NTT DOCOMO Outlook for 5G Deployment

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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.

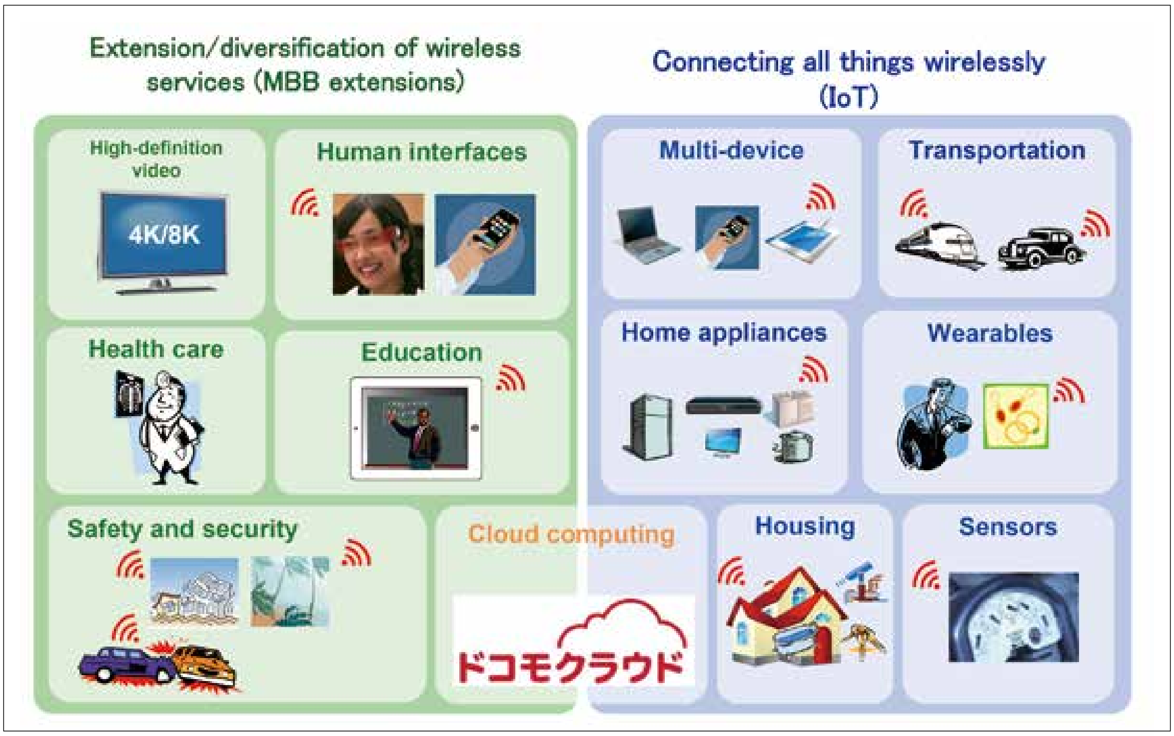
NTT DOCOMO began studying 5G around 2010, when we started our commercial LTE services, and has been advancing various R&D activities including proposing technology concepts, conducting transmission experiments, and leading standardization discussion. This article discusses NTT DOCOMO's outlook for 5G 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.

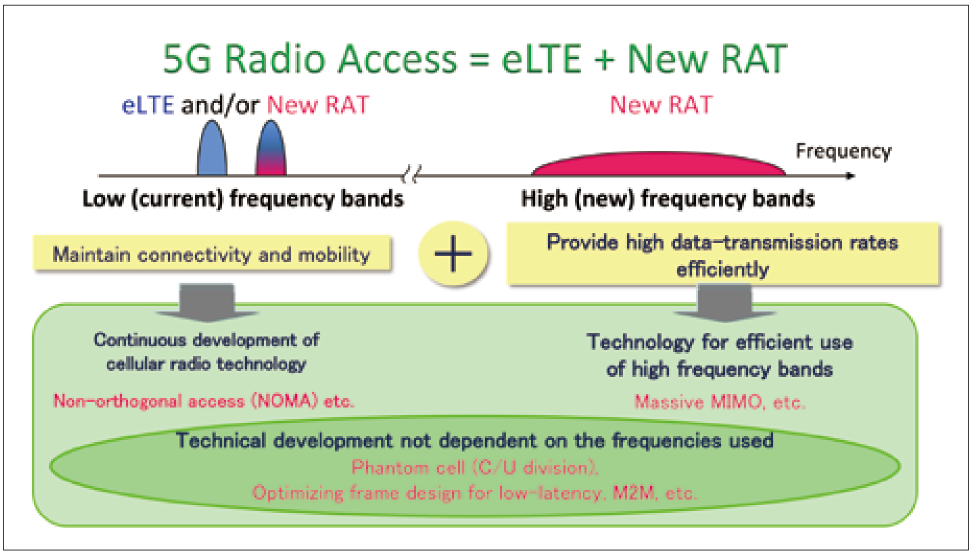
It will also be necessary to introduce New RAT using centimeter-wave (3-30 GHz) and millimeter-wave (30 GHz and higher) frequencies that have not previously been used for mobile communication. To maintain adequate coverage while improving performance with these high frequencies will require optimization 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

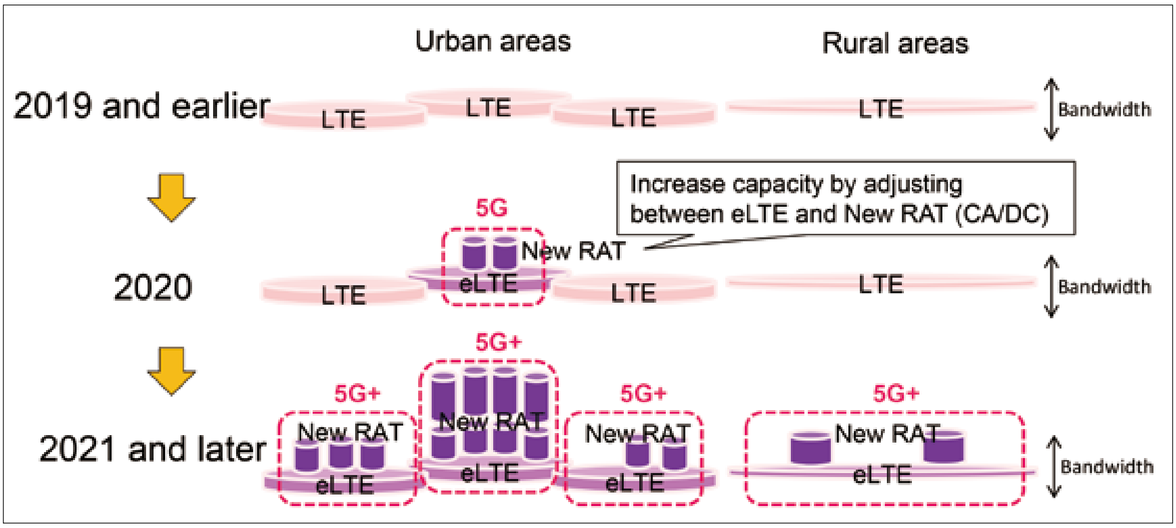
A 5G development scenario combining eLTE and New RAT in this way is shown in Figure 3. For the first introduction of 5G, targeted for 2020, 5G involving eLTE and New RAT will be developed mainly in urban areas that require increased capacity. Use of eLTE and New RAT will be integrated through carrier 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

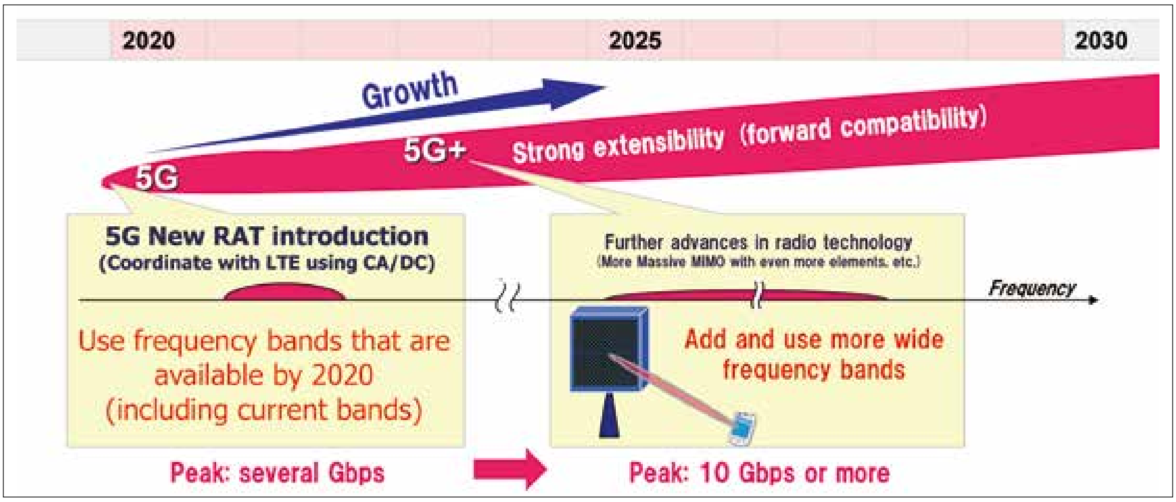
Figure 2: NTT DOCOMO 5G technology concept



■ 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.

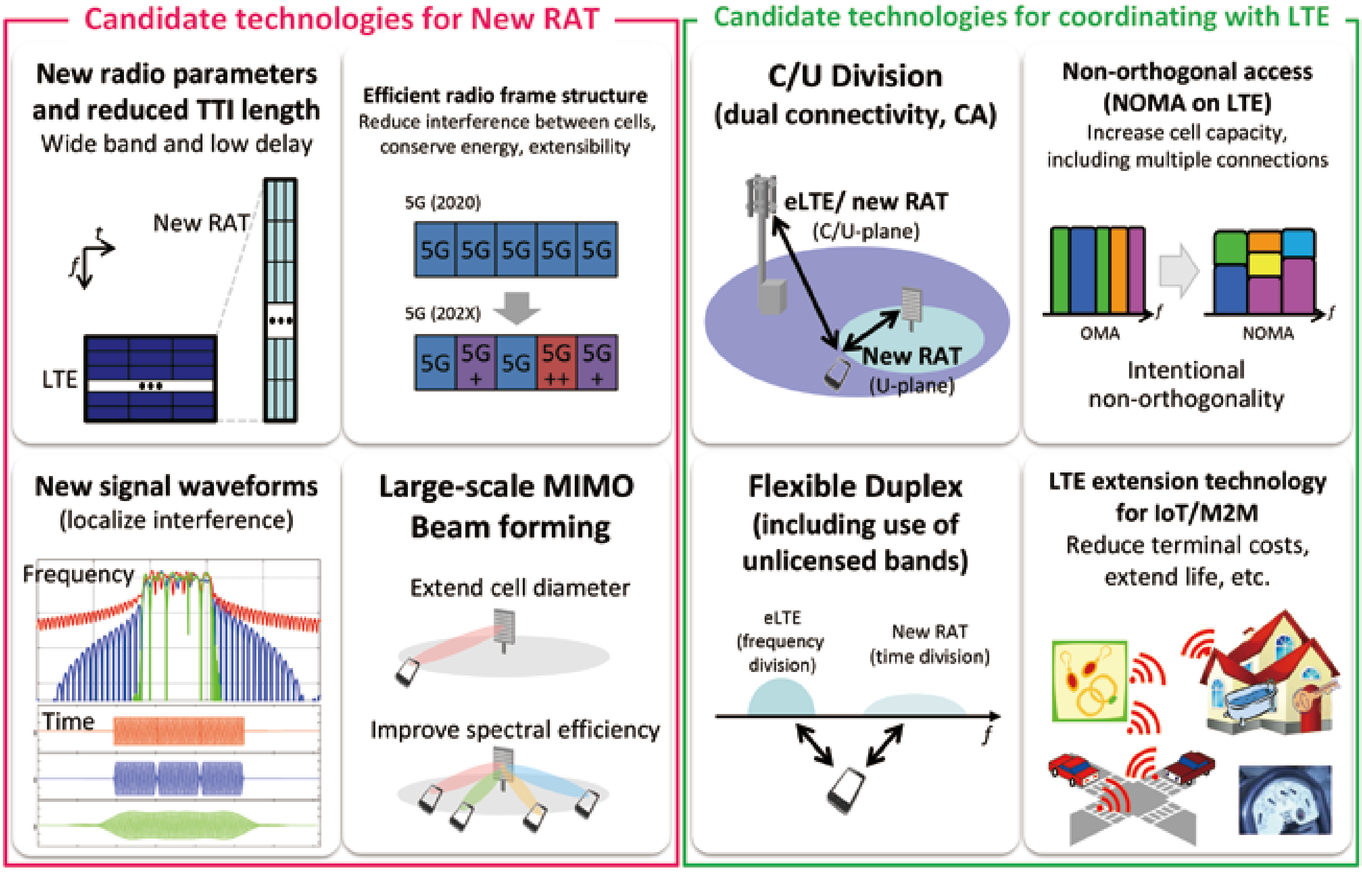
3. NTT DOCOMO 5G Initiatives

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

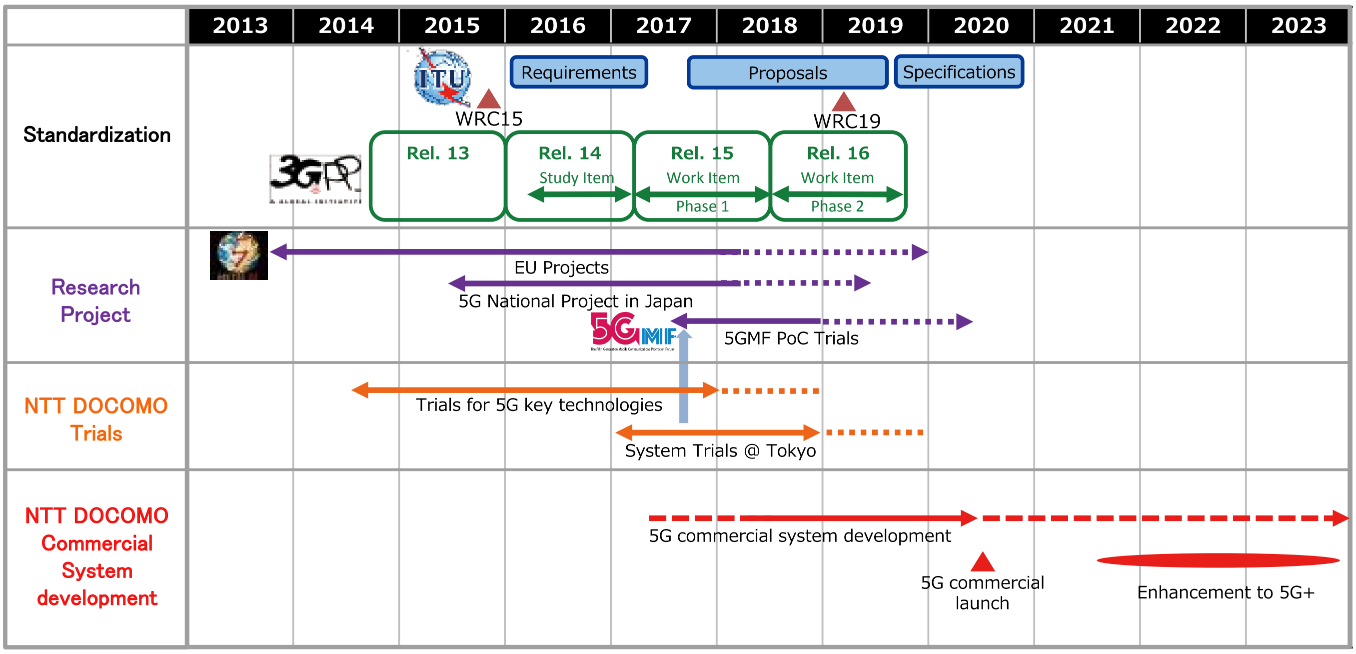
This article has given an overview of R&D initiatives, including global trends, toward 5G next-generation mobile communications systems, which will enable services such as even faster, high-capacity MBB, and IoT that will connect diverse objects to networks wirelessly. NTT DOCOMO will continue to promote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