engaged in verification trials with Ericsson and Intel, among others.

2.3 South Korea

South Korea is currently gearing up to host the 2018 Winter Olympics in Pyeongchang, and Samsung is working towards holding trials in partnership with other companies including KT and SK Telecom. They aim to implement 20 Gbps high-speed communication using the 28 GHz band. They envisage that this band will be used for applications such as holographic projections, super multiview displays, VR and Giga Wi-Fi in press centers, airports, conference halls and the like, and hope to begin commercial services in 2020.

In research and development, through the efforts of 5G R&D projects (the Core Technology Project and Giga Korea Project), there are plans to invest $490 million by 2020, and for the creation of new 5G markets, the participation of small and medium-sized enterprises is being encouraged and the transfer of technology is also being supported.

In February 2016, four companies — KT, NTT DOCOMO, SK Telecom and Verizon — co-founded the 5G Open Trial Specification Alliance to promote cooperation between companies performing 5G verification trials.

In January 2017, the K-ICT frequency plan was announced with the aim of ensuring the availability of frequencies for commercial 5G services. By around 2018, South Korea plans to allocate the 27.5–28.5 GHz (or 26.5–28.5 GHz, depending on the status of device development) and 3.4–3.7 GHz bands.

2.4 China

At the Mobile World Congress (an international event covering 5G and other technologies that was held in June 2016), China Mobile announced its intention to implement 5G services by 2020. The Chinese Ministry of Industry and Information Technology announced that research, development and testing of 5G technology would take three years from 2016 through 2018.

China Mobile and Huawei are both promoting efforts to implement 5G services in collaboration with NTT DOCOMO.

3. Partnerships between Japan and other countries

Towards the implementation of 5G by 2020, 5G promotion organizations are being established through cooperation between industry, academia and governments in the world's leading countries and regions in the same way as the 5GMF in Japan (see Figure. 2). Each organization is publishing white papers summarizing the usage fields and technical issues of 5G, and is promoting research and development efforts.

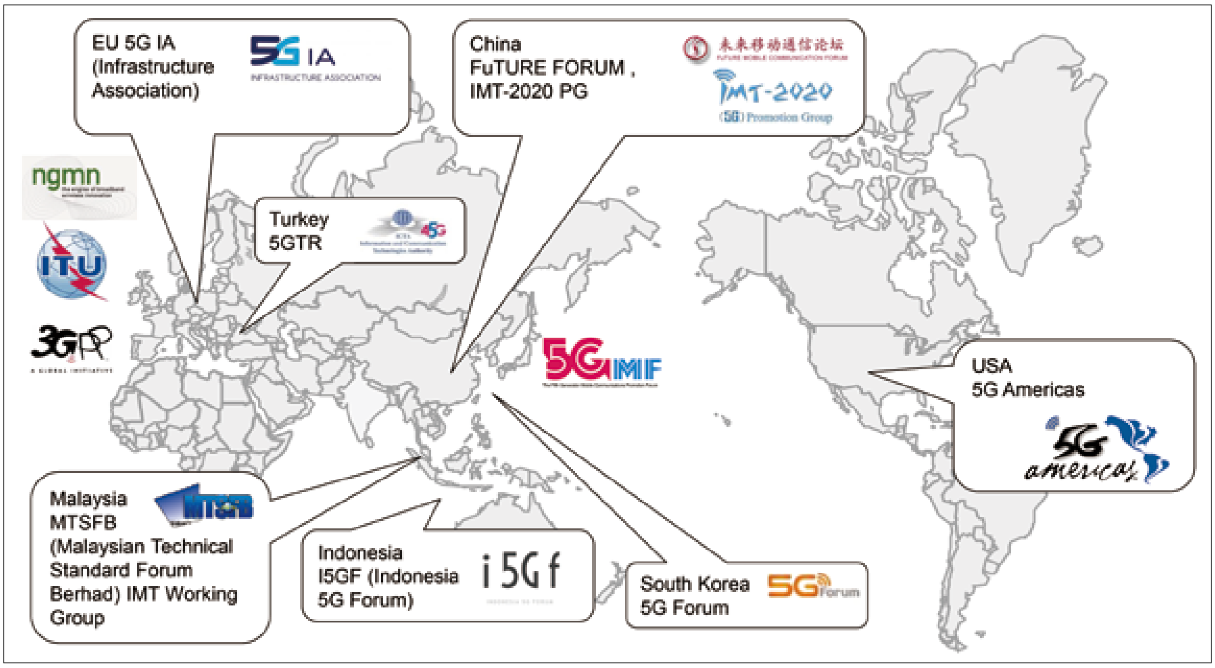
To strengthen international cooperation between organizations, the 5GMF has been holding workshops and setting up memoranda of understanding (MoUs) (Figure. 3). In particular, the 5G promotion organizations of Europe, the US, China and South Korea (5GIA, 5G Americas, IMT-2020 PG and the 5G Forum) have entered into a multilateral MoU, on the basis of which each region will take turns to hold a biannual Global 5G Event. The first such event took place in Beijing in May 2016, and the second was held in Rome in November. In May this year, the third of these events is due to be held in Tokyo.

4. Final report of the Radio Policy 2020 Study Group

The Radio Policy 2020 Study Group was opened by the Senior Vice-Minister for Internal Affairs and Communications between January and July 2016, and studied promotion policies aimed at the realization of new mobile services including 5G and next-generation ITS (Intelligent Transport Systems).

In its final report of July 2016, 5G is positioned as the ICT platform for the IoT era in which the circulation of vast quantities of diverse kinds of data concentrated in the cloud. The report presents nine fields of use, three projects and nine promotion models, and concludes that the promotion of these projects will accelerate efforts to realize 5G by 2020. This article summarizes

■ **Figure 2: 5G promotion organizations in each country and region**



■ **Figure 3: International cooperation activities in 5GMF**

Cooperation with 5G promotion organizations (creation of MoUs, etc.)

- Cooperation with Europe:MoU with the 5G Infrastructure Association @Frankfurt, March 2015
- Cooperation with Korea: MoU with the 5G Forum @Tokyo, April 2015
- Cooperation with Indonesia: MoU with the Indonesian 5G Forum @Bali, September 2015
- Japan/Europe/US/China/South Korea Alliance: Multilateral MoU with 5G Infrastructure Association (Europe), 5G Americas (USA), 5G Forum (South Korea) and IMT-2020 (5G) Promotion Group (China) @Lisbon, October 2015
- Cooperation with Malaysia: Agreement (MoC) with IMT Sub-WG 5G @Cyberjaya, April 2016
- Cooperation with China: MoU with the IMT-2020 (5G) PG @Beijing, June 2016

Holding international conferences, etc.

- Japan–Europe 5G Symposium @Hiroo,Feburary 2016: Held jointly with the French embassy in Japan, and the Delegation of the European Union
- CEATEC 5G workshop @MakuhariMesse, October 2016
- Global 5G event (2nd)@ Rome, Italy, November 2016
- Japan–Turkey 5G workshop@Ankara, Turkey, January 2017

Photo (left): Japan–Europe 5G Symposium

Photos (center, right): The Global 5G Event

the 5G final report of the Radio Policy 2020 Study Group.

Prior to 4G, services were centered around the distribution of information to devices such as smartphones and tablets. On the other hand, 5G not only provides eMBB, but also facilitates Ultra-Reliable Low-Latency Communications (URLLC) and mMTC to large numbers of sensors and terminals, and is expected to be used in a much wider diversity of fields including automobiles. Achieving horizontal development in the following nine fields is vital for the spread of 5G.

(1) Sports (fitness, etc.)
(2) Entertainment (games, tourism, etc.)

(3) Offices / workplaces
(4) Medical care (healthcare, nursing)
(5) Smart houses / daily life (daily necessities, communications, etc.)
(6) Retail (financing, payments)
(7) Agriculture, forestry and fisheries
(8) Smart cities / smart areas
(9) Traffic (passenger transport, freight distribution, etc.)

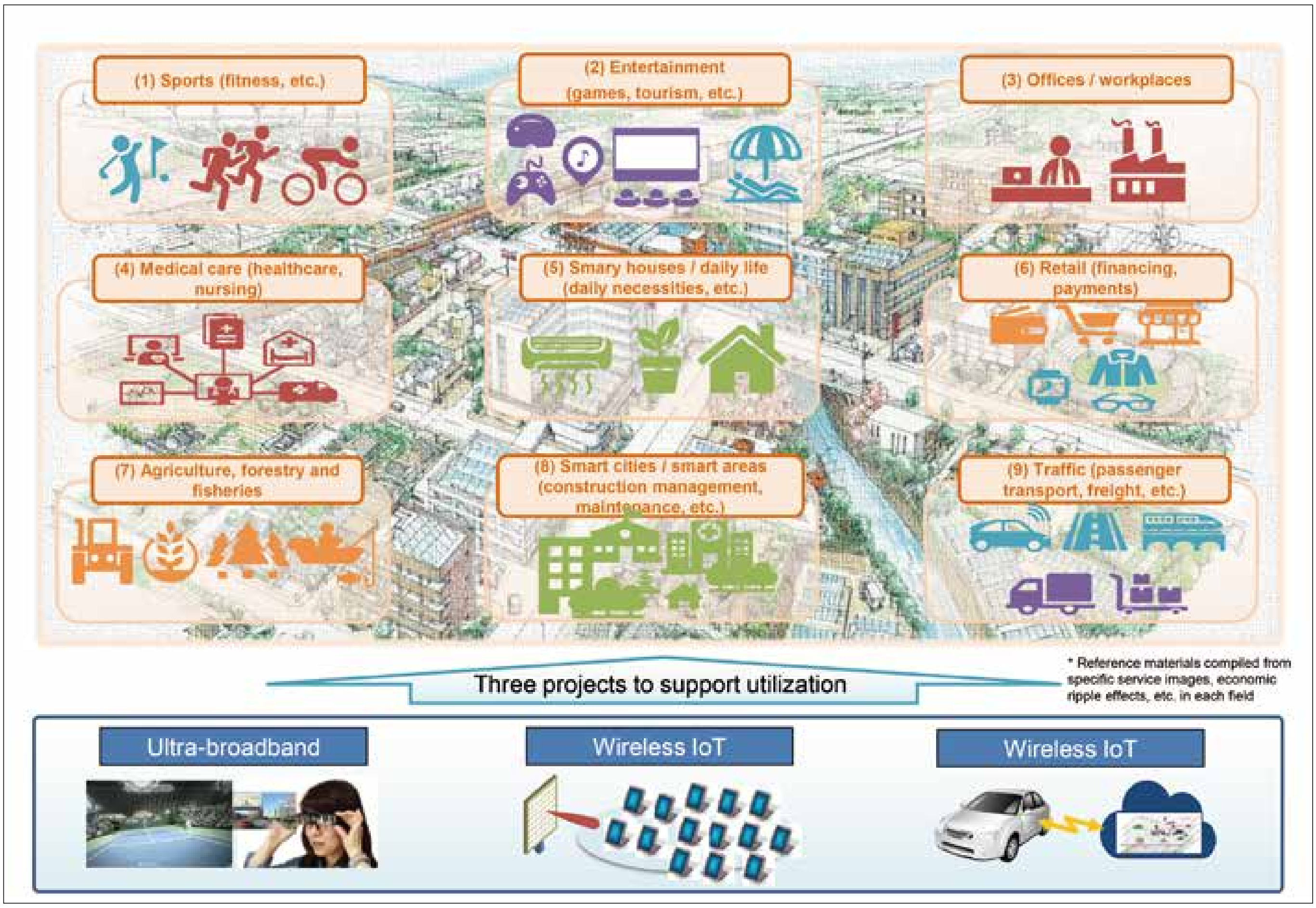
To further develop these nine fields, cooperation with diverse utilization fields is essential from the stage of R&D and verification before a system is introduced, rather than going ahead with horizontal deployment from the stage where 5G is implemented. Therefore, to achieve the early deployment of 5G in these nine fields, based on the main requirements of 5G (mMBB, mMTC, and URLLC), it was shown that three projects should be promoted: ultra-broadband, wireless IoT, and next-generation ITS (see Figure. 4).

With regard to these three projects, three specific "promotion models" were shown simultaneously for each project (see Fig. 5). For the advancement of future projects, it is essential to construct an implementation system involving not only communication providers and the vendors of communication equipment, but also the users of this technology, and to consider the specific contents of these projects.

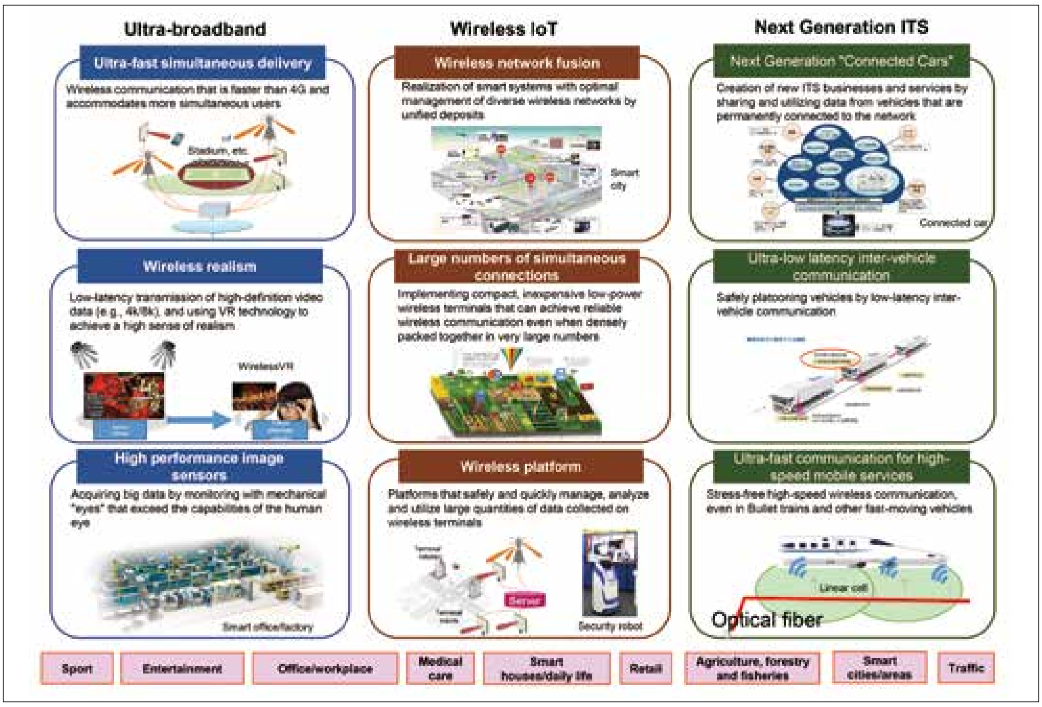
In the promotion of these projects, actions were taken from the following four viewpoints:

(1) Strategic R&D and verification: It is important to promote R&D focused on key technologies, and to conduct R&D and verification based on strategic cooperation with other countries as in European joint studies.
(2) Environmental improvements aimed at business expansion: Systems and maintenance should be studied at the same time as research and development, and frequencies should be reserved by taking factors such as international harmony and ease of social implementation into consideration.
(3) Deployment in regions that contribute to regional stimulation, etc.: Open test beds that allow a wide diversity of stakeholders to get involved have been set up not only in Tokyo but in all regions, and such measures have contributed to regional revitalization and local creation.
(4) National standardization and international development: We will promote ongoing strategic national standardization and international development in partnership with 5GMF stakeholders and other related

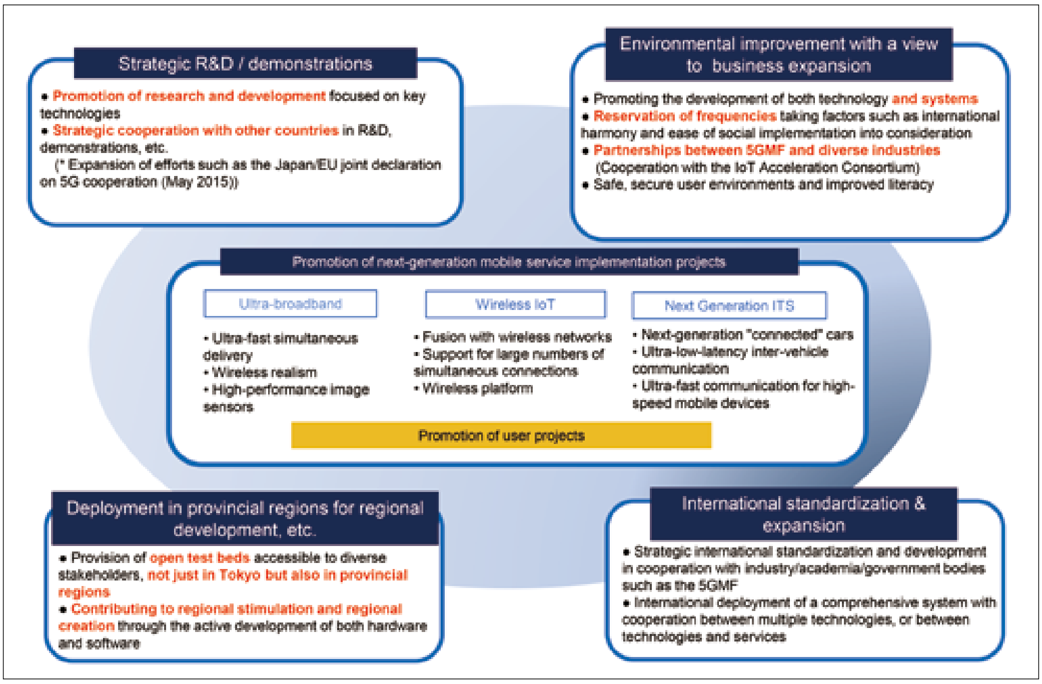
■ **Figure 4: Promotion and uptake of next-generation mobile service implementation projects**



■ Figure 5: Nine promotion models



■ Figure 6: Comprehensive project promotion measures



individuals from industry, academia and government, and the international expansion of a comprehensive system that links technologies and services.

Based on feedback from users, we also expect that promotion efforts coupled with a fast PDCA cycle will help with the resolution of issues facing society and with the creation of new value in the 5G era.

5. Conclusion

Based on these recommendations at the Radio Policy 2020 Study Group, the Minister for Internal Affairs and Communications asked the Information and Communications Council to study the technical specifications of Next-Generation Mobile Communication Systems in October 2016. From the 2017 fiscal year, comprehensive trials are due to be held based on the above three projects.

Fifth Generation Mobile Communications Promotion Forum (5GMF) White Paper

— Realizing 5G mobile communication systems for 2020 and beyond —

Secretariat of The Fifth Generation Mobile Communications Promotion Forum
Association of Radio Industries and Businesses
The Telecommunication Technology Committee

1. Introduction

The Fifth Generation Mobile Communications Promotion Forum (5GMF) was established in September 2014, prompted by the MIC interim report, "Radio policy vision round-table," to accelerate study of 5th generation mobile communications systems (5G) in Japan and to facilitate collaboration with other countries, and contribution to international standardization at the ITU-R and other organizations. The 5GMF began its activities bringing together participants from industry, academia and government, promoting cooperation and collaboration among specialists in a wide range of fields not limited to information and communications.

At its inception the 5GMF had four committees, and in January 2016 it established the "5G Trial Promotion Group" to promote research activities (Figure 1). As of August 19, 2016 there were 101 members. The executive office of 5GMF is being handled by the Association of Radio Industries and Businesses (ARIB) and the Telecommunications Technology Committee (TTC).

This article introduces 5GMF activities and gives an outline of the "5GMF Whitepaper, 1st Ed. (English)," which is a result of those activities. It was written by the 5GMF Secretariat.

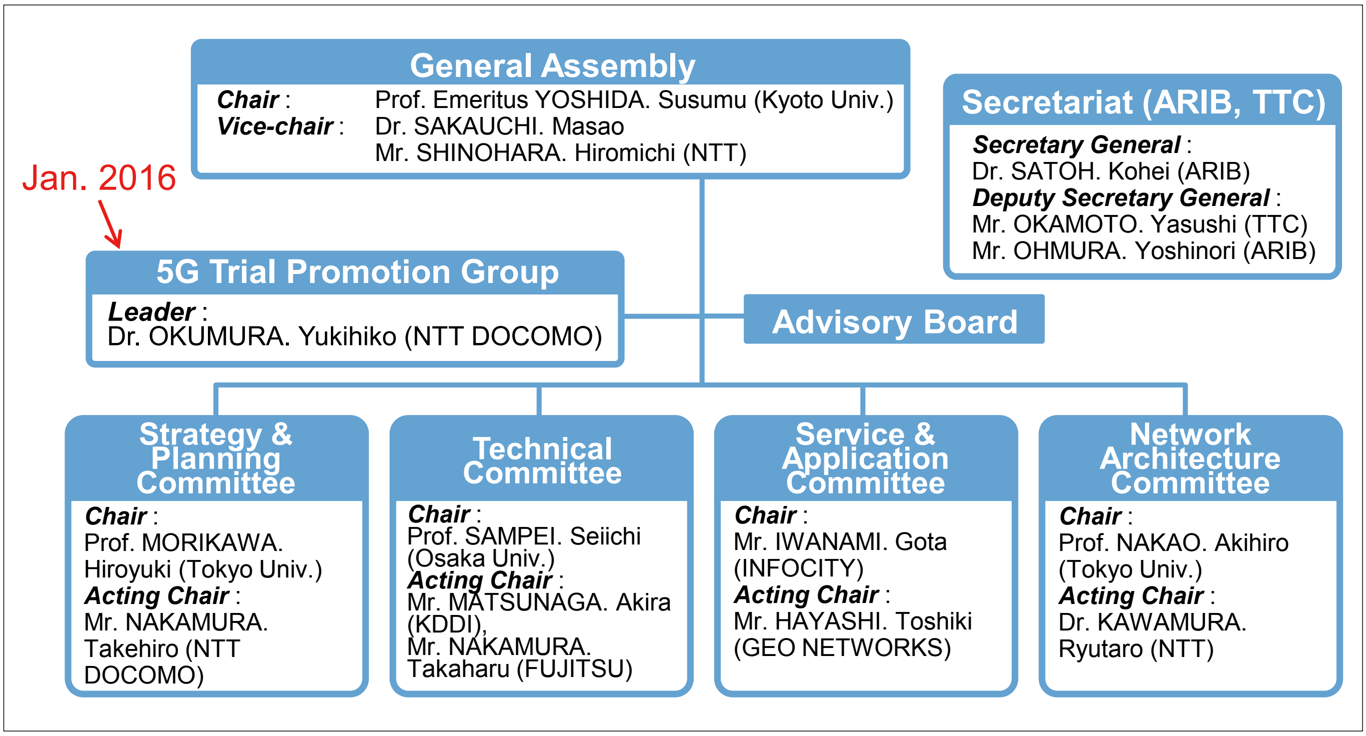
2. Overview of 5GMF activities

This highest decision making body in the 5GMF is the general meeting, held once every fiscal year and including reports of the year's activities, plans and settlement of budgeting, setting regulations and electing the executive. The advisory currently includes persons with university or other academic research experience, and from communications operators, manufacturers, related organizations and the Ministry of Internal Affairs and Communications, totaling 30 people. In advisory meetings, these members actively exchange ideas regarding overall 5GMF activities. The main activities are outlined below.

2.1 Creation of the white paper

An important 5GMF task from its inception has been the creation of the first edition of the white paper, "5G Mobile Communications Systems for 2020 and Beyond" (English version). It is a result of the research activities of the four

Figure 1: Organizational Structure of 5GMF



committees and was published on the 5GMF Web page (http://5gmf.jp/) at the end of May, 2016. Executive summaries in Japanese and English were also published.

2.2 Studying comprehensive verification test plans for 5G systems

A special meeting was held in January 2016 to study plans and frameworks for performing "comprehensive verification testing for 5G systems" starting in FY2017, and the "5G System Comprehensive verification test promotion group" was formed.

The group gathered testing projects from members of each committee and group, totaling more than 30 projects (as of July 2016). Most of the projects involved (1) entertainment systems at stadiums and other event venues, (2) mobile monitoring and security systems for safety and security in society, (3) high-speed, highly-reliable communication for mobile situations such as high-speed trains, or (4) support for remote control, monitoring and automatic operation of robots or vehicles. In the future, with reference to materials such as the MIC report from the "Radio policy 2020 council," projects that need to be done will be selected and decisions made for creating concrete plans and frameworks for carrying them out.

2.3 Supporting collaboration and events with 5G organizations

Memorandums of Understanding (MoU) have been reached with six overseas 5G promotion organizations, and various workshops have been held. Lecturers have been actively sent from 5GMF to 5G-related workshops and other events within and outside of Japan, presenting results of our activities. 5GMF has also conducted activities such as co-hosting workshops during CEATEC JAPAN, Wireless Technology Park (WTP) and other events, for the benefit of general attendees.

3. Introduction to the 5GMF white paper

The 5GMF white paper gives a comprehensive summary of studies of 5G concepts and implementation issues, in the hope of promoting use of 5G in industry, creating new business markets and expanding businesses overseas. The four committees worked closely together in creating the white paper. Final editing was completed by an editorial task force gathering together representatives from each of the committees.

3.1 Overall concept

Study for this white paper was done with reference to advanced research in the "Mobile Communications Systems for 2020 and beyond," white paper published at the end of September 2014, by the "2020 and Beyond Adhoc committee," which was established in September 2013 by the ARIB Advanced Wireless communications research committee.

In creating the white paper, study was conducted with an awareness of differences in user environments, implemented services, system performance and other aspects of 4th generation communications systems such as IMT-Advanced, and earlier systems.

■ Figure 2: Content of 5GMF White Paper

5GMF issued first White Paper "Mobile Communications Systems for 2020 and beyond" in the end of May 2016.

Chapter & Title	Chapter & Title
Scope	8. Requirements for 5G
1. Introduction	9. Spectrum Implications
2. Objectives	10. Overview of 5G Technologies
3. Market and User Trends of ICT	11. 5G Radio Technologies
4. Traffic Trend	12. 5G Network Technologies
5. Cost Implications	13. Conclusion
6. 5G Key Concept	Annex : Future businesses and services
7. Typical Usage Scenarios of 5G	

3.2 5GMF white paper organization

The white paper is composed of the Scope section, 13 sections of content, and an annex, as shown in Figure 2. These sections are outlined below.

3.2.1 Introduction and Objectives (Sections 1 and 2)

The introduction discusses societal background necessitating the study of 5G and outlines the content in Sections 3 and following. It identifies the main purpose of the white paper as clarifying the key concepts and technologies required to realize 5G.

3.2.2 Market and User Trends (Section 3)

This section discusses the sort of communications environment and services needed in the 5G era, as Internet use expands from PCs to smartphones and tablets and further to new devices such as sensors, robots and automobiles, and more diverse services are implemented.

3.2.3 Traffic Trends and Cost Implications (Sections 4 and 5)

The potential for new forms of communication as traffic increases in the future is identified, with object-to-object and other forms of communication. The importance of building 5G using technologies that are flexible and can be gradually extended is shown, in consideration of construction and operating costs, since such a broad range of communication requirements must be met.

3.2.4 Key Concepts and key technologies (Section 6)

As shown in Figure 3, two key concepts for 5G will be "Fulfillment of End-to-End Quality," able to satisfy users in all kinds of scenarios, and "Extreme Flexibility," so that this quality can be provided, adapting to all kinds of user scenarios with flexibility.

Key technologies for realizing 5G include "Advanced Heterogeneous Networks," and "Network Softwarization and Slicing."

Examples of typical use cases (ultra-high-reliability, ultra-low latency, large-scale communication, extended mobile broadband, etc.), and performance extensions needed to realize them, are also given, based on the vision recommended by the ITU-R in M.2083-0 ("IMTVision – Framework and overall objectives of the future development of IMT for 2020 and beyond").

3.2.5 Typical Usage Scenarios (Section 7)

Various usage scenarios in the four categories of (1) entertainment (Figure 4), (2) transportation, (3) industrial applications, and (4) disaster countermeasures are described and studied in detail. The importance of dynamically optimizing the network with changes in time, place and conditions in each of these usage scenarios is identified.

3.2.6 Radio and Network technologies (Sections 8 to 12)

The desirable frequency bands for 5G, particularly in the 6 to 100 GHz range were studied. This was done in three stages: from a use-case and technical perspective (Stage 1, Figure 5), from a

Figure 3: Potential 5G applications mapping

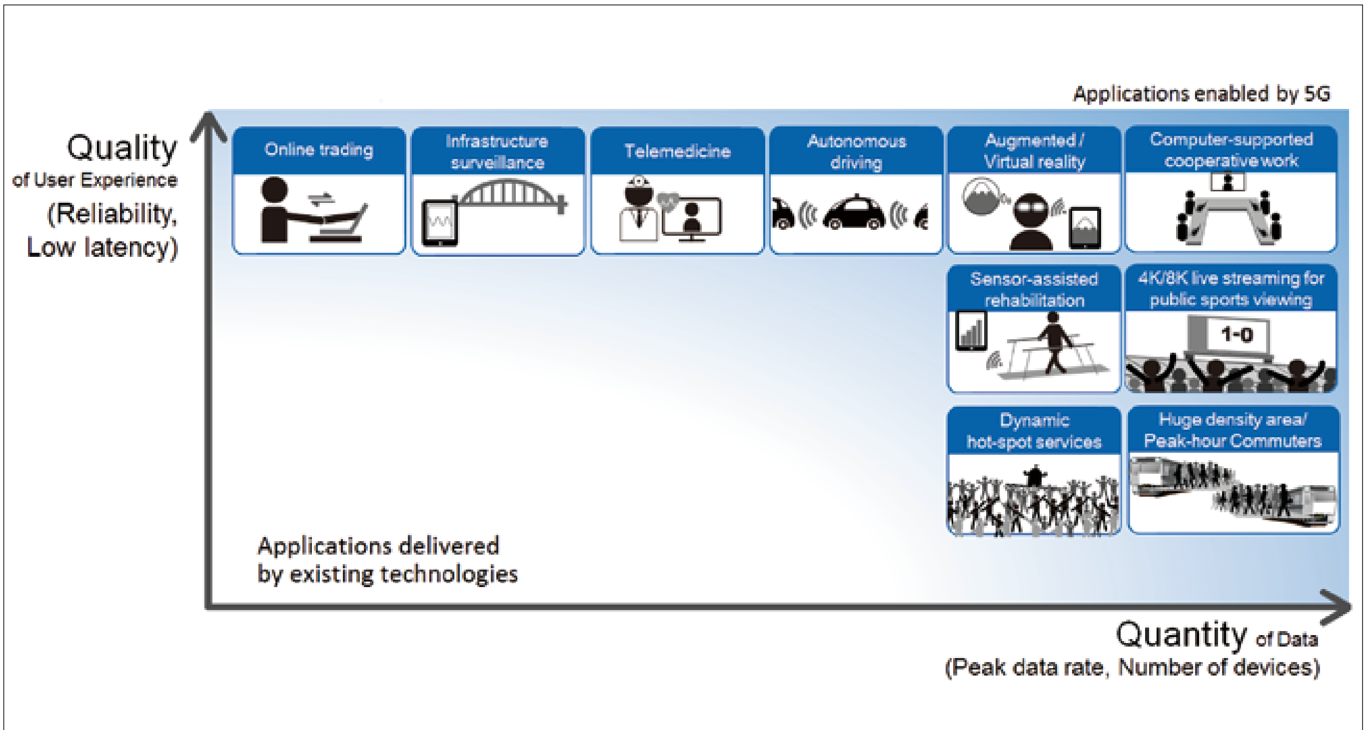


Figure 4: Usage scenarios in entertainment

Figure 5: Stage 1, classification and evaluation of characteristics of frequency bands at or above 6 GHz

Frequency range	Low (6-30GHz)	Middle (30-60GHz)	High (60-100GHz)
Desirable continuous bandwidth range (Note 1)	Approx. 300 MHz – 1.5 GHz	Approx. 1.5 GHz – 3 GHz	Approx. 3 GHz – 5 GHz
Coverage example (Note 2)	Hundreds of m – approx. 1 km	⟷	Dozens of m – approx. 100 m
Usage scenarios	Usable in diverse mobile communication scenarios (indoor, penetrating indoor from outdoor, hotspots, etc.)	⟷	Scenarios with higher bandwidth or density (indoor, hotspots, etc.)

(Note 1) These are desirable continuous bandwidth values determined with reference to existing 3GPP frequencies and bandwidths and assuming a fractional bandwidth of 5%, and do not necessarily represent required (or requested) bandwidths or bandwidths allocated by regulatory authorities. From the perspectives of spectral efficiency and implementation, it is desirable that these bands are continuous (Conversely, for 5G applications such as mobile broadband or M2M, bandwidth from hundreds of MHz to several GHz is desirable, but bandwidths usable for 5G in each range must each be considered individually).

(Note 2) Coverage values depend on radio propagation conditions, deployment scenarios and the radio technology used.

perspective of interoperating and coexisting with current systems (Stage 2), and from an international collaboration perspective (Stage 3). The results of Stage 2 of the study are given as a list of desirable frequency bands.

An overview of radio access technologies and network technologies studied for introduction of 5G systems, and associated issues, is also given.

3.2.7 Conclusion and Future Business Prospects (Section 13 and Annex)

5GMF has contributed the results of this study to international standardization activity at the ITU and 3GPP and is collaborating further with 5G organizations outside of Japan. It will continue its activities promoting introduction of 5G systems in 2020 and beyond.

The Annex discusses future business prospects based on current trends in the study of 5G systems.

3.3 Future prospects

The white paper provides a comprehensive study of 5G, and the next edition will be revised with new results from activities such as the comprehensive verification testing scheduled to begin in FY2017 and future studies of frequencies to be used for 5G.

4. Conclusion

The 5GMF will continue promotional activities for the use of 5G aimed at industry and the public, who are its users. We hope for continued cooperation, expanding and invigorating activity toward implementation of 5G in 2020 and beyond.

NTT DOCOMO Outlook for 5G Deployment

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5G Laboratory, NTT DOCOMO, Inc.

1. Introduction

Today, with the spread of smartphones and tablets, it has become easy to use services, applets, video and music through the Internet, anywhere and at any time, but demand for even more advanced services is still increasing. Mobile traffic has also increased sharply since 2010, and communication providers are expected to implement mobile broad band (MBB) to accommodate this increasing traffic while providing these services with excellent quality. Recently, business related to the Internet of Things (IoT), in which all kinds of objects are connected wirelessly to networks, has also become a major focus, and an increasingly important role in the future for communications providers will be to provide infrastructure that supports a whole new range of services made possible by IoT.

Because of these developments, expectations have increased dramatically for the early realization of 5th-Generation mobile communications systems (5G) as the successor to LTE and LTE-Advanced, which are the 4th-Generation systems (4G). The 3rd-Generation Partnership Project (3GPP), which is a standardization organization for mobile communications systems, held the “3GPP RAN Workshop on 5G” meeting in September 2015. This marked the beginning of serious discussion on standardization for 5G.

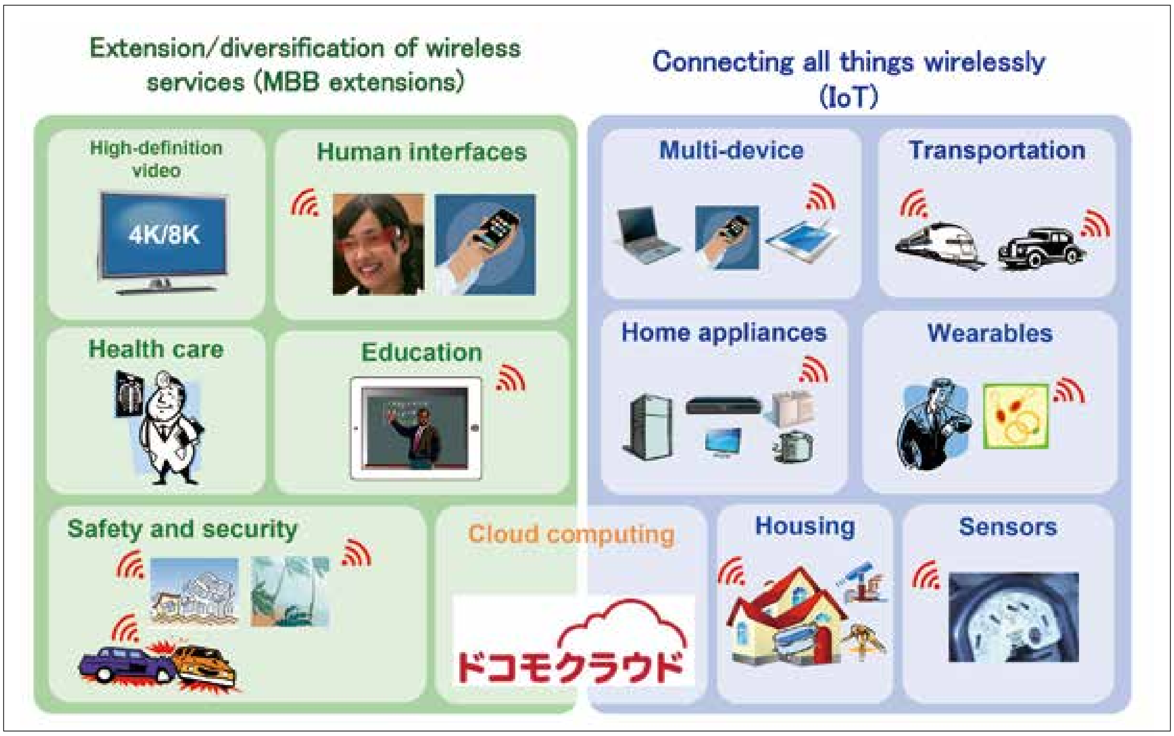
NTT DOCOMO began studying 5G around 2010, when we started our commercial LTE services, and has been advancing various R&D activities including proposing technology concepts, conducting transmission experiments, and leading standardization discussion. This article discusses NTT DOCOMO’s outlook for 5G Deployment by 2020 and gives an overview of these initiatives.

2. 5G Deployment Concepts

2.1 5G Technology Concepts

Regardless of the generation of mobile communications, whether 2G or 3G, smartphones can be used, and it should be possible to provide most of the services provided by 5G with 4G as well. However, even the same services can be used in more environments and more conveniently as the communications technology improves. New services relying on 5G communication quality will be introduced in the future, and 5G will be taken for granted before we know it.

Figure 1: Various services envisioned for 5G



It is difficult to predict what the killer service will be in the 2020s—the 5G era—but the services currently being anticipated can be categorized into two trends, as shown in Figure 1. The first trend is extension and diversification of MBB services, including high-definition (4K/8K) video streaming, augmented reality (AR), and communication of media other than sound and video, such as touch and bodily motion (tactile communication). The second trend is IoT, connecting all kinds of objects to the network wirelessly, through machine-to-machine (M2M) and other communication.

There are two possible radio access technology development approaches to realize these future services. One is to develop LTE and LTE-Advanced further while the other is to introduce an entirely new radio access technology (RAT). The former is a continuous evolution of the existing LTE systems, maintaining backward compatibility, and the latter prioritizes performance over maintaining backward compatibility with LTE.

NTT DOCOMO has defined a 5G concept involving a combination of an evolution of LTE/LTE-Advanced, called enhanced LTE (eLTE), and a new RAT (New RAT), as shown in Figure 2. In this concept, services such as basic coverage and broadcast would be provided by eLTE, and performance improvements, such as dramatically increased speed and capacity, would be provided by New RAT using much wider frequency bandwidths. Radio access technologies that can be applied regardless of bandwidth have been proposed for 5G, such as non-orthogonal multiple access (NOMA)[1], which can improve system capacity even at current bandwidths, and radio frame designs that reduce latency. Applying such technologies to the existing bands is a promising eLTE approach, particularly when 5G is first introduced and it is desirable to maintain backward compatibility with LTE.

It will also be necessary to introduce New RAT using centimeter-wave (3-30 GHz) and millimeter-wave (30 GHz and higher) frequencies that have not previously been used for mobile communication. To maintain adequate coverage while improving performance with these high frequencies will require optimization of radio parameters and technologies such as massive MIMO[1], using many antenna elements. In the future, New RAT could also be applied in existing frequency bands, but there will need to be sufficient benefits relative to an eLTE approach.

2.2 Incremental Approach to 5G Technology Deployment

A 5G development scenario combining eLTE and New RAT in this way is shown in Figure 3. For the first introduction of 5G, targeted for 2020, 5G involving eLTE and New RAT will be developed mainly in urban areas that require increased capacity. Use of eLTE and New RAT will be integrated through carrier aggregation and dual connectivity technologies[2], increasing capacity and maintaining coverage. The areas where 5G is developed will be expanded later to include non-urban areas, and extremely-high-frequency bands such as millimeter waves can be added as needed. We refer to such further evolution of 5G after 2020 as “5G+”.

To implement New RAT by 2020, it will be necessary to complete 3GPP standardization during 2018. On the other hand, for radio interface standardization at ITU-R satisfying 5G (IMT-2020) requirements, completion by the end of 2019 will be soon enough according to the ITU-R schedule at 3GPP. Thus, many domestic and international enterprises have reached an agreement in the 3GPP that an approach introducing technologies in stages (the former being 5G and the later being 5G+) will be effective[3]. To complete the first New RAT specification in this relatively short time, it was necessary to prioritize a fundamental design

Figure 2: NTT DOCOMO 5G technology concept

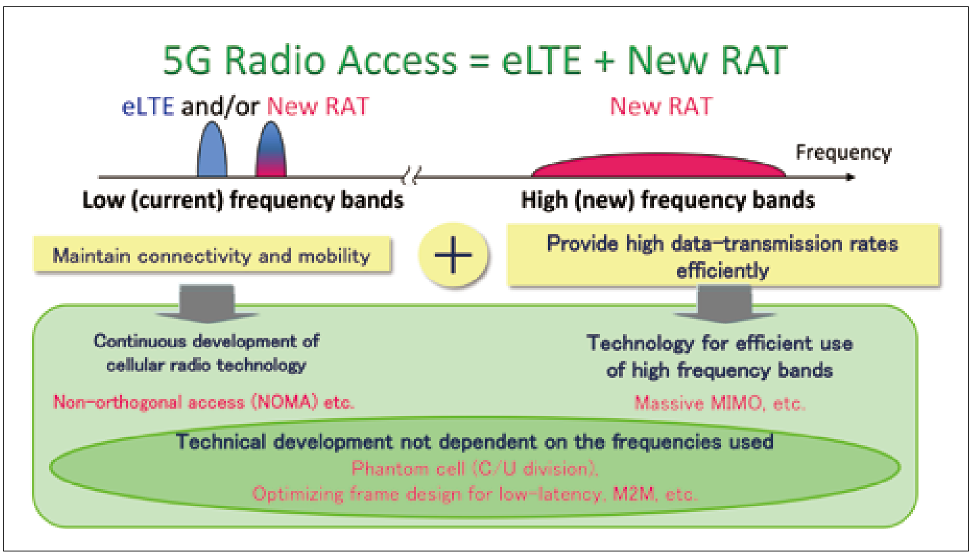


Figure 3: 5G Deployment

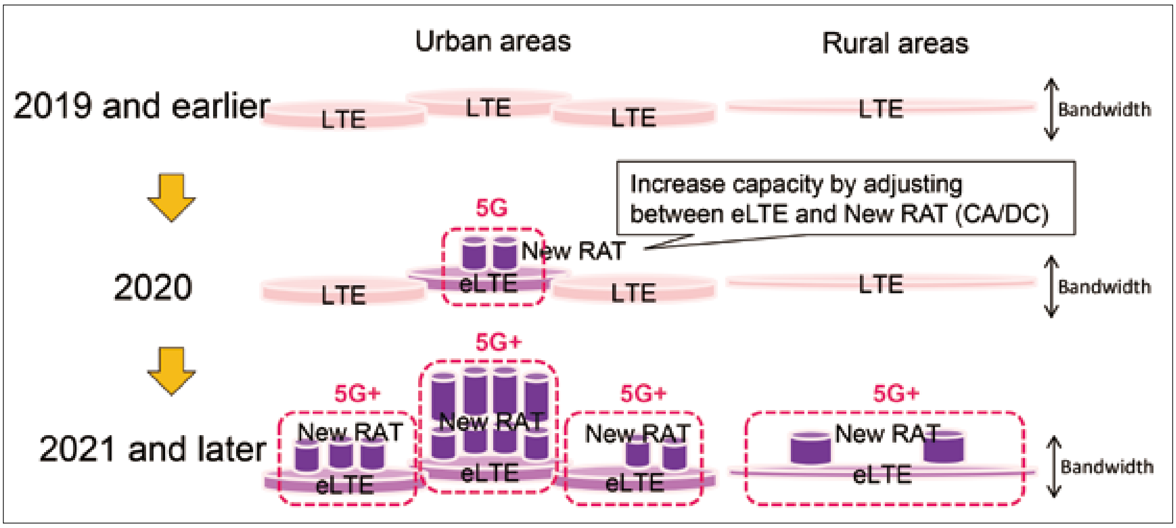
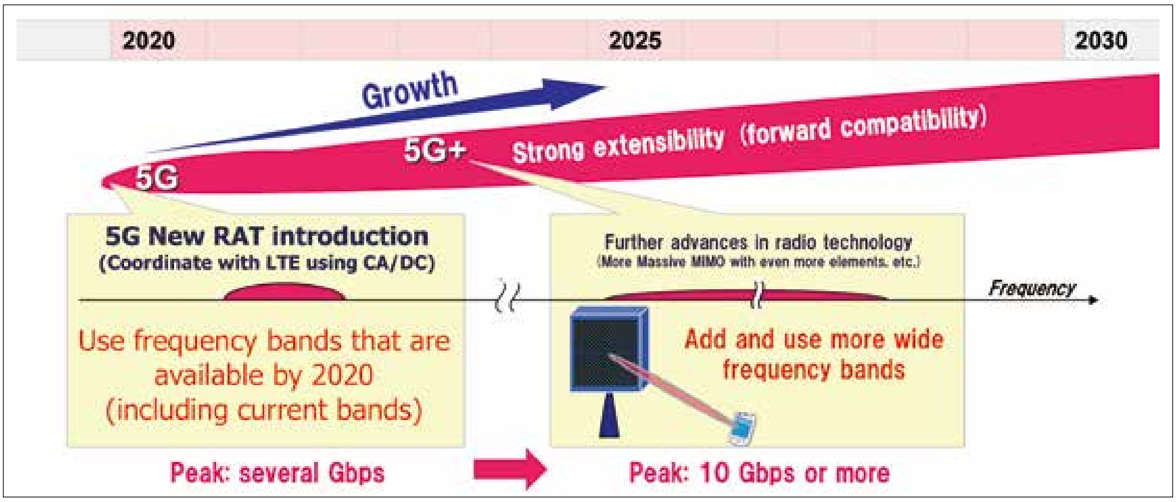


Figure 4: 5G introduction and ongoing evolution



emphasizing future extensibility (forward compatibility) rather than including many features from the very beginning. Also, 5G+ must also be an evolution of 5G while maintaining compatibility, as shown in Figure 4. This will be similar to the compatibility relationship between LTE and LTE-Advanced with 4G.

Figure 5 shows some candidate radio access technologies targeted for introduction in 2020. As mentioned earlier, two trends for 5G are the expansion of MBB and IoT services. Deployment of 5G is also expected to start in urban areas, where increased capacity is needed, and gradually expand from there. As such, when 5G is first introduced in 2020, a good approach would be to have New RAT supporting MBB extensions for improved speed and capacity where they are needed in urban areas. eLTE, which can provide area coverage, will complement it with various IoT functions such as support for large numbers of M2M terminals. With 5G+ in the future, many more functions will be added to New RAT to handle diverse services and scenarios, including some we have not yet imagined.

3. NTT DOCOMO 5G Initiatives

3.1 Technical Studies and Simulator Prototypes

NTT DOCOMO began studying 5G around 2010, after starting its commercial LTE service, and has proposed requirements and technology concepts for the next generation mobile communications system under the name, “Future Radio Access” (FRA)[4][5]. NTT DOCOMO first began using the name “5G” at the CEATEC JAPAN 2013 trade show in October, 2013, when it received the Minister for Internal Affairs and Communications Award for work visualizing a 5G technology concept and developing a real-time simulator to evaluate capacity increases from 5G technologies. In September, 2014, this technical concept was published in an NTT DOCOMO 5G White Paper[1].

To show that capacity-increasing 5G technologies will be effective in various environments, the 5G real-time simulator was updated to create Tokyo (Shinjuku), Stadium, and Rural versions (the Tokyo and Stadium versions have been published on YouTube[6][7]). The latest version is the version from Ise-Shima,

Figure 5: Candidate technologies for 5G radio access

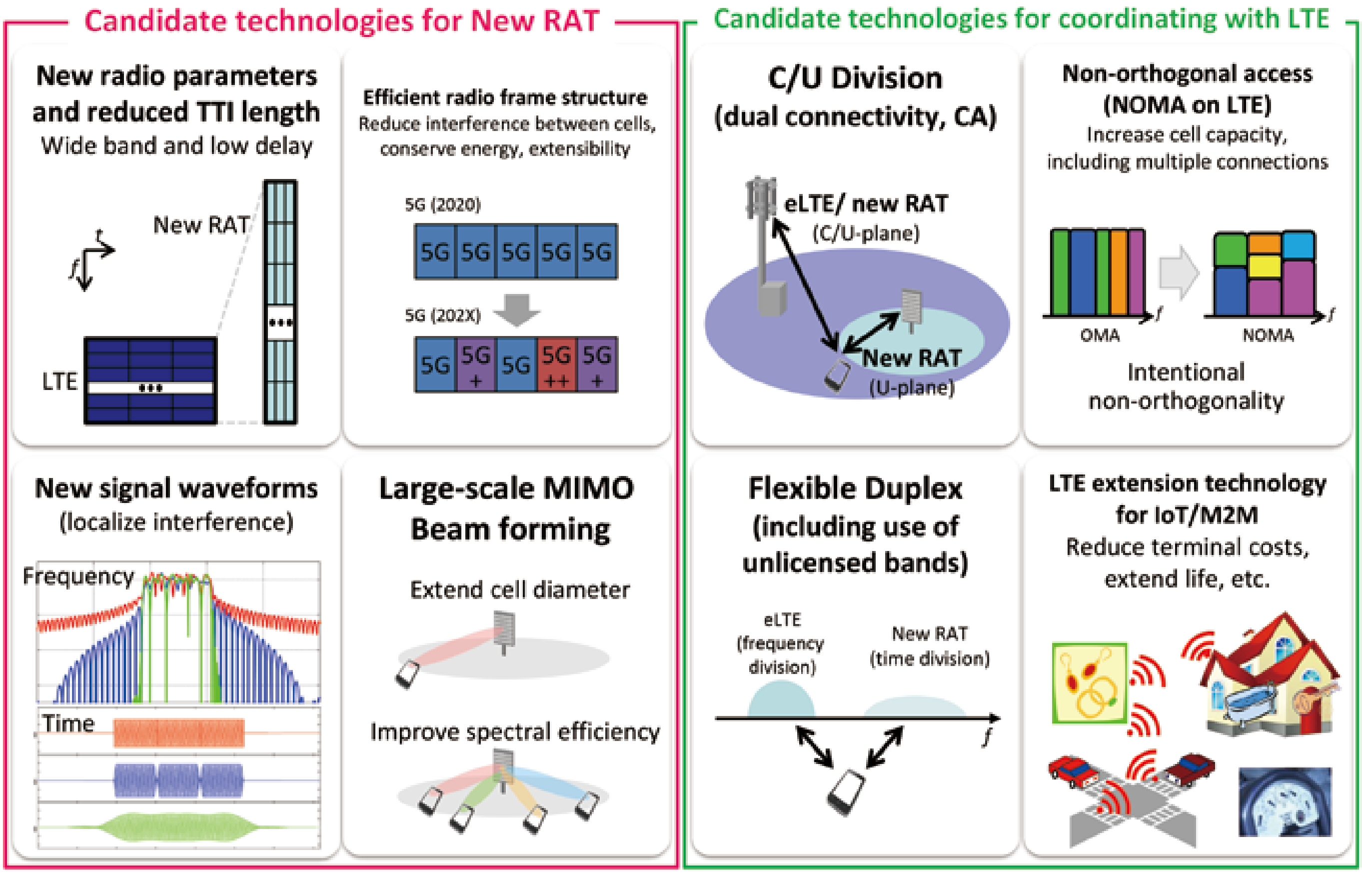


Figure 6: 5G Simulator Ise-Shima version

Figure 7: Outdoor experiment achieving 20 Gbps throughput

where the 2016 G7 Summit was held. This simulator can demonstrate 5G transmission quality on various vehicles such as buses, trains and ships, as shown in Figure 6.

3.2 5G Transmission Experiments

In December, 2012, NTT DOCOMO conducted the first successful 10 Gbps transmissions in a mobile environment as joint research with the Tokyo Institute of Technology[8]. We then began 5G experiments with major global vendors in May 2014 and later expanded collaboration on experiments with the 5G Tokyo Bay Summit 2015 in July 2015. We currently have agreements with 13 companies to collaborate on 5G experiments[9].

In February this year we successfully tested 5G multi-user communication exceeding 20 Gbps for the first time in collaboration with Ericsson Inc.[10]. The test involved two users in an outdoor environment, using the 15 GHz band and is shown in Figure 7. Multiple beams at the same frequency (800 MHz bandwidth) from the base-station antenna transmitted data simultaneously to two mobile terminals, achieving wireless data communication totaling over 20 Gbps at the receivers.

Current 5G transmission experiments being conducted with various vendors can be classified into (1) experiments on technologies to improve bandwidth efficiency in wide frequency bands including current cellular bands, (2) experiments on radio interface design using millimeter-wave and other high-frequency bands and massive MIMO transmission using large numbers of antenna elements, (3) experiments on key devices (chip sets) with vendors to study 5G terminal devices, and (4) experimenting measurement technologies with instrumentation vendors for evaluating performance of 5G radio transmission technologies and radio equipment (See Table).

The type (1) experiments focuses on experimenting various technical elements such as radio transmission methods and signal waveform design suited to broadband communication, M2M and other applications, increasing system capacity using very-densely-placed optical-feed small cells, and improving bandwidth efficiency through MIMO transmission. The type (2) experiments focuses on experimenting broadband mobile communication technologies for more efficient use of frequencies higher than those currently in use, such as frequencies over 6 GHz, and specifically, high-speed/high-capacity transmission technologies using very large numbers of antenna elements, which can help compensate for radio propagation losses in high frequency bands, and technical elements for applying millimeter-wave bands to mobile communications. The type (3) experiments will focus on experimenting prototypes for implementing compact, low-power 5G devices, and the type (4) experiments will involve experiments to elucidate millimeter-band radio wave propagation and to develop methods for evaluating active antenna systems composed of large numbers of antenna elements.

Figure 8 shows photographs from the 5G Tokyo Bay Summit 2016, held in May, 2016, where this collaborative experiment was exhibited.

The schedule anticipated for introduction of 5G in 2020 is shown in Figure 9. Transmission experiment on radio technologies and systems related to services and applications is scheduled to begin in 2017 and will focus on the 4.5 GHz and 28 GHz bands, which are promising candidates for 5G. In 3GPP standardization, the Phase I specification for New RAT is scheduled for completion by mid-2018, and the Phase II specification is scheduled for completion during 2019. NTT DOCOMO has set a goal of introducing 5G (and 5G+) conforming to these 3GPP specifications starting in 2020.

4. Conclusion

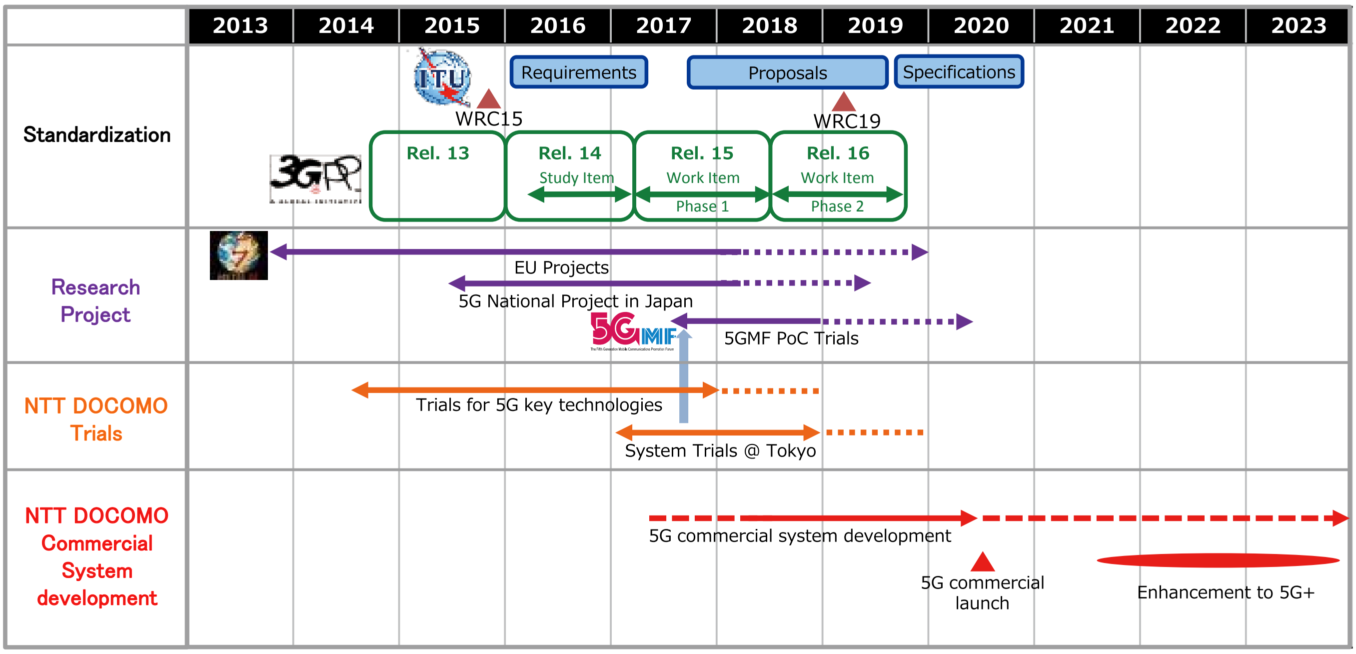
This article has given an overview of R&D initiatives, including global trends, toward 5G next-generation mobile communications systems, which will enable services such as even faster, high-capacity MBB, and IoT that will connect diverse objects to networks wirelessly. NTT DOCOMO will continue to promote R&D and standardization efforts to implement 5G services by 2020 and to further its development (5G+) thereafter.

Table: Overview of test collaboration with major global vendors

	Vendor	Testing overview
(1) Experiments on technology for improving spectral efficiency over a wide range of frequency bands to which it can be applied	Fujitsu (Japan)	- Experiments on coordinated radio resource scheduling for super dense base stations using RRH
	Huawei (China)	- Experiments on MU-MIMO using TDD channel reciprocity, new signal waveforms, and advanced multiple access
	NEC (Japan)	- Experiments on a beamforming technology that controls directivity in the time domain using very-many-element antennas to increase the system capacity per unit area in small cells
	Panasonic (Japan)	- Experiments on system control technologies for efficient communication combining multiple frequencies, such as high frequency bands and wireless LAN frequency bands, and system solutions applying advanced imaging to 5G communications technology
(2) Experiments that focus on development of high frequency bands	Ericsson (Sweden)	- Experiments on a new radio interface concept, for use with high frequency bands, and a Massive MIMO technology combining spatial multiplexing and beamforming
	Mitsubishi Electric (Japan)	- Basic experiments on a multi-beam, multiplexing technology using virtual arrangements of massive numbers of antenna elements, which will realize ultra-high speeds in high frequency bands
	Nokia Networks (Finland)	- Experiments on ultra-wideband radio transmission, assuming use for efficient EHF band mobile communication
	Samsung Electronics (South Korea)	- Experiments on hybrid beamforming, combining digital and analog techniques to realize stable, ultra-sideband transmission in high frequency bands as well as a beam control technology for tracking mobile stations
(3) Experiments on 5G terminal devices	Intel (USA)	- Experiments involving compact, low-power chipset prototypes for mobile terminals, such as smartphones and tablets that will realize the 5G concept of high-speed, high-capacity and high reliability.
	Qualcomm (USA)	- Collaboration on study and testing for compact, low-power 5G device implementations to enable provision of mobile broadband extended to peak data rates of several Gbps
	MediaTek (Taiwan)	- Experiments to verify chipsets required for non-orthogonal multiple access (NOMA) and 5G terminals
(4) Evaluation on performance of ultra-high frequency bands	Keysight Technologies (Japan)	- Study of communication performance measurement technology for base stations and terminals, for ultra-wideband communication in high frequency bands - Experiments on antenna performance measurement technology for Massive MIMO - Measuring and analysis of radio propagation characteristics in high frequency bands and generation and analysis of signal waveforms
	Rohde & Schwarz (Germany)	- Study of antenna performance and evaluation technology for base station communications performance for schemes such as Massive MIMO, which use ultra-wide bandwidths in high - Measuring and analysis of radio propagation characteristics in high frequency bands, generation and analysis of signal waveforms.

■ **Figure 8: 5G Tokyo Bay Summit 2016**

■ **Figure 9: Anticipated schedule for introduction of 5G**



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[7] NTT DOCOMO 5G Real-time Simulator (Stadium Ver.) Introduction:
https://www.youtube.com/watch?v=UVE3BN-9nmg
[8] Press release: "DOCOMO and Tokyo Institute of Technology Achieve World's First 10 Gbps Packet Transmission in Outdoor Experiment — Paving the way for super-high-bit-rate mobile communications —," February, 2013.
[9] Press release: "DOCOMO to Collaborate on 5G with Five Additional Vendors —Expands 5G collaborations to 13 world-leading vendors—," July 2015.
[10] Press release: "DOCOMO and Ericsson Succeed in World's first trial to achieve a cumulative 20 Gbps with two simultaneously connected mobile devices in 5G Outdoor Trial," February 2016.

KDDI's Perspectives Towards 5G

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1. Introduction

Towards the realization of fifth-generation mobile communication systems (hereafter called 5G) in 2020, verification trials and demonstrations are ongoing in parallel with standardization activities at ITU-R and 3GPP.

It is expected that 5G will not only make improvements to networks, including substantial expansion of network capacity and enhanced peak data rates, but will also bring about major transformations in current mobile communication systems, including a greater diversity of applications, a more prominent role in society, and a closer relationship with industry.

This article describes the expectations of 5G, the shape of things to come in the 5G era, and the technologies that will make 5G a reality.

2. The environment surrounding 5G and the shape of things to come in the 5G era

2.1 Expectations

The changes that characterize 5G include the following:

(1) Substantial increase of network capacity and flexibility to satisfy diverse requirements efficiently.

The vision document of ITU-R* stipulates three use scenarios of 5G, namely, enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC). 5G is expected to offer a variety of new applications and also to provide experiences that are difficult to achieve with previous generation systems including 4G technology. At the same time, 5G networks will have to adapt flexibly and efficiently to these increasingly diversified requirements. To offer enhanced capabilities including high speed and low latency, the 5G network will require closer end-to-end interworking, including radio access, backbone and core networks.

(2) Implementation of IoT, where everything is connected

The connection of everything by IoT, will create new added value. For example, it will be possible to track large numbers of objects and analyze them by using big data. To create this new added value, it will be necessary to develop new applications and build 5G networks that meet their requirements in cooperation with "vertical players" and business partners that use 5G.

(3) The dramatic rise in the role and expectations of supporting social infrastructure.

In the 5G era, it is expected that 5G will be an indispensable asset for society and will play a significant role in supporting the social infrastructure in 2020 by helping to solve various social issues.

As shown in Figure 1, 5G is expected to play numerous important roles in the changing society, including providing exciting entertainment services, supporting numerous industrial developments, helping to address social problems, such as the revitalization of local communities, and acting as a social platform that ensures the safety and security of its users. In anticipation of the advent of 5G era, KDDI is aiming to respond to the above expectations by expanding its network capability, implementing various new use scenarios, and targeting the provision of value-added services beyond communication services to realize life design in collaboration with the industry sector.

2.2 The 5G world

Figure 2 shows the use cases that are expected as a result of the enhanced capabilities of 5G. Typical examples are illustrated below.

(1) VR and AR

Typical services that make use of enhanced mobile broadband capability and ultra-low latency will include virtual reality (VR) and augmented reality (AR). One possible application of VR is "free-viewpoint" video, which allows people to view video from any angle. For example, video streams captured from different angles in a stadium could be used to synthesize video from any angle selected by the viewer. VR is going to provide ultra-realistic experiences that have never been offered before.

(2) Connected cars

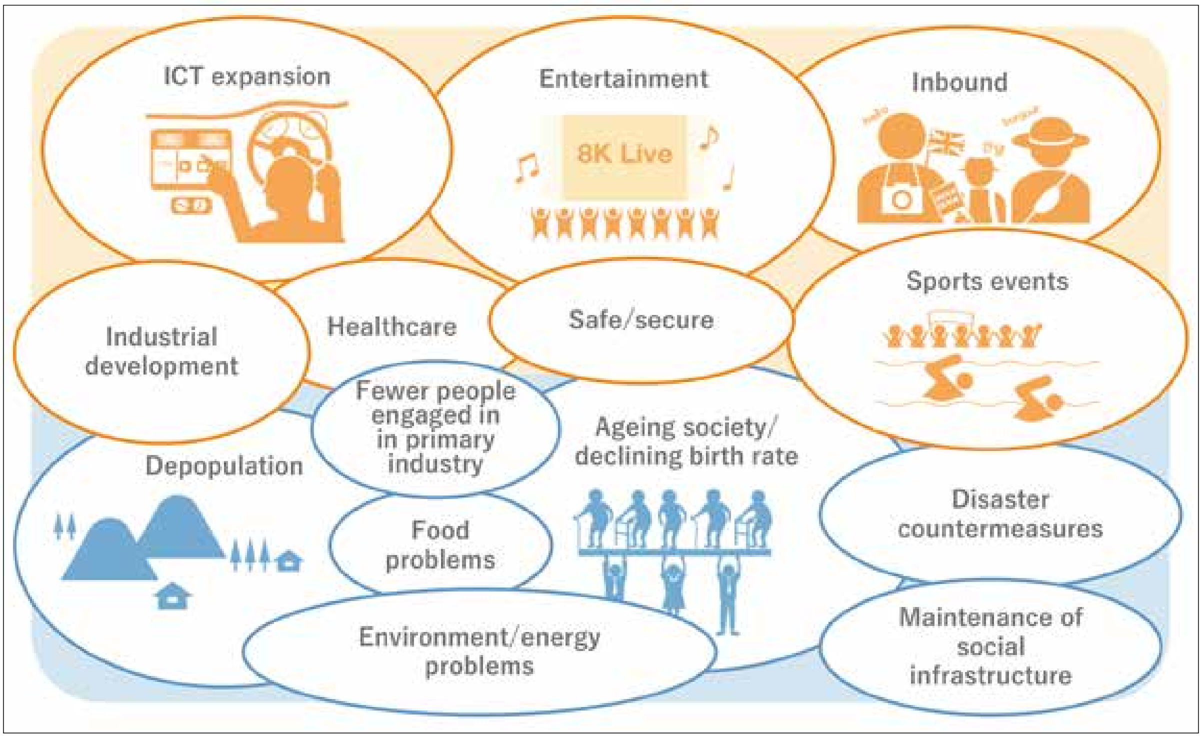
5G's ultra-low latency and high reliability are expected to open up new possibilities in various fields such as connected cars and the remote control of farm equipment. It is also expected to meet the requirements for ensuring that people are able to live safely and securely . Some connected car applications will require safe and secure service features, including vehicle diagnostics, driver health monitoring, and emergency vehicle communication in the event of an accident.

(3) IoT (Massive machine-type communications)

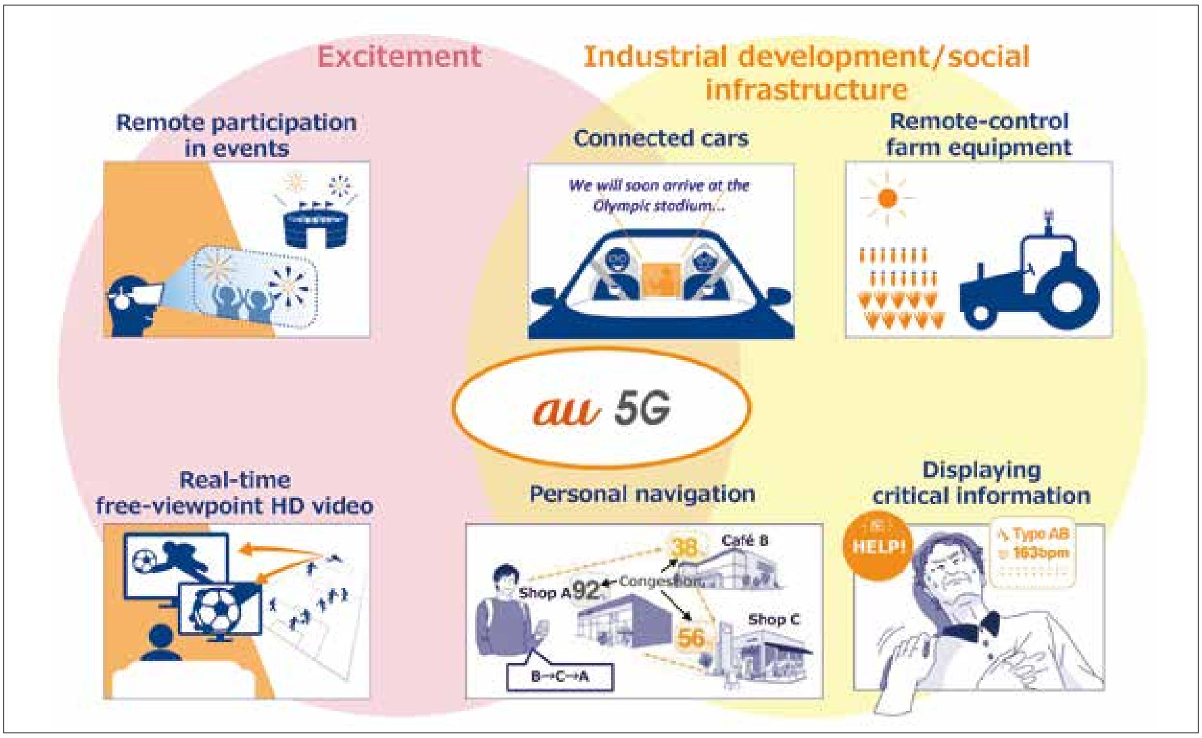
In the 5G era, IoT is expected to cause a dramatic increase in the number of connected devices and diverse use cases. This will contribute to the development of — and significant changes to — industry and the social infrastructure. In the industrial sector, it is envisaged that new value will be created by analyzing and processing big data from a number of sensors using optimal

* IMT Vision: "Framework and overall objectives of the future development of IMT for 2020 and beyond", ITU-R, Rec. M.2083-0, September, 2015

■ **Figure 1: Changes in the environment towards 2020**



■ **Figure 2: The 5G world**



computing resources in the network. It is also expected that data from indoor and outdoor sensors and wearable devices will be utilized to contribute to people's wellbeing and safety.

In the example of "personal navigation", a number of sensors will be used to collect huge amount of information in real time, such as the weather and traffic conditions. The information collected this way will be used to navigate an optimal route according to the user's schedule, in combination with information that has already been stored on the network.

3. System architecture for 5G services, and the "user-centric" concept

As mentioned above, the augmentation of 5G network capabilities — including their capacity, peak data rate, massive machine-type communications, high reliability and low latency — will give rise to various new applications, and the 5G networks will have to adapt flexibly and efficiently to their diverse requirements. Unlike previous systems, where users must sometimes adapt to the system's performance, the aim of the 5G network is to provide users with a satisfactory experience every time, and in any place.

New experiences and new value can also be created, by using big data, numerous sensors and enhanced network capability to propose new values to users. 5G thus aims to implement the concept of a user-centric service that provides quality of experience that meets the user demand. System architectures for this purpose should be built and the following network technologies should be embodied:

① Dynamic sharing of computing roles between hierarchical layers
② Construction of radio access network areas
③ Provision of a seamless network where users need not be aware of differences in technology

3.1 Optimal network usage for different roles

In the 5G network, in addition to realization of the new requirements expected to 5G, such as low latency and real-time communications, it is also necessary to use appropriate network resources efficiently to satisfy the requirements of diverse applications. Figure 3 shows an example of the hierarchical structure of computing resources. In addition to computing in the cloud and client devices, it will also be useful to perform computing at network edges in some applications in the 5G era. These three layers share out computing tasks dynamically and optimally in consideration of the following characteristics, thereby making efficient use of the network resources and ensuring that 5G services satisfy their requirements. One idea is that big data processing may be performed by the cloud, which is suitable for collecting large amounts of data, while real-time processing and localized processing could be conducted by edge computing and devices respectively.

- Cloud: totally optimal, centralized, integrated
- Edge: partially optimal, distributed, cooperative
- Device: locally optimal, autonomous

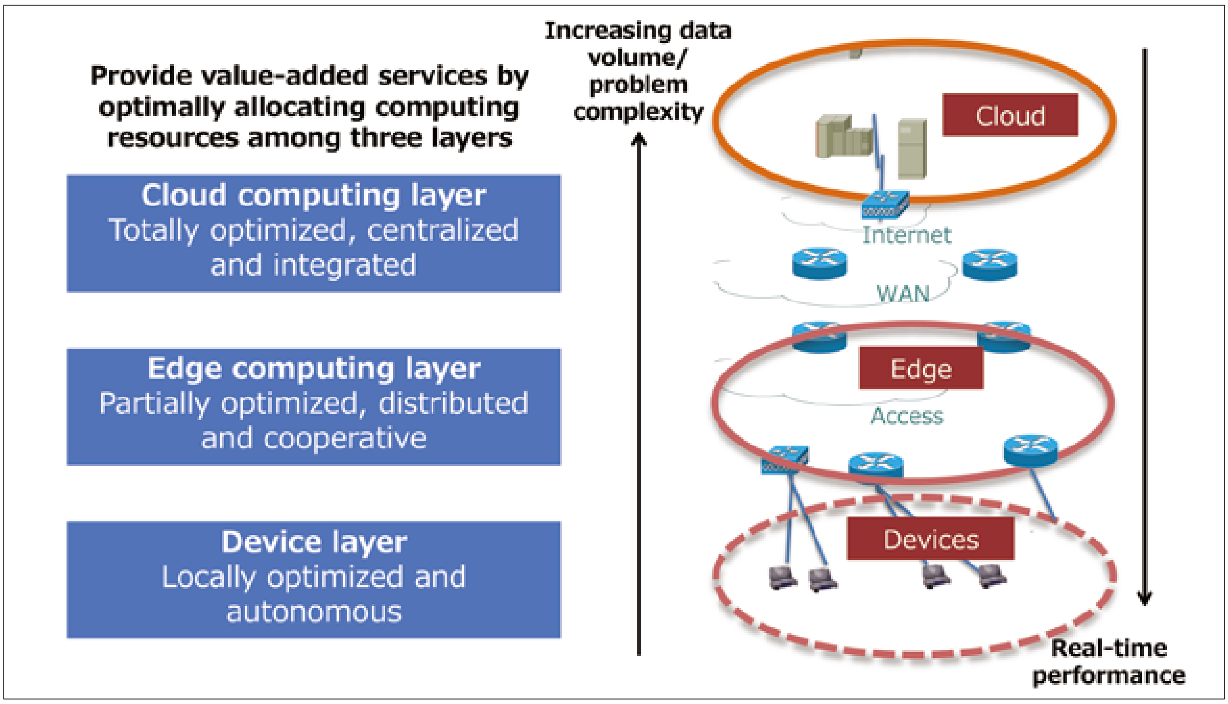
3.2 Area structure of wireless systems

To meet the diverse requirements of different use cases, such as high capacity/high peak data rate, massive machine type communications, and low latency, an optimal wireless area must be built by taking into consideration the following elements:

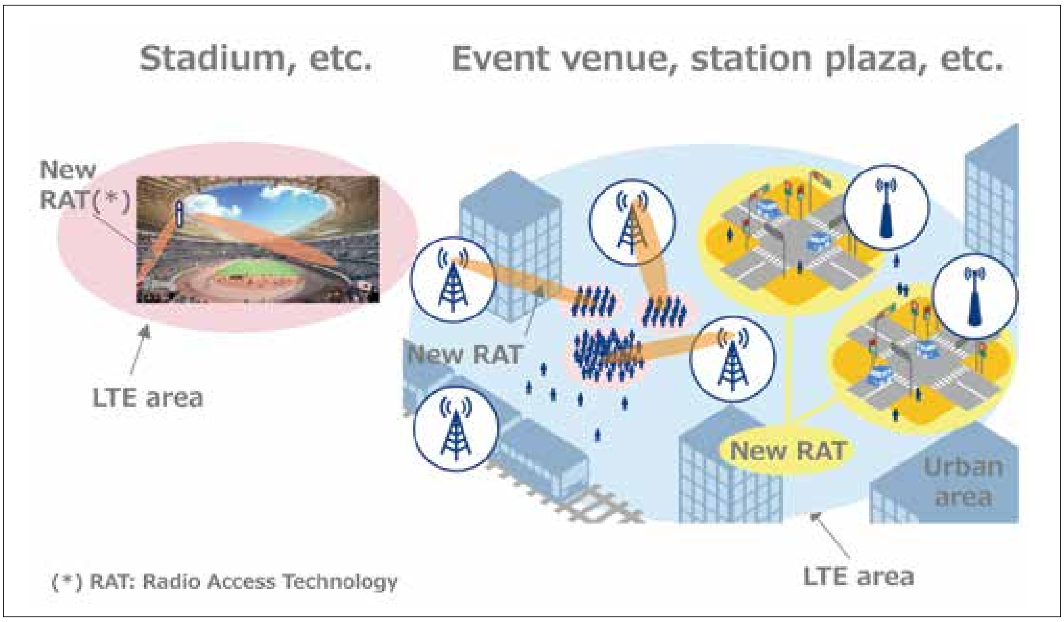
- Characteristics of the frequency band used by the system (above 6 GHz, below 6 GHz, etc.)
- Choice of multi access technologies (Massive MIMO, beamforming, etc.)
- Envisaged use cases (mobile broadband, IoT, low-latency, etc.)
- Requirements (speed, cell size, indoor/outdoor, terminal density, etc.)
- Need for interworking with existing systems

For example, a new radio access network may be deployed in a service area (e.g. stadium) in order to provide new ultra-realistic VR/AR services as shown in Figure 4. Another example is an event venue or train station plaza, where a new radio access network may be deployed to accommodate densely concentrated traffic.

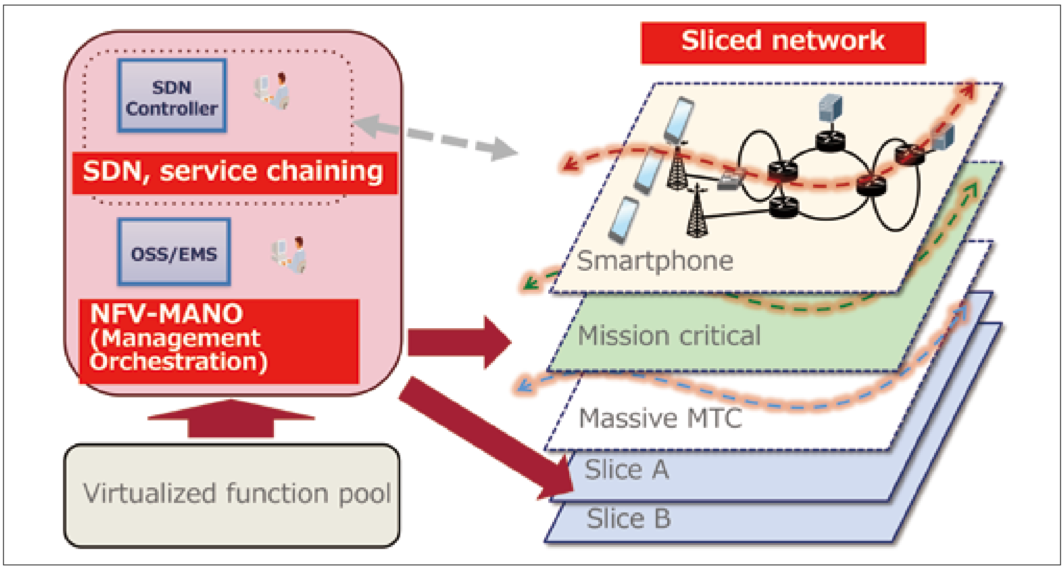
■ Figure 3: Providing value-added services by optimal resource allocation



■ Figure 4: Examples of deployment of 5G networks



■ Figure 5: Flexible network structure & operational enhancement



3.3 Seamless networks

5G must be able to cooperate with various other wireless systems including previous generations such as 4G, and should be able to select the optimal network from a variety of infrastructures, platforms and technologies without making the user aware of the difference of technologies. As a result, the network should communicate as a seamless whole to provide the user with an excellent experience at anytime, anywhere.

To respond flexibly to the diverse requirements of 5G applications and to build a network that strengthens links with industry and vertical players, a seamless network may be virtually divided into a sliced network as shown in Figure 5, allowing it to respond efficiently and flexibly to diverse service requirements. The capabilities to be realized and the element technologies that will be required are listed below:

- Responding to diverse network requests:
  Sliced network
- Flexible network structure:
  NFV (network function virtualization)
  SDN (software defined network), service chaining
- Enhancing the speed and functioning of network architecture:
  NFV
  NFV-MANO (management & orchestration)

4. Conclusion

This article introduced the environments that 5G systems will face and the world 5G will seek to realize, as well as the 5G system architecture that will be needed to achieve these goals. As we approach the launch of 5G, it is expected that standardization activity and verification tests/trials will be performed more actively, and KDDI will promote its efforts continuously to realize user-centric 5G services.

Launch of i-dio Broadcasting (V-Low Multi-media broadcasting)

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1. Introduction

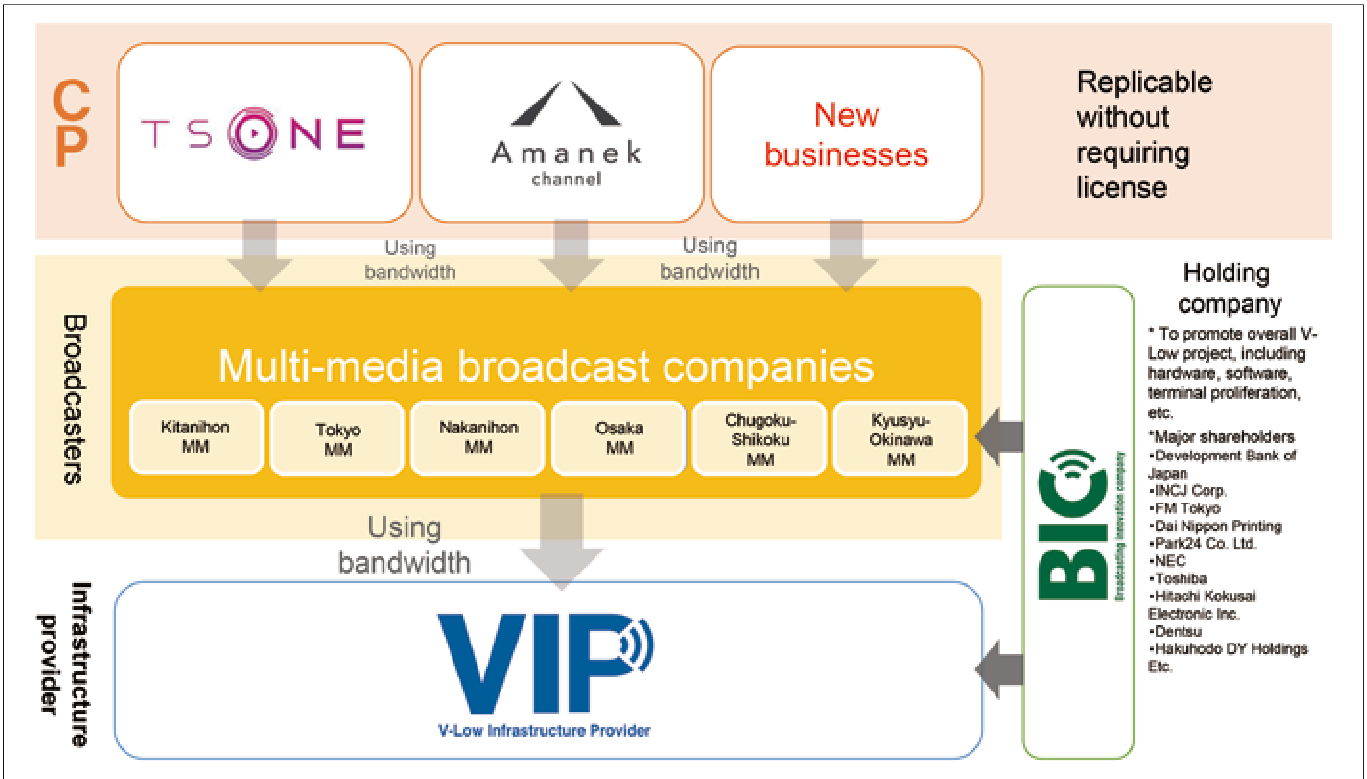
With the end of analog television broadcasting in Japan, new V-Low multimedia broadcasts in the VHF band are being introduced under the name "i-dio", with pre-broadcasts in Tokyo, Osaka and Fukuoka in March, 2016, and a grand opening in July of that year, which will expand into the Tokai region (Parts of Aichi, Gifu, and Mie Prefectures). This article gives an introduction to this service from the author, who is from Tokyo Multimedia Broadcasting Co. Ltd., the authorized core i-dio broadcaster for the Kanto and Koshinetsu regions. For descriptions of the i-dio system and infrastructure please also refer to the January 2015 issue of the ITU Journal (New Breeze Winter 2015 issue).

2. Operator structure

Infrastructure providers and broadcasters are separated for i-dio, with VIP Co. Ltd. establishing and operating national broadcast facilities and promoting the reception environment, and six multimedia broadcasting companies, handling the use and programming of the V-Low bandwitch in regional broadcasting blocks. Production of actual broadcast content is done by content provider (CP) companies that contract with the multimedia broadcasting companies to use bandwidth. Currently, Tokyo Smartcast Inc. (TS Inc.) and Amanek Telematics Design Inc. (Amanek Inc.) have joined as content providers (CP) for all of Japan, and additional CPs will be joining to provide regional and national content in the future.

The current broadcast area includes four regions, the metropolitan areas of Tokyo, Osaka, Fukuoka, and the Tokai region (Aichi, Gifu, Mie, and parts of Shizuoka prefectures), but VIP Co. Ltd. is planning to complete facilities throughout the country by 2019.

Figure 1: Operator roles and structure



3. Evolving infrastructure and receiver environment for broadcasting

i-dio is a broadcast platform that differs from conventional broadcasting in that it is not limited to video and audio, but can distribute various types of content on the broadcast signal. Content providers can also join with programs for a variety of uses and from industries other than broadcasting. For these reasons, both broadcast facilities and the receiver environment must be very flexible.

3.1 Broadcast infrastructure

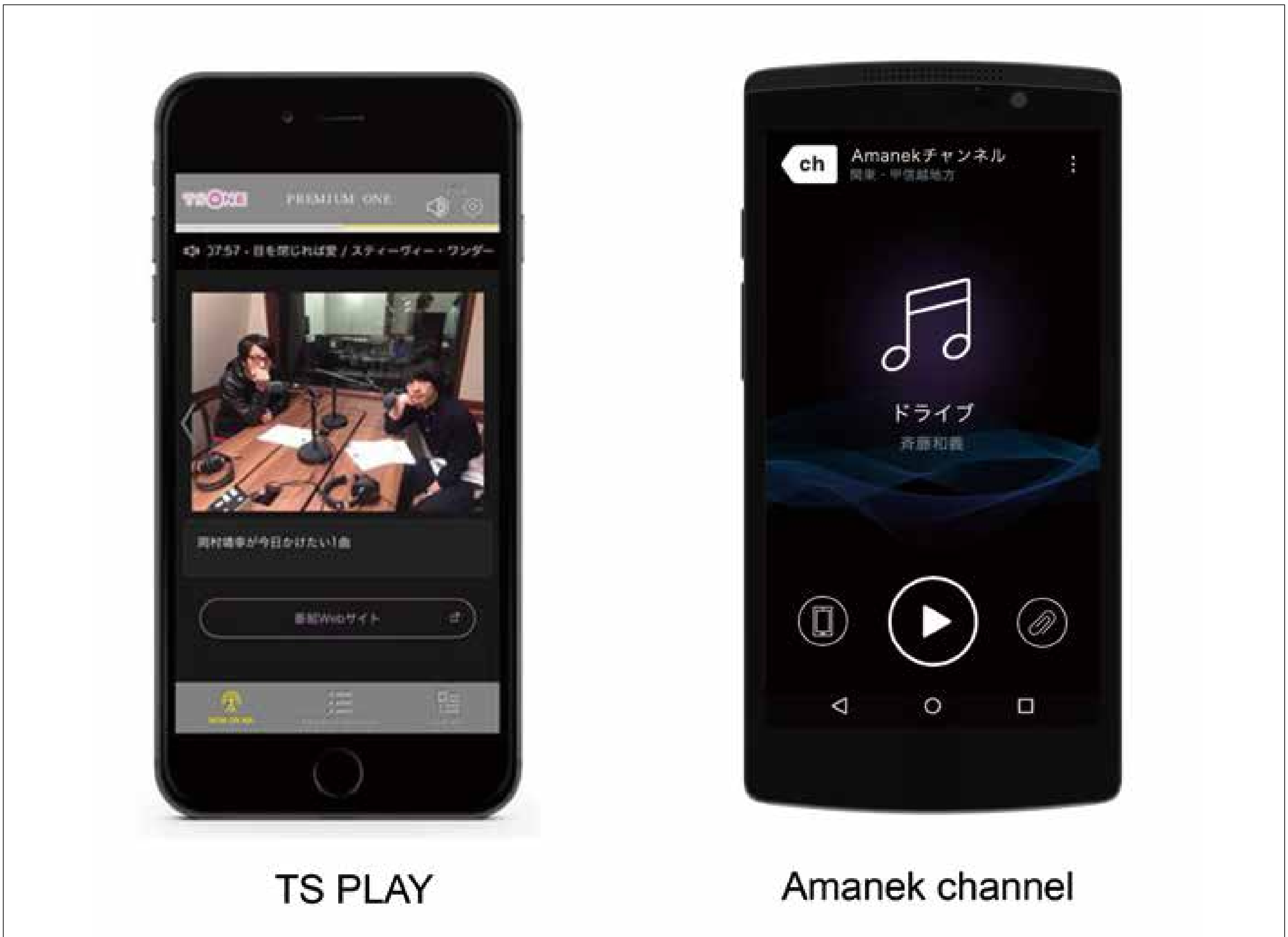
A master facility established in each regional block is able to handle a mix of audio, video and data. The regional master facilities are controlled from the center facility through the network, and the center performs all submission, monitoring and operations work for the network. CP companies connect to the center facilities through private networks and submit broadcast content daily. The center facility performs frequent updates, adds broadcast channels, and supports changes in content composition.

3.2 Receiver applications

The receiver environment for i-dio mobile broadcasts consists mainly of dedicated compact and rechargeable receiver devices called “i-dio Wi-Fi tuners” on existing smartphones, providing 100,000 free-of-charge monitors as of when the Wi-Fi tuner station began operation. SIM-free smartphones with an on-board i-dio tuner have also entered the market. VIP Co., Ltd. is also offering free, public receiver applications for iOS and Android and individual CPs are offering specialized receiver applications to support data broadcasts and advanced services that use their own formats.

TS Inc. is providing its TS PLAY application specialized for

■ **Figure 2: TS PLAY, Amanek channel application overview**



its channel and enhanced with features such as music purchasing. Amanek Inc. is providing its Amanek Channel applet, optimized for listening while driving a vehicle and providing information with automatic text-to-speech. Each company's applications update independently, always evolving with the broadcasts.

3.3 Simultaneous IP complementary broadcasts

As a temporary measure until broadcast facilities are established and dedicated receivers have become widespread, VIP Co., Ltd. is providing a free-of-charge IP simulcast complementary service called "Internet Reception Mode", in each broadcast block. This enables users to experience the services through the Internet, even in regions where the reception environment has not yet been completed.

4. Broadcast services provided to the public

The main services currently being provided to the public are described below. All of these broadcasts are provided free-of-charge.

"TS ONE"

This is a high-quality radio channel provided by TS Inc. The channel provides original content, with music programming from the highest quality 320 kbps AAC sources, and data broadcasts of studio photographs and music purchase information, providing new opportunities to explore music. As interest increases in high resolution audio sources ("Hi-Res Audio"), programs featuring quality live broadcasts and environmental sound are becoming popular.

"Amanek Channel"

Amanek Inc. is providing a digital radio channel for drivers. It provides "Big data" on topics such as weather, traffic, and tourism. The receiver selects suitable content by linking with GPS, and uses text-to-speech (TTS) to provide a fine-tuned service. It is attracting attention from the automotive industry as a car radio of the future that adjusts content to suit the user.

Tokyo multimedia broadcasting Co., Ltd. is also producing channels for jazz, classical and foreign music selections, and a simple video channel is provided nation-wide. Regional multimedia broadcasting companies are also providing audio channels linked with local FM stations, and regional information utilizing the advantages of broadcasting over wide-area blocks.

5. Broadcast services for local governments and business use

Evolution of i-dio is not limited to digital radio, and it can broadcast data in various forms to all of Japan. In the IoT era, the explosive increase in devices connecting to the Internet is expected to over-run communications infrastructure, so as IoT develops in Japan, it will be essential to strengthen the broadcasting infrastructure, which does not become congested. From past experience, it is also important for disaster mitigation after a large-scale disaster.

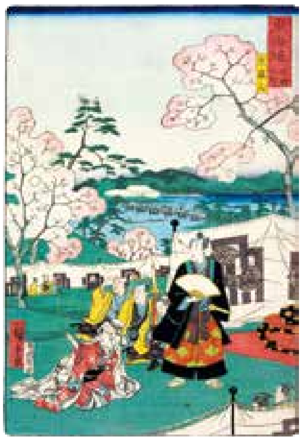
Currently, i-dio has begun providing the V-ALERT® service, which issues disaster prevention information for local governments to dedicated disaster radios and is able to remotely turn on these radios. Local governments have increasingly begun using this service. There are also everyday applications, such as distribution of updates to digital signage, and broadcast of firmware updates to devices in vehicles. Collaboration in field testing with enterprises planning to enter this area is also progressing.

6. Future prospects

i-dio is maximizing the features of V-Low multimedia broadcasting, meeting the needs of the IoT era with broadcast signals that do not become congested, and continually pursuing flexible content distribution. Examples that have already been implemented include technologies to distribute content to digital signage terminals, and provide information specific to small regions during disaster through the V-ALERT® service.

This format is also attracting attention from outside of Japan, as a new mobile broadcasting format that inherits know-how gained from ISDB-T digital terrestrial broadcasting. We will continue to advance this technology as an unprecedented model integrating communications and broadcasting.

Cover Art



Tokaido meisho no uchi Kyo Arashiyama (Kyoto Arashiyama, a famous place along the Tokaido Road)

Utagawa Hiroshige Ⅱ (1826-1869)

Collection of the Art Research Center (ARC), Ritsumeikan University
Object number: arcUP3257

The 4th APT/ITU Conformance and Interoperability Event

Kaoru Kenyoshi
Senior Expert, NEC Europe

1. Introduction

The 4th APT[*1]/ITU Conformance and Interoperability (C&I) Event was held on 13th and 17th November 2016 during ITU Telecom World 2016 at the IMPACT Convention and Exhibition Center in Bangkok, Thailand. This event was jointly organized by APT and ITU to promote activities to deepen the understanding of C&I throughout countries in the Asia-Pacific region, and to improve the capabilities of each APT member nation and resolve their problems. This event featured conformance & interoperability testing, and showcased technologies including SDN/NFV, IPTV, seamless network technologies and "Bridging the Standardization Gap" projects. Four exhibitors took part in testing and showcasing at this event, and around 8,800 people from 130 countries visited ITU Telecom World. This article provides a broad description of the 4th APT/ITU C&I event.

2. Cooperation of ITU with national/regional SDOs

In response to strong demands from developing countries, the ITU-T adopted resolution 76[*2] at WTSA08 (October 2008, Johannesburg, South Africa), and has been working to resolve interoperability issues as a key priority. Each of the ITU-T's study groups has developed recommendations relating to conformance and interoperability, and interoperability events relating to IPTV and home networks have been held by SG16 and SG15 respectively. ITU has decided to implement four action items (1. Assessing product conformity with ITU-T recommendations, 2. Holding interoperability events, 3. Cultivating human resources for capacity building, and 4. Establishing test centers in developing countries) and a business plan. As the lead SG for test specification and C&I testing, ITU-T SG11 is working to set up an action plan to address C&I issues. At WTSA12 (November 2012, Dubai, UAE), SG11 was assigned as the parent SG of Joint Coordination Activity on Conformance and Interoperability Testing (JCA-CIT), which coordinates C&I initiatives associated with multiple ITU-T study groups. Eight meetings of JCA-CIT were held from April 2013 to July 2016 to strengthen SG11's efforts. Resolution 76 is still attracting considerable interest from developing countries, and was significantly revised and reaffirmed at WTSA-16 (October- November 2016, Hammamet, Tunisia).

In Japan, TTC[*3] has completed the specifications JT-Q3401 and JT-Q3402 based on the ITU-T NGN UNI/NNI specifications ITU-T Q.3401/Q.3402 by adding technical details for interconnections, and HATS[*4] has performed terminal-to-terminal interconnection tests based on this UNI specification. In June 2009, TTC established IoP-AG (Interoperability Advisory Group), which is continuing to study NGN interoperability and submit contributions to SG11. At ITU-T SG11, this activity has so far resulted in the completion of ITU-T Recommendations Q.3909 (test framework), Q.3948 (VoIP test specification) and Q.3949 (TV phone test specification) which were proposed by TTC. Based on the test specification recommendations developed by SG11, the HATS Interoperability event took place on December 11–12, 2012 with the support of the ITU. Since then, HATS and ITU have continued to jointly organize annual Interoperability events in Japan.

3. APT/ITU Conformance and Interoperability event

3.1 Discussions for preparation in ASTAP

The APT/ITU conformance and interoperability event was first discussed based on Japanese contributions proposed at the 36th APT Management Committee (November 2012, Bangkok). The first C&I event was held in September 2013 during the 22nd ASTAP[*5] meeting in Bangkok. Since then, we have regularly held this event back-to-back with the ASTAP meeting in the autumn season every year. However, for the fourth year in 2016, there was no autumn ASTAP meeting because WTSA-16 was held in October – November 2016, so there was no chance to organize an event during the ASTAP meeting in 2016. At the 26th ASTAP meeting (September 2015), we reviewed the report of the 3rd C&I event which was held during the 26th ASTAP meeting, and we started discussing the 4th C&I event. At this meeting, three options were proposed to promote and attract more visitors and exhibitors:

1) Collaborating more closely with ITU, including collocated

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*1 APT: Asia Pacific telecommunity
*2 Resolution 76 "Studies related to conformance and interoperability testing, assistance to developing countries, and a possible future ITU mark programme"
*3 TTC: Telecommunication Technology Committee
*4 HATS: Harmonization of Advanced Telecommunication Systems
*5 ASTAP: Asia-Pacific Telecommunity Standardization Program

events at ITU meetings

2) Joining other APT events such as the APT Policy and Regulatory Forum (PRF)

3) Creating a new APT forum independent of ASTAP to organize C&I events.

Based on these proposals, detailed studies were started at the 27th ASTAP meeting in March 2016. In ASTAP EG-ITU-T (Expert Group on ITU-T Issues), the outline of the ITU Telecom World 2016 (November 2016) was introduced and it was proposed that the C&I event should be held during ITU Telecom World 2016, either at the same venue or nearby. We also agreed to establish a Coordination Committee to facilitate discussions, and appointed Kaoru Kenyoshi as its chairperson. Since May 2016, we have held three telephone conferences to investigate the specific details of testing and showcasing, announce the event, and invite participation from individuals and companies. This event was announced on the APT and ITU websites, and participants were invited from the APT and ITU member countries. As the result of these efforts, OKI electric, NEC, NICT and TTC provided showcases and took part in the event.

3.2 Outline of the 4th C&I event

The 4th APT/ITU C&I Event was held on 13th and 17th November 2016 during the ITU Telecom World 2016 in Bangkok. Around 8,800 people from 130 countries visited ITU Telecom World.

1) Testing: 13th November 2016
  a) IPTV Conformance and Interoperability testing (OKI, NEC)

2) Showcasing: 14th – 17th November 2016
  a) SDN/NFV (NEC)
  b) IPTV(including IPTV-MAFR (Multimedia Application Framework)) (OKI)
  c) Seamless network (NICT)
  d) Bridging the standardization Gap (TTC)

We organized IPTV Conformance and Interoperability testing as a closed event among participating companies at the IMPACT Forum on the day before the opening of ITU Telecom World 2017. During ITU Telecom World 2017, we organized a showcase at the ITU pavilion in the exhibition area at IMPACT Challenger, which was visited by many guests.

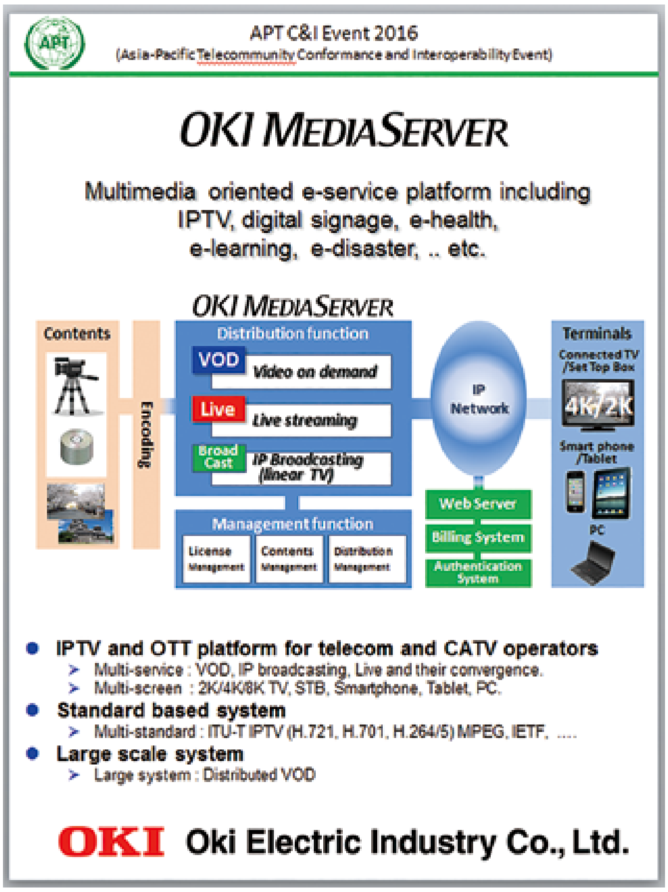
3.3 Showcases

The following showcases were provided by the exhibitors:

1) IPTV (Oki Electric, Japan)

Oki exhibited Internet Protocol TV (IPTV) solutions based on ITU-T standards (ITU-T H.721, H.265, etc.). Their OKI MediaServer is a core product that provides a platform for e-services such as IPTV, digital signage, e-health, e-learning, and e-disaster, including a state-of-the-art 4K/8K ultra high definition television linear TV service. 4K/8K television has around 4,000/8,000 horizontal pixels respectively, which allows it to display clear and life-like video over IP networks implemented by telecom carriers and CATV operators. There was also a demonstration of an e-health service powered by IPTV. Visualizing a viewer's physical condition via an IPTV display may help the viewer to be more health-conscious and start exercising more.

2) SDN/NFV (NEC Corporation, Japan)



■ **Figure 1: Oki Media Server**

NEC Corporation exhibited a Network-as-a-Service (NaaS) solution focusing on helping service providers generate new revenue in both B2B and residential markets by using SDN/NFV technologies. This solution provides a complete, end-to-end environment that supports the definition, provisioning, orchestration and lifecycle management of complex services. It leverages advances in both network and function virtualization to allow a new level of flexibility and automation, lowering costs and reducing time-to-market.

Part of this solution is a cloud marketplace, which is unique in that it brings together basic network services (such as vCPE and Software defined WAN), value-added network services (such as firewalls, bandwidth-on-demand, and WAN optimization) and cloud-based business productivity applications. This marketplace allows service providers to personalize their offers.

The solution is powered by AVP (Agile Virtualization Platform and Practice) for consulting and comprehensive system integration services. AVP consists of: i) an Agile Collaboration environment, where business planners, system architects and operators can collaborate to rapidly create new applications, ii) Business Enablement Applications (BEA), which are designed to fill the gaps with existing BSS by providing pre-integrated applications supporting emerging business models, and iii) Hybrid Operations Management (HOM), which is focused on operating both virtual and traditional networks simultaneously.

3) Seamless network (NICT, Japan)

The seamless network concept was exhibited by NICT, who presented an overview of on-going projects of seamless access network technologies related to ASTAP EG-SACS (Expert group on seamless access communication system). Radio over fiber (RoF) technology, which achieves seamless convergence between radio and optical networks, is applicable not only to low-latency signal transport technology including millimeter-wave front-haul/back-haul systems for rural areas and train communication networks, but also to distributed radar system in the millimeter-wave band for foreign object debris detection. They also presented a video showing a field trial demonstration of the millimeter-wave radar system at Narita International Airport in Japan.

4) Bridging the standardization Gap (TTC, Japan)

TTC exhibited one of its activities regarding "Bridging the standardization Gap". The purpose of this activity is to overcome the standardization gap from the viewpoint of using the latest ICT/NGN to improve people's lives and bring more

Figure 2: NaaS Solution

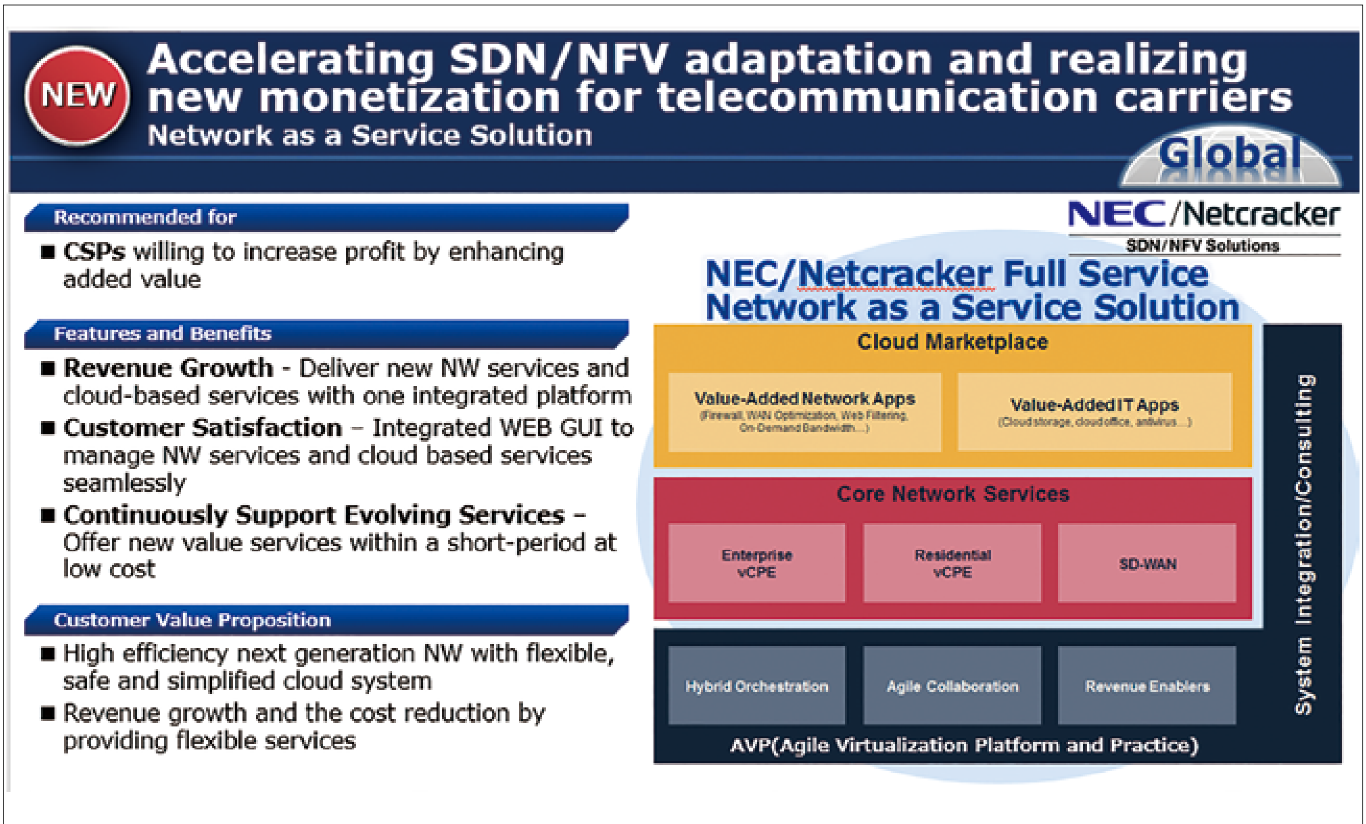


Figure 3: RoF system

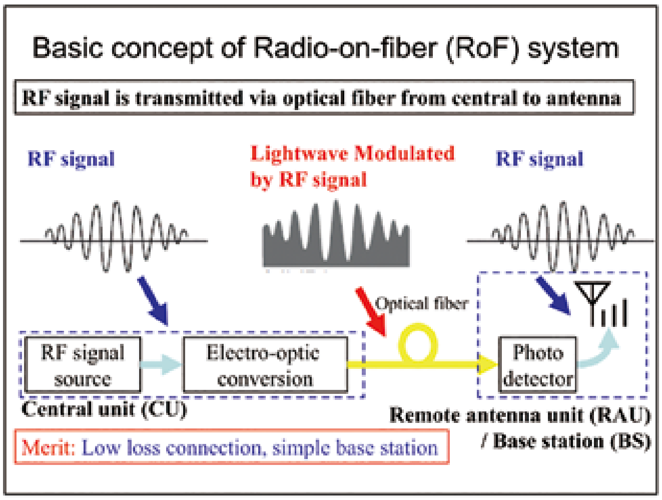
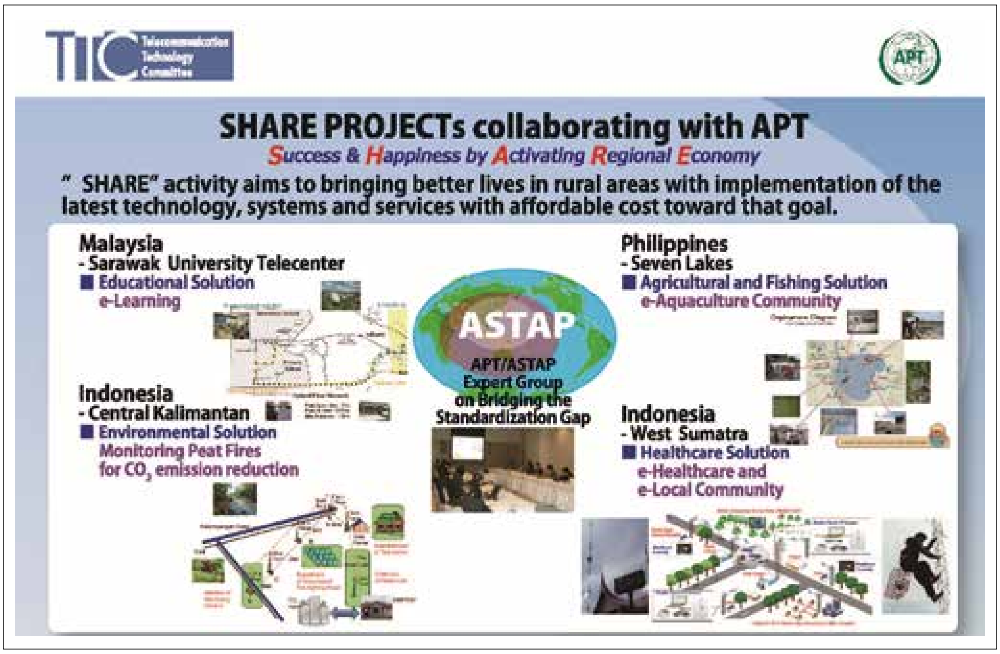


Figure 4: Business Activities of TTC



happiness to developing countries, and implementing the latest technologies, systems and services in an affordable way. In other words, this activity aims to build capabilities to apply the latest standardized technologies and systems to various applications and services based on experience of implementing new solutions in projects supported by APT. Contributions from Indonesia, Japan, Malaysia, Philippines, Thailand and Vietnam as well as collaborative initiatives with Asia-Pacific Telecommunity projects have resulted in several projects being carried out in different countries, each addressing five applications over ICT/NGN to be developed as solutions for social issues in rural areas, namely: e-agriculture, e-education, e-environment, e-healthcare and e-disaster management.

TTC introduced the new "Handbook for ICT Projects for Rural Areas". This handbook is a collaborative effort of various member countries, namely Indonesia, Japan, Malaysia, Philippines, Thailand and Vietnam to provide the research community with a guidebook on initiating ICT projects in rural areas. It was developed based on the experience gained by the members when implementing ICT projects in areas of education, agriculture, aquaculture, health and the environment management in Indonesia, Malaysia, Philippines, Thailand and Vietnam.

3.4 Outcomes and future events

The 4th APT/ITU C&I event was the first event to provide conformance and interoperability testing and showcasing during ITU Telecom World. It showed off the latest activities and solutions of APT and ITU on C&I, not only to APT member countries but also to visitors to ITU Telecom World from around the world. The showcases were attended by government officials, VIPs of the ITU, major mobile and network operators from Thailand such as TOT, CAT and AIS, and ICT administrators. It was useful for exhibitors from industries such as OKI and NEC to find new business opportunities and strengthen their customer relations. It was feared that the event might not happen due to the death of King Bhumibol Adulyadej of Thailand one month before. But in the end, most of the visitors wore black and white mourning colors to express their condolences. After the opening ceremony of ITU Telecom World, the princess and prime minister of Thailand and Mr Houlin Zhao, ITU Secretary-General visited the exhibitions.

APT will continue to prepare for the 5th C&I event in 2017. The most promising option is to hold it during ITU Telecom World 2017 (25-28th September 2017, Busan, South Korea). We plan to discuss the details of this event at ASTAP-28 (March 2017, Bangkok).

4. Closing

Spurred on by the experience of the latest APT/ITU C&I event, we have started discussions aimed at forging closer links between the business world and the activities of the APT to contribute directly to the construction of the network infrastructure in APT member countries. Holding a C&I event was proposed due to the considerable amount of interest in C&I in all countries, and the expectation of active participation from industries. We have continued to hold an annual C&I event since 2013. We hope to be able to hold this event jointly with APT and ITU in order to combine our cumulative experience and knowledge of APT and emerging topics in ITU-T such as 5G, IoT, e-service and VoLE interoperability. We aim to hold future C&I event to contribute to the development of Asia-Pacific countries and support the business activities of our exhibitors. I would like to thank everyone who helped make the C&I event a success, and I hope you will be able to offer your continued support at the next event.

Photo 1: Exhibition Entrance

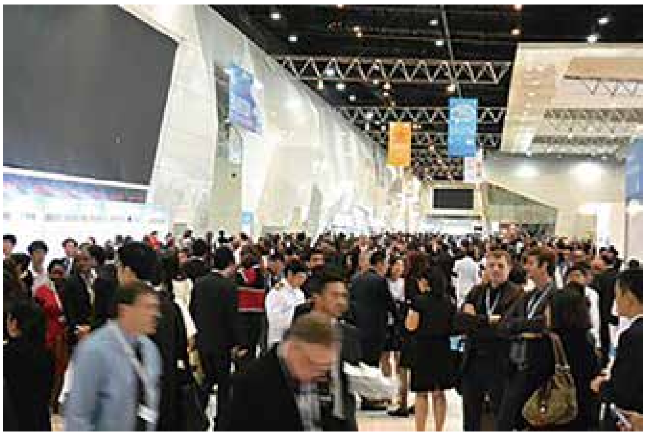


Photo 2: Exhibition Overview (APT/ITU C&I booth on the upper left)

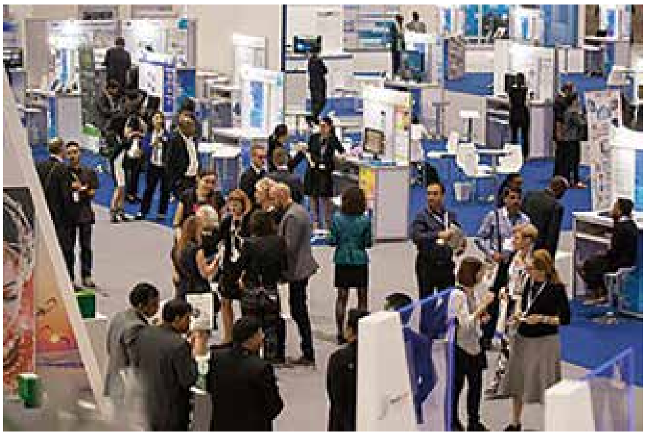
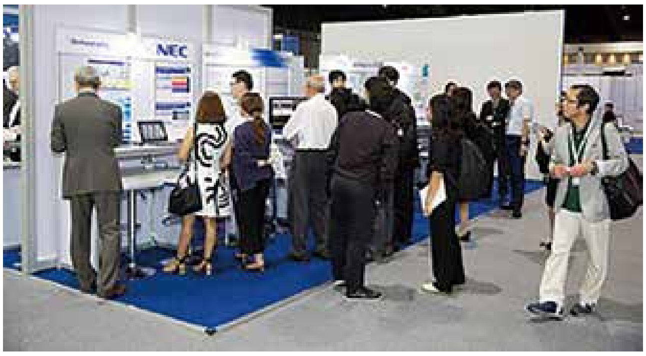


Photo 3: Exhibition Overview (APT/ITU C&I booth)



= A Serial Introduction Part 3=
Winners of ITU-AJ Encouragement Awards 2016

In May every year, The ITU Association of Japan (ITU-AJ) proudly presents ITU-AJ Encouragement Awards to people who have made outstanding contributions in the field of international standardization and have helped in the ongoing development of ICT.
These Awards are also an embodiment of our sincere desire to encourage further contributions from these individuals in the future.
If you happen to run into these winners at another meeting in the future, please say hello to them.
But first, as part of the introductory series of Award Winners, allow us to introduce some of those remarkable winners.

Ryota Mibu

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Fields of activity: Network Functions Virtualization (NFV)

Open Source and Standardization in Network Virtualization Technology

It is a great honor to receive the ITU-AJ Encouragement Award (ICT Field), and I would like to express my appreciation not only to the Selection Committee but also to everyone who helped me along the way. This award recognizes the contribution that has been made to the standardization of network virtualization technology from the seemingly unrelated field of open-source development.

Network Functions Virtualization (NFV) seeks to simplify the construction and operation of carrier systems by virtualizing various network functions and eliminating hardware dependencies. It is expected to provide benefits including flexible resource sharing, greater agility for the launch of new services, and fast disaster recovery. Furthermore, it is also expected to evolve into a common platform for telecom and IT/cloud services, since it shares many aspects with IT/Cloud technology in the telecom domain.

In 2014, an open source project called Open Platform for NFV (OPNFV)[1] was launched with the aim of contributing to the development of standard NFV specifications by implementing a reference NFV platform. This platform was expected to elevate the role of open source technology in the IT / cloud domain, but became entrenched due to differences in the requirements of existing open source technology.

I am the leader of the OPNFV Doctor project, which aims to solve this problem by implementing fault management (an important part of telecom carrier systems where high availability is required). We started by organizing the requirements and solutions, and creating generalized use cases and scenarios. We then submitted a list of required functions to OpenStack[2], which is becoming the de facto open source cloud platform. OpenStack is continuing to work out the design details and implement the necessary functions. These functions were also incorporated into OPNFV's reference literature when it was released after verification with functional testing. It is currently referred to in the standardization activities of ETSI ISG NFV Stage 3.

The speed of development in these open source projects has been remarkable. For example, the function that I oversaw was implemented in OpenStack in about 6 months from the proposal. One of the attractions of the open source project is that engineers from multiple companies were able to complete a feasible specification in a short period of time. We believe that the development of standard specifications can be accelerated by making use of open source projects in this way.

This activity has also been attracting attention in OpenStack, and a demonstration was carried out at the event of October 2016[3].

[1] https://opnfv.org/
[2] http://openstack.org/
[3] https://www.youtube.com/watch?v=Dvh8q5m9Ahk

Yoshio Miyadera

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Fields of activity: Maritime Radiocommunication

International Standardization of Maritime Radiocommunication

I'd like to present a brief introduction to maritime radiocommunication, which is the field of international standardization that I am involved with. Maritime radio uses all sorts of frequencies and radio systems. The frequencies in current use range all the way from 400 kHz to 30 GHz, and the radiocommunication systems are too numerous to list, but examples include the use of Narrow Band Direct Printing (NBDP) for Maritime Safety Information (MSI) broadcasting, analog voice communication, digital voice communication, various forms of data communication, distress communication via Digital Selective Calling (DSC), the Automatic Identification System (AIS) for ship collision avoidance, the Emergency Position Indicating Radio Beacon (EPIRB) system for distress communication, radar systems and GPS navigation equipment. There are even stations still communicating by Morse code, including some high-seas fishing vessels.

Although analog systems prevailed in maritime radio for many years, digital communication has gradually been making inroads since the launch of GMDSS in 1992. More recently, the introduction of data communications has really taken hold following the HF and VHF band allocations of WRC-12.

At WRC-15, digital communication was also introduced for UHF maritime on-board communications, and VHF band data communication was formalized as the VHF Data Exchange System (VDES). At WRC-15, it also became possible to use Ka band (20/30 GHz) satellite communication (ESIM: Earth Stations in Motion) for high-speed data communication on board ships. The use of satellite communication in VDES is due to be discussed at WRC-19.

These diverse forms of maritime radiocommunication require an internationally unified communication systems structure such as the GMDSS (Global Maritime Distress and Safety System), and the ITU's activities are essential for achieving international standardization. I hope to continue with my international standardization efforts as a communication professional in order to promote the effective use of frequency resources and the introduction of new technology, and to ensure the safety and security of seafarers everywhere.

Akihiro Nakao

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Fields of activity: Computer Networks

Network Softwarization and Slicing Technology for the Fifth-generation Mobile Network

I am very grateful to ITU-AJ for this award.

This award recognizes the research and development of 5th generation (5G) mobile communication systems promoted throughout Japan centered on the Fifth Generation Mobile Communication Promotion Forum (5GMF), especially the importance of an infrastructure with extreme flexibility as advocated by the 5GMF Network Committee and by the ITU-T IMT-2020 focus group (FG) from the viewpoint of standardization, working in partnership with the TTC and Japanese companies and leading discussions.

We advocated the concepts of network softwarization and network slicing to the ITU-T as key technologies. Network softwarization is a very important trend in communication networks whereby software is being used to implement network equipment and functions, allowing services to be configured and deployed faster and with greater flexibility.

Since the communication infrastructure is implemented in software, it can be modified flexibly and it is also possible to implement network functions in the vicinity of terminals, as in multi-access edge computing (MEC).

Network slicing refers to the concept of slicing up network infrastructure into independent sets of programmable computing, storage, and network resources that implement network functions and services in such a way that separate slices accommodate the traffic of applications and services with different requirements.

Since 5G networks must accommodate diverse groups of applications with greatly differing requirements, including eMBB (enhanced Mobile Broad Band), URLLC (Ultra Reliable and Low Latency Communication) and mMTC (massive Machine Type Communication), it is important to have technology for end-to-end service construction.

Thus, in the communication infrastructure to be implemented in the near future, it will be essential to quickly identify key global technology trends and actively ensure that priority is given to discussions of standardization in order to maintain the competitive edge of Japanese companies.

Based on our recent achievements, Q21 was established by ITU-T SG13, and in February 2017 work started on the standardization of network softwarization technology in IMT-2020. In the future, we intend to strongly promote Japan's leadership in the field of 5G wired technology and wireless technology, especially in the fields of network softwarization and slicing where Japan is expected to lead the rest of the world.

Kunihiro Toge

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Fields of activity: ITU-T SG15

Standardization of Maintenance and Operation of Outdoor Facilities for FTTx

It is a great honor to receive the ITU-AJ Encouragement Award, and I would like to express my sincere appreciation not only to the Selection Committee but also to everyone who helped me with my standardization activities.

I began participating in ITU-T Study Group 15 in 2012, and have mainly been working on the standardization of outdoor FTTx facilities such as optical cables and optical passive devices. In 2013, I started serving as Rapporteur of ITU-T Q17/SG15 (maintenance and operation of optical cable networks) and actively contributed to new Recommendations and revisions in this area.

I have mainly focused on organizing these Recommendations into three categories relating to optical cable network maintenance, facility management and disaster management. By doing so, I hope to make it easier for users to understand the current Recommendations, especially in countries that are continuing to deploy FTTx.

The primary goal of this activity is to create an environment where many countries can easily voice their concerns regarding daily maintenance and operation. The most important aspect of standardization in this area is to identify common issues among operators as a starting point for discussions of systems and technical requirements. Japan has a lot of experience in FTTx maintenance and technologies. It is important not only to promote Japan's experiences but also to find operational issues that are shared by various operators and countries for future standardization.

Currently, ITU-T Q17/SG15 is working on the standardization of frameworks for disaster management and water detection in underground optical cable networks, and exploring new operational system requirements for the maintenance of passive optical access networks and supporting infrastructures. I will continue to lead discussions while serving as Rapporteur of ITU-T Q17/SG15. I hope that our activities will help solve the operational issues of international/regional operators, and promote advances in commercial technologies and products.

New Breeze 平成二十九年四月十日発行（年四回一、四、七、十月の十日発行）第二十九巻第二号（通巻百十四号）

定価 一冊 一、六二〇円（本体価格 一、五〇〇円、消費税 一二〇円） 年間購読料 六、四八〇円（本体価格 六、〇〇〇円、消費税 四八〇円）

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