

Special Articles on 5G Technologies toward 2020 Deployment

NTT DOCOMO 5G Activities —Toward 2020 Launch of 5G Services—

NTT DOCOMO is researching and developing 5G, the next-generation mobile communications system, toward deployment in 2020. The 5G system is expected to enable a variety of new services including enhanced MBB having even higher bit rates and capacity and IoT connecting all kinds of things to the network by wireless means. This article presents an overview of NTT DOCOMO's 5G activities. It describes services and requirements envisioned for the 5G era, NTT DOCOMO's 5G definition and technical concept, and standardization strategy and activities toward a 2020 launch of 5G services.

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1. Introduction

Today, we can enjoy services and applications as well as videos and music over the Internet in an anytime-and-anywhere, trouble-free manner thanks to the proliferation of smartphones, tablets, and other smart devices. Nevertheless, the demand for even more advanced services is growing. At the same time, mobile communications traffic has increased dramatically since 2010, so in addition to accommodating higher volumes of traffic, telecom carriers will be expected

to provide a Mobile Broad Band (MBB) system that can provide these services in all types of environments at an even higher level of user quality. In addition, the Internet of Things (IoT)*1 has been attracting considerable interest in recent years as a world that will connect all kinds of things to the network by wireless means. Going forward, it will become increasingly important for telecom carriers to provide the infrastructure that can support services in new business domains opened up by IoT.

Amid these expectations, there have

been lively discussions in recent years on fourth-generation (4G) LTE and a fifth-generation mobile communications system (5G) as the next-generation of LTE-Advanced. Organizations promoting 5G and 5G research projects have been launched in various regions throughout the world and spirited debates on the 5G concept and associated requirements have taken place. In this regard, the 3rd Generation Partnership Project (3GPP), a leading standardization organization for mobile communications systems, held a gathering called “3GPP RAN Workshop

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*1 **IoT**: General term for a control and information-communications format that connects various “things” to the Internet and cloud.

on 5G” in September 2015 marking the beginning of serious discussions on 5G standardization.

NTT DOCOMO began studying 5G in 2010 and has since been involved in a variety of 5G activities from proposing technical concepts to promoting transmission experiments and standardization discussions. In this article, we present an overview of these activities and describe, in particular, services and requirements envisioned for the 5G era, NTT DOCOMO’s 5G definition and technical concept, and standardization strategy and activities toward the launch of 5G services in 2020.

2. 5G Services and Requirements

2.1 Services in the 5G Era

There is no direct relationship between services and the mobile communications generation. The 2G and 3G systems can provide advanced services as long as smartphones can be used, and it can be said that 4G can provide most of the services provided by 5G. On the other hand, advances in communications technologies can make the same service more enjoyable in a greater variety of environments. In time, we will see the birth of new services that presume the communications quality of

5G, and before we know it, 5G will become the norm—one day, we will take it for granted.

A diverse array of services can be envisioned for the 5G era. These can be broadly divided into the two trends of enhanced MBB and IoT as shown in **Figure 1**.

- (1) Enhanced MBB, or high-speed, high-capacity, and low-latency communications, will enable richer and more sophisticated services and applications over the wireless network. For example, Enhanced MBB raises the possibility of high-definition video streaming (4K^{*2}/8K^{*3} video),

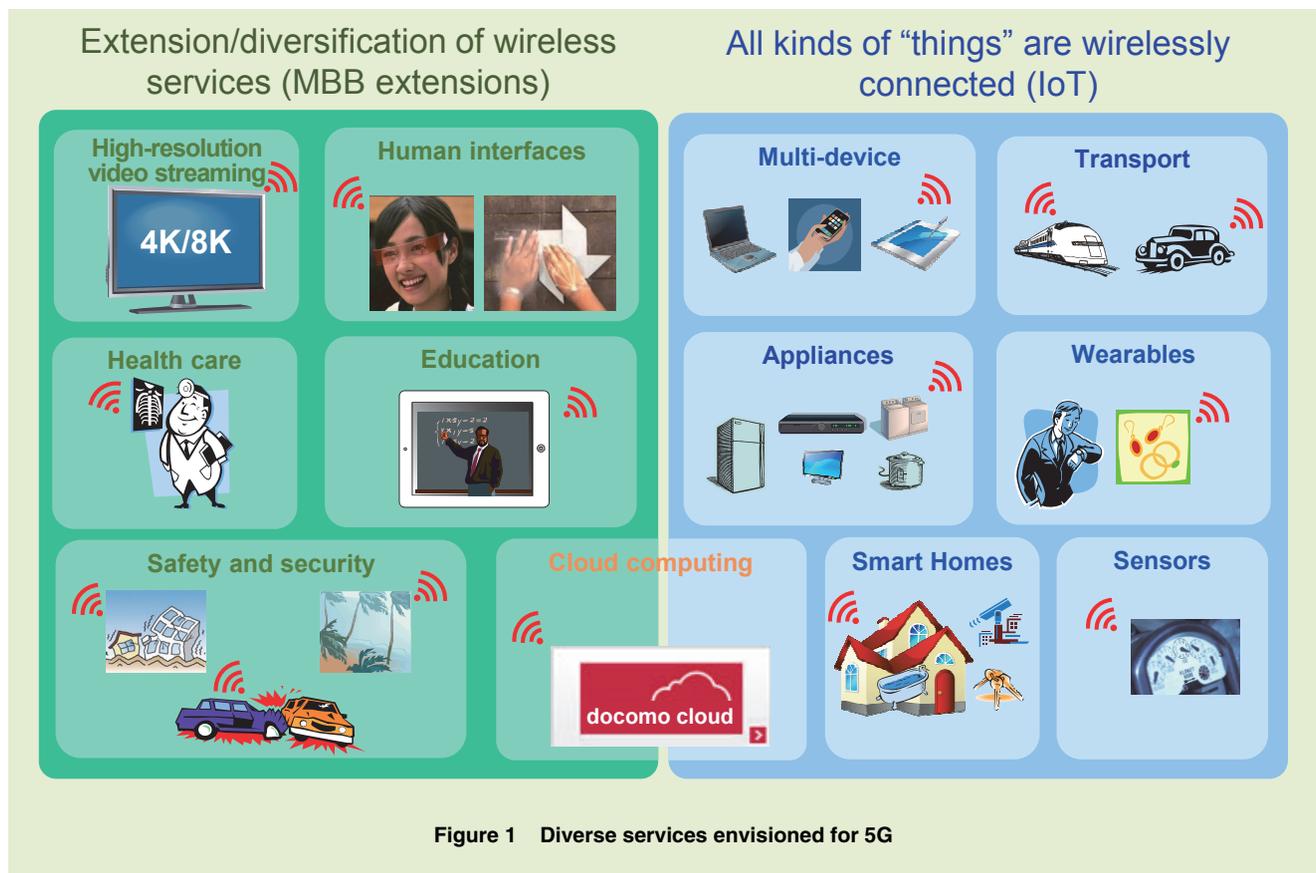


Figure 1 Diverse services envisioned for 5G

*2 4K: Picture format having a display resolution of 3,840 × 2,160 or 4,096 × 2,340 pixels.

*3 8K: Display format having a resolution four times that of 4K (twice that in each of the horizontal and vertical directions).

media-rich social network services, Augmented Reality (AR)^{*4} services closely coordinated with the huge amount of data on the cloud^{*5}, and media communications using touch, body movement, etc. (haptic communications) as opposed to audio and video. Additionally, it should enable wireless communications to become a lifeline for people and facilitate the provision of services that demand safety and certainty such as autonomous driving.

(2) The IoT world, in which all sorts of things will come to be wirelessly connected to the network, is expected to provide a wide

variety of services to users and companies over the wireless network. This will be achieved by connecting vehicles, homes, home appliances, eyeglasses, wristwatches, accessories, robots, sensors, etc. to the network by Machine to Machine (M2M)^{*6} technology and managing and controlling the huge amount of data so collected in an automatic and intelligent manner.

2.2 5G Requirements

To support the many and varied services that 5G is expected to make possible in the future, new requirements to deal with recently evolving trends such as IoT will have to be considered in

addition to universal requirements for existing mobile communications systems. In short, a wide range of requirements can be envisioned for 5G as summarized below (Figure 2).

(1) Higher system capacity

The volume of mobile communications traffic has been increasing at an explosive rate in recent years with predictions that it will reach 1,000 times that of 2010 levels in the 2020s. Dealing with this explosive increase will require a dramatic jump in system capacity (total bit rate per unit area). This is considered to be the most basic requirement for 5G.

(2) Higher bit rate

Considering the future prolifer-

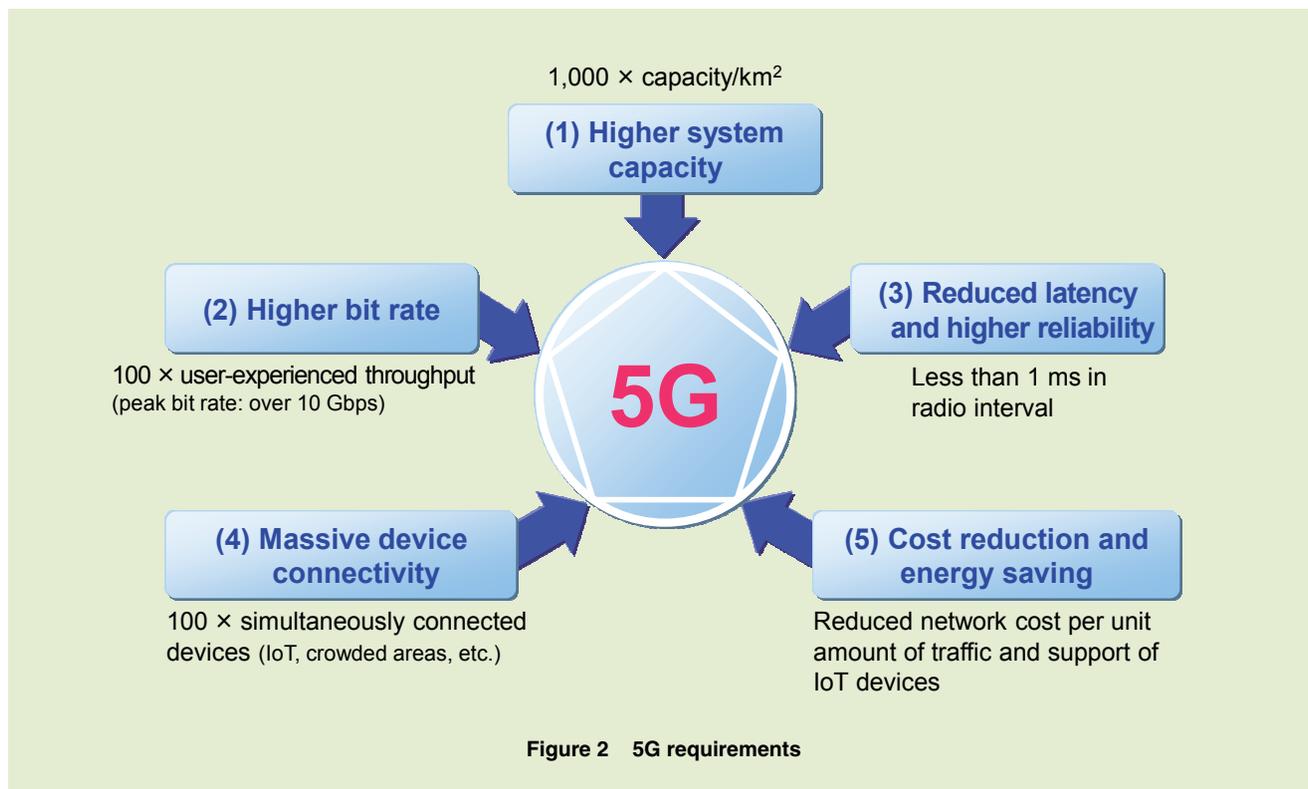


Figure 2 5G requirements

*4 **AR:** Technology for superposing digital information on the real world in such a way that it appears to the user to be an actual part of the scene.

*5 **Cloud:** A format and structures for providing services over networks. Server resources can be

distributed according to usage conditions, which provide good scalability.

*6 **M2M:** Information communications performed automatically between machines.

ation of rich content and cloud services, it is essential that 5G provide a quantum leap in bit rate too. In particular, it is important that the level of quality required for service provision be satisfied at all times regardless of time of day or location. Specific targets are a user-experienced throughput about 100 times that of LTE (several 100 Mbps – 1 Gbps) in all sorts of scenarios including mobile environments and a peak bit rate over 10 Gbps in a good wireless environment.

(3) Reduced latency and higher reliability

New services such as haptic communications and AR that require a level of latency lower than that in the past are expected to appear in the 5G era. 5G will require a latency of less than 1 ms in the radio interval, or one fifth that of LTE. Additionally, for services that demand safety and certainty such as autonomous driving, high reliability will be required in addition to low latency.

(4) Massive device connectivity

The number of devices constantly connected to the wireless network is predicted to increase dramatically in the IoT era. It will be necessary to support a massive number of simultaneously connected devices in all types of scenarios. These will include environments in which a large number of users have amassed such as stadium and event

venues and situations such as natural disasters in which many attempts at accessing the network can be expected to occur simultaneously.

(5) Cost reduction and energy saving

While setting high performance targets in 5G is important to provide even better services to users, it is also necessary to provide those services at reasonable costs to users. This means that network cost per unit amount of user traffic must be greatly reduced. Furthermore, to provide a superb network in a natural environment, such high levels of performance must be provided with as small an amount of energy as possible. Additionally, considering the expanded use of IoT devices in the form of compact sensors that can be attached, for example, to pets, making devices themselves as inexpensive as possible and extending the life of batteries are important. The wireless network must be able to support such IoT characteristics.

The above 5G requirements are also being studied at the Mobile and wireless communications Enablers for Twentytwenty (2020) Information Society (METIS)*7, a European project, and at Next Generation Mobile Networks (NGMN)*8, an alliance of world-leading telecom carriers [1][2]. NTT DOCOMO has been a participant in both of those organizations.

3. NTT DOCOMO's 5G Definition and Technical Concept

1) Two Approaches

There are two approaches available for deploying Radio Access Technology (RAT)*9 toward 2020. One is to use LTE and LTE-Advanced in more evolved forms, and the other is to introduce completely new RAT. The former involves continuous evolution while maintaining backward compatibility with the existing LTE system while the latter places priority on improving performance over maintaining backward compatibility with LTE.

2) Technical Concept (eLTE + New RAT)

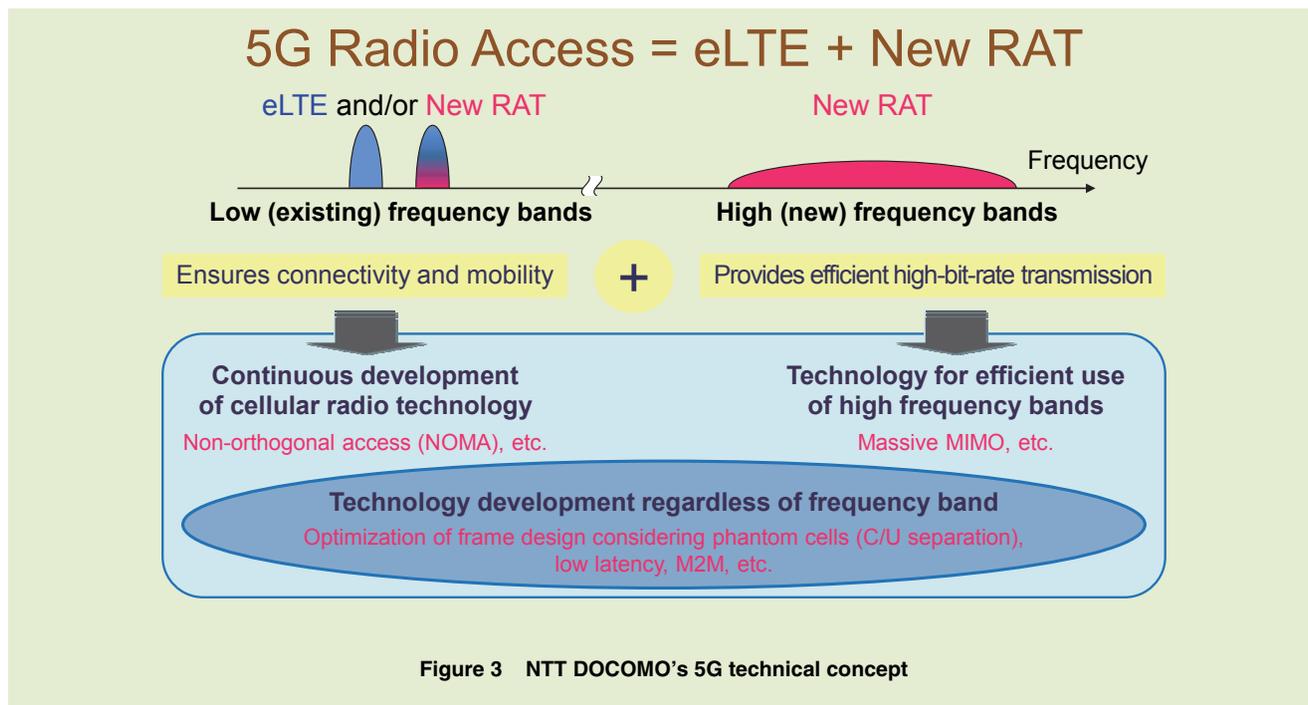
As shown in **Figure 3**, NTT DOCOMO defines 5G as a combination of continuous evolution in LTE/LTE-Advanced, that is, enhanced LTE (eLTE), and newly introduced RAT (New RAT). This concept achieves improved performance such as dramatic leaps in bit rate and capacity by New RAT applicable to broader frequency bands while providing a basic coverage area*10 and basic services such as broadcasting by eLTE. The 5G system can also incorporate Non-Orthogonal Multiple Access (NOMA) [3] technology that can improve system capacity in existing frequency bands and radio access technologies that can be applied regardless of the frequency band such as fast-retransmit control for achieving low latency. When applying

*7 **METIS:** A 5G-related EU research project that ran from November 2012 to April 2015 with participation by telecom vendors, telecom carriers, universities, and other parties.

*8 **NGMN:** An alliance of world-leading telecom carriers whose objective is to study requirements and operating scenarios for enhancing mobile broadband and contribute to industry.

*9 **RAT:** Radio access technology such as LTE, 3G, and GSM.

*10 **Coverage area:** The area over which a single base station can communicate with UE (cell diameter). As coverage is increased, the number of base stations required decreases.



such technologies to existing frequency bands, an eLTE approach is desirable to maintain backward compatibility with LTE.

Furthermore, to improve performance while securing sufficient coverage in high frequency bands that have not been used in mobile communications up to now such as those of centimeter waves (3–30 GHz) and millimeter waves (30 GHz and higher), it will be necessary to introduce New RAT that optimizes radio parameters and applies Massive Multiple Input Multiple Output (MIMO) technology [4] that uses a massive number of antenna elements.

Moreover, applying New RAT to existing frequency bands at a particularly early stage will require suitable gain in capacity and user throughput, and a design that enables coexistence with LTE

at identical frequencies would be desirable.

3) Deployment Scenario

An example of a 5G deployment scenario that combines eLTE and New RAT in the above way is shown in **Figure 4**. Initial 5G introduction scheduled for 2020 will be achieved by deploying eLTE and New RAT mainly in urban areas that require higher capacities. Here, eLTE and New RAT will interwork through Carrier Aggregation (CA)^{*11} and Dual Connectivity (DC)^{*12} technologies [5] to achieve higher capacities while ensuring coverage. In the future, the 5G deployment area will expand considerably from urban to suburban areas, so the addition of very high frequency bands such as those of millimeter waves can be expected as the need arises. This further evolution of 5G in 2021 and beyond

will be referred to as 5G+ below.

4. 5G Standardization System Strategy

4.1 Stepwise Standardization Approach

As shown in **Figure 5**, NTT DOCOMO aims to introduce 5G in 2020 while also planning for its continuous evolution as 5G+ in subsequent years. In 2020, frequency bands that exist today, new frequency bands that will become available by then, and unlicensed bands will all be candidates for 5G frequency bands. However, for 5G+ in later years, discussions at the International Telecommunication Union-Radio communication sector (ITU-R)^{*13} and at its World Radio communication Conference (WRC)^{*14-19} in particular may result in the addition of new frequency bands, so we can

^{*11} **CA:** A technology for increasing bandwidth while maintaining backward compatibility by simultaneously transmitting and receiving multiple component carriers.

^{*12} **DC:** A technology that achieves wider bandwidths by connecting two base stations in a master/slave relationship and performing transmission and reception using multiple component carriers supported by those base stations.

^{*13} **ITU-R:** Radiocommunication Sector of the ITU which recommends methodologies for subjective video quality assessment in addition to administration and coordination activities related to radiocommunications.

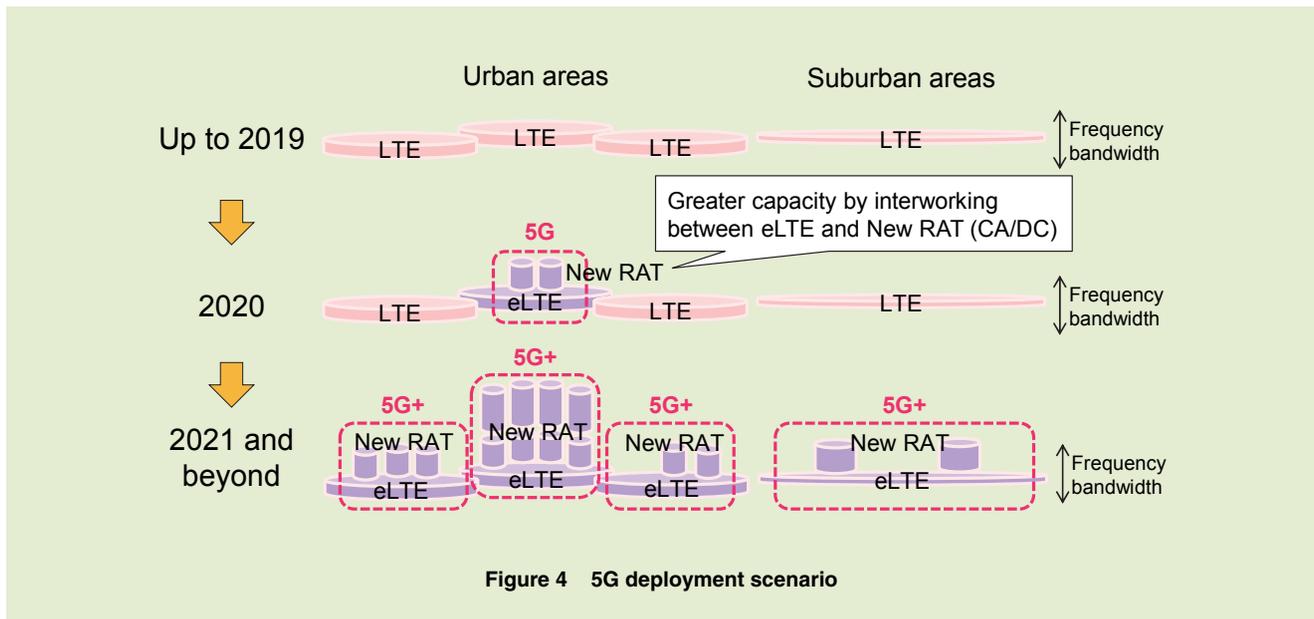


Figure 4 5G deployment scenario

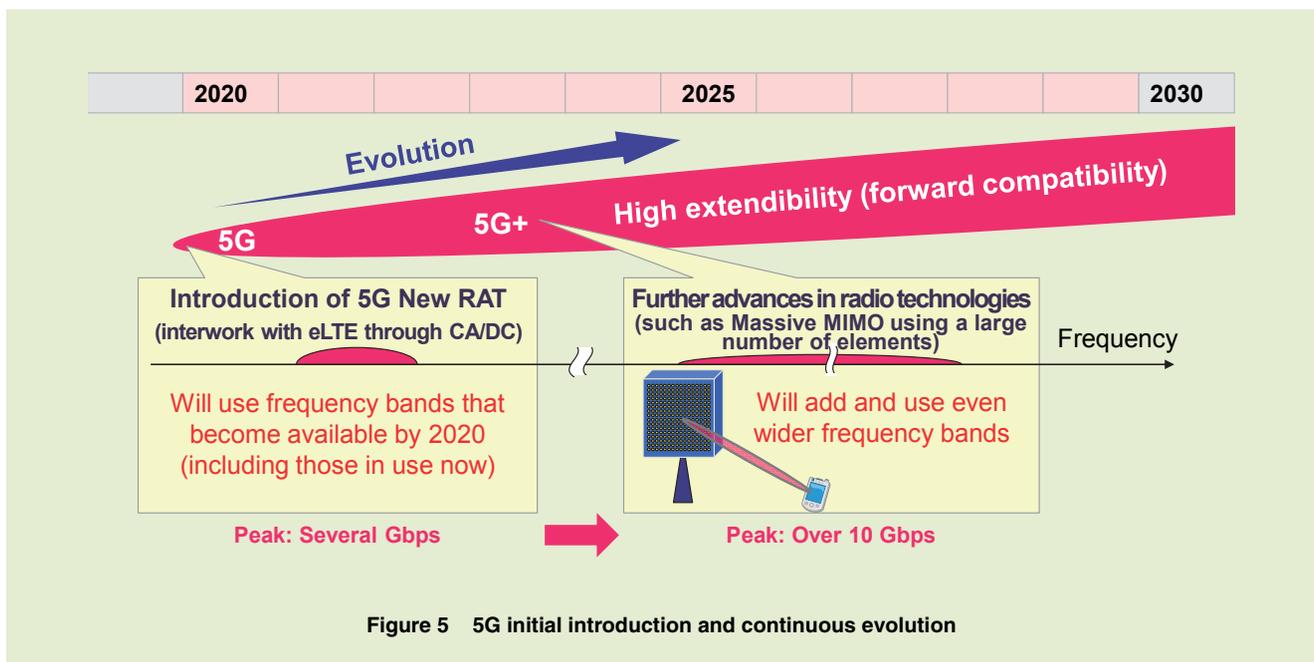


Figure 5 5G initial introduction and continuous evolution

envision that technologies applicable to radio access and the network may have to be extended as well.

1) Stepwise Standardization

To introduce New RAT in 2020, it appears that the standardization of initial specifications at 3GPP would have to be

completed by the end of 2018. However, the standardization of radio interface specifications that satisfy the requirements of ITU-R 5G (IMT-2020) needs to be completed only by the end of 2019 at 3GPP based on the ITU-R schedule. For this reason, we consider two-step

standardization to be an effective approach, with the first step corresponding to 5G and the second step to 5G+. The goal in this stepwise standardization of New RAT is to complete initial specifications toward 2020 deployment in a limited time period. This, however, will

*14 WRC: A conference that reviews, and if necessary, revises Radio Regulations, the international treaty governing the use of radio-frequency spectrum, and the orbits of geostationary and non-geostationary satellites. The conference normally meets once every three to four years,

and is attended by administrations, ITU registered corporations and related organizations.

require that a priority be placed on performing good basic design emphasizing future extendibility (forward compatibility) rather than incorporating abundant functions from the start.

As shown in **Figure 6**, 5G is configured as a combination of eLTE and New RAT while 5G+ will evolve con-

tinuously while maintaining compatibility with 5G. This is similar to the compatibility relationship between LTE and LTE-Advanced in 4G.

2) Roles of eLTE and New RAT in 5G, 5G+

As described above, both enhanced MBB and IoT can be viewed as service

trends in 5G and a sequential expansion of the 5G service area from urban areas requiring high capacity can be expected. Consequently, at the 5G introductory stage in 2020, New RAT will prioritize support for enhanced MBB featuring higher bit rates and higher capacity as required for urban areas (**Figure 7**). At

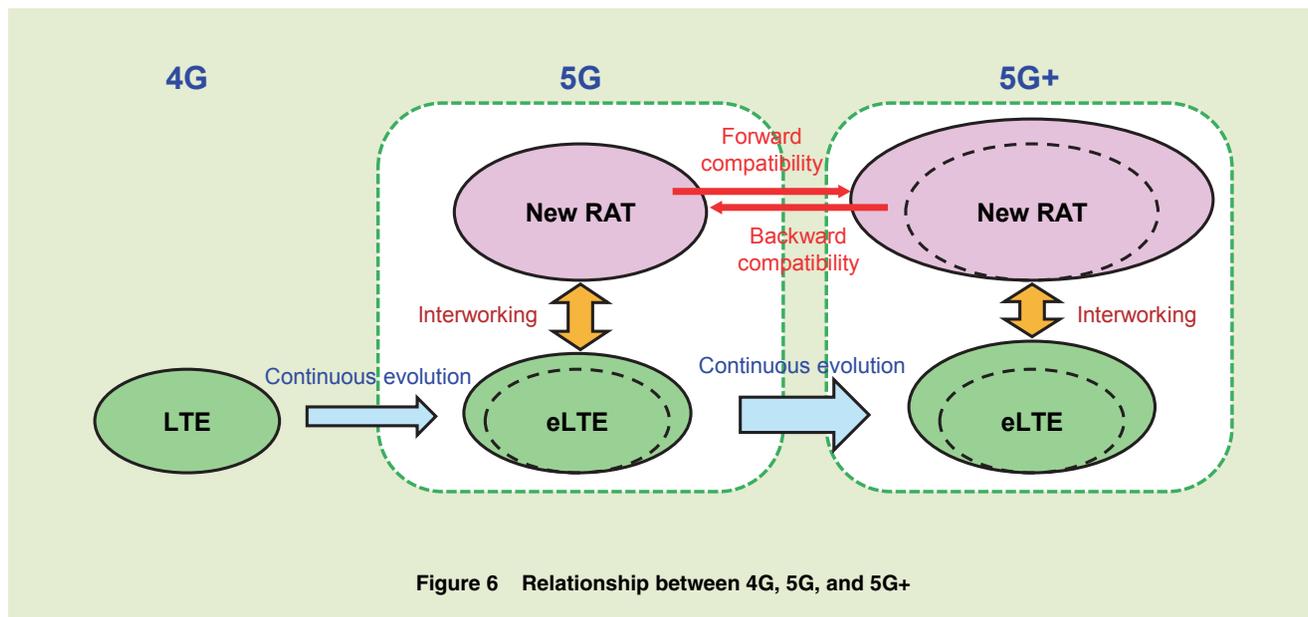


Figure 6 Relationship between 4G, 5G, and 5G+

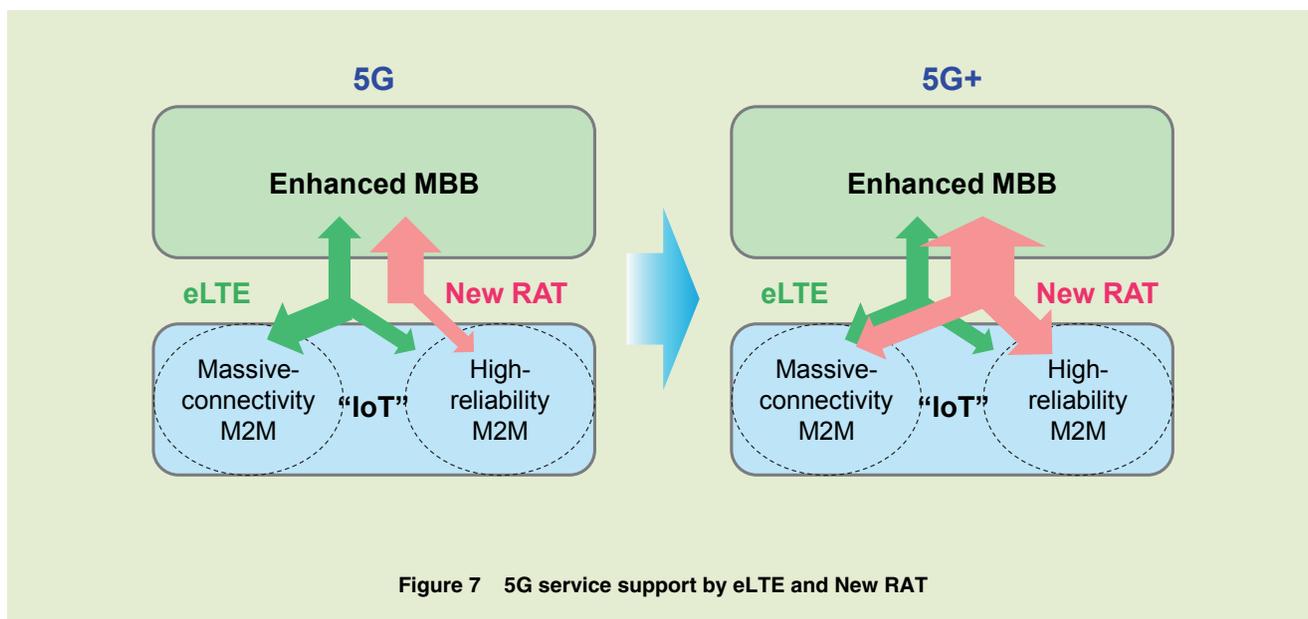


Figure 7 5G service support by eLTE and New RAT

the same time, eLTE, which provides full coverage, will supplement the above by supporting a variety of IoT-related functions such as those that support low-cost M2M terminals and M2M communications requiring high reliability. Then, in the future 5G+ period, we can expect New RAT itself to incorporate many functions and to progressively support a variety of services and scenarios including 5G services that are still unknown. In short, NTT DOCOMO considers that 5G services in 2020 will be achieved by combining eLTE and New RAT technologies. Candidates for radio access

technologies targeting initial introduction of 5G in 2020 are shown in **Figure 8**. These technologies are described in other special articles in this issue.

4.2 Overview of 3GPP Workshop on 5G

A “3GPP Workshop on 5G” was held in September 2015 marking the beginning of 5G standardization at 3GPP. A typical scene at this workshop is shown in **Photo 1**. The workshop featured ten presentations from external organizations (such as the 5G Mobile Communica-

tions Promotion Forum (5GMF)), 54 presentations from individual companies, and three joint presentations each from a group of companies, all of which produced lively discussions and Q&A sessions. More than 450 delegates attended the workshop with each company expressing great interest in 5G.

With the aim of completing the standards and specifications necessary for 2020 deployment of 5G services, NTT DOCOMO proposed to 3GPP a stepwise approach to 5G standardization as laid out in joint and independent contributions [6][7]. A general consensus

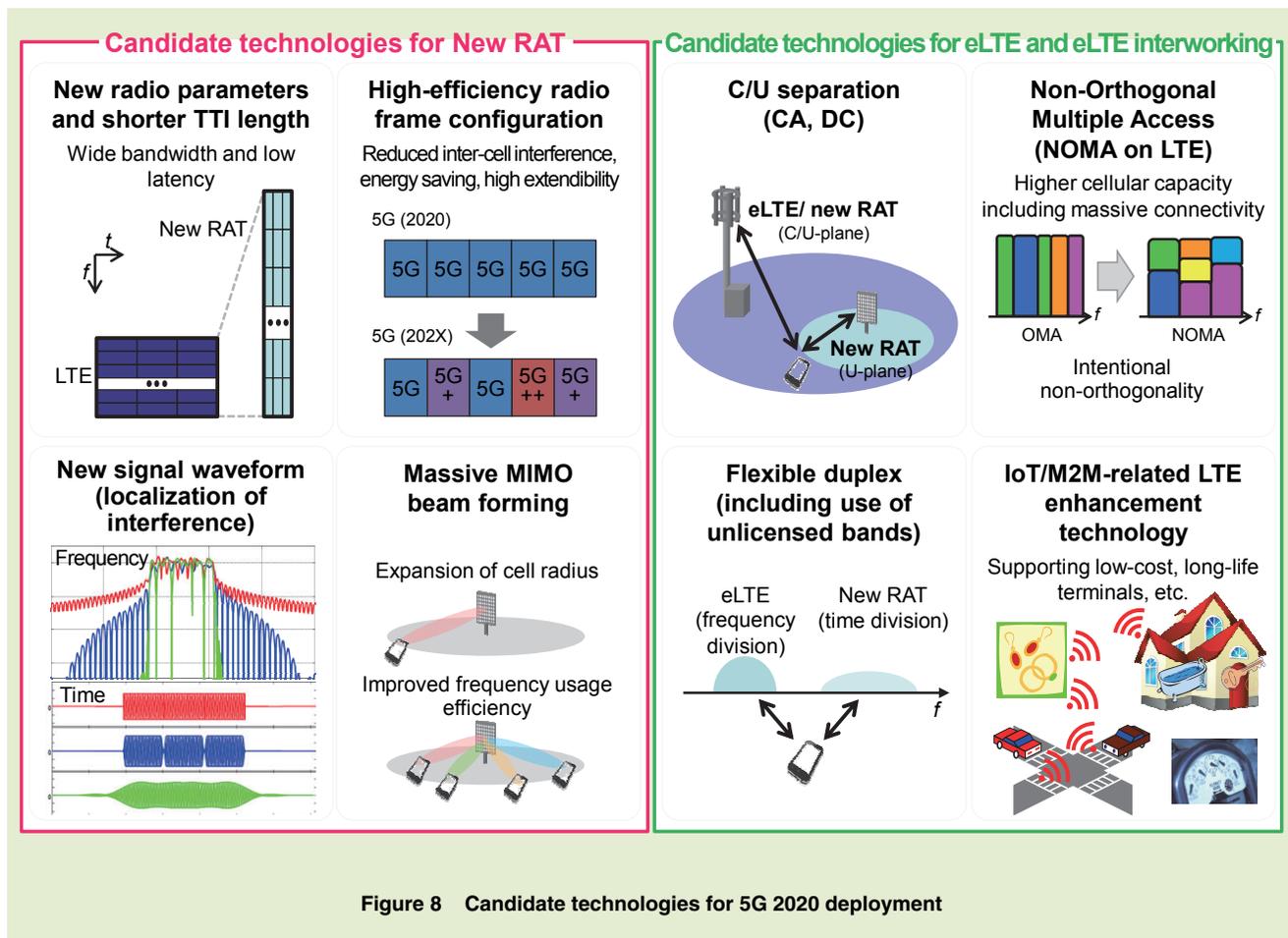


Figure 8 Candidate technologies for 5G 2020 deployment

was obtained in discussions held on this stepwise approach, but companies expressed a variety of opinions on the actual technologies to be emphasized in each step of standardization, so the plan is to hold more discussions going forward. According to the 3GPP Radio Access Network (RAN) chairman, pol-

icies (plans) regarding the standardization schedule can be summarized as follows [8].

- Begin Study Item (SI) on channel modeling in September 2015 (discuss status of high frequency bands up to December 2015 and begin study in RAN WG1

in first quarter of 2016)

- Begin SI on 5G requirements and scenarios in December 2015
- Begin SI on technology solutions in March 2016 (form a consensus prior to beginning the SI on what priority to assign to functions and topics of discussion in stepwise standardization)
- Complete Phase 1 specifications (Release 15) for New RAT by September 2018
- Complete Phase 2 specifications (Release 16) for New RAT by December 2019



Photo 1 3GPP workshop scene

The tentative schedule for 5G and 5G+ is shown in **Figure 9**. The plan here is to introduce 5G including Phase 1 specifications for New RAT in 2020.

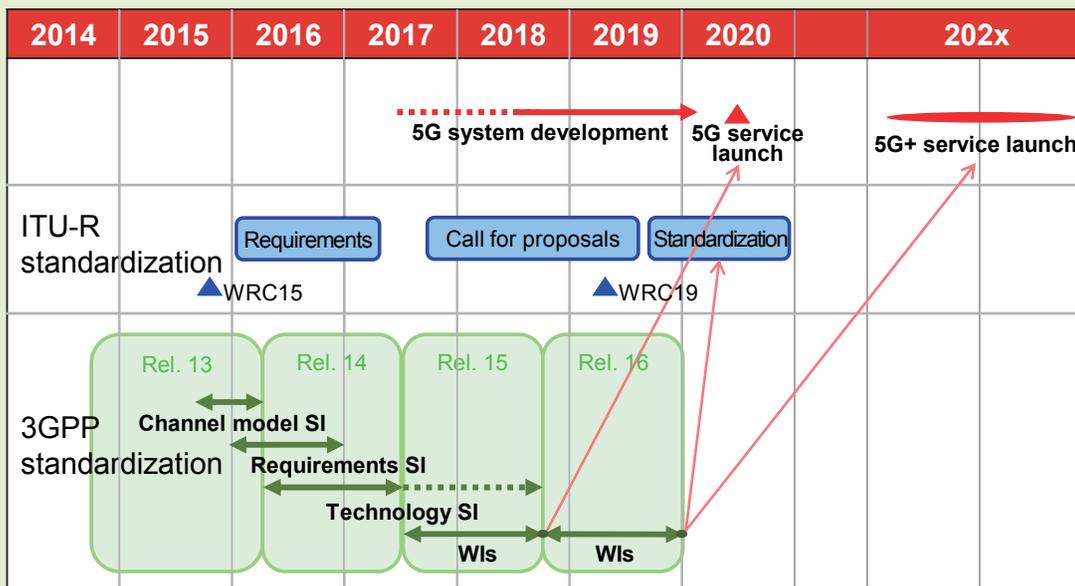


Figure 9 Standardization schedule (tentative)

Phase 2 specifications, meanwhile, will satisfy ITU-R requirements and will be rolled out as 5G+ several years later.

5. Overview of 5G-related Activities

5.1 International and Domestic 5G Activities

5G studies have been gaining momentum throughout the world for several years at international organizations and 5G study groups in various countries and regions, as summarized below.

- ITU-R

At ITU-R, Working Party 5D (WP 5D) is working on IMT-2020, which is the name given to the future IMT system corresponding to 5G. This work aims to extract the main capabilities that need to be achieved and summarize their quantitative values. The plan here is to begin detailed studies on requirements at the February 2016 meeting and to complete specifications sometime in 2020.

- NGMN

NGMN, an alliance of world-leading telecom carriers, released a white paper in March 2015 on use cases, requirements, and technology candidates toward 5G [2].

- European projects

A variety of 5G study projects have been completed or are underway in Europe under the 7th Framework Programme (FP7). These include METIS, a collaborative pro-

ject between industry and academia begun in November 2012, 5th Generation Non-Orthogonal Waveforms for Asynchronous Signaling (5GNow), Beyond 2020 Heterogeneous Wireless Networks with Millimeter-Wave Small Cell Access and Backhauling (MiWaveS), and Interworking and JOINT Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks (iJOIN). METIS, in particular, released more than 30 deliverables before its project completion in April 2015 thereby contributing to the formation of 5G concepts in the research community. In addition to the above, the European Commission^{*15} announced its Horizon 2020 program as a framework for promoting R&D and innovation in Europe. This program is being publically funded with nearly 80 billion euros over a seven-year period beginning in 2014. As part of this program, the 5G Public Private Partnership (5G-PPP) was established in December 2013 as an institution for coordinating 5G-related projects.

- Asian projects

In Asia as well, 5G studies are progressing as 5G-related projects. In China, two organizations, the IMT-2020 (5G) Promotion Group and FuTURE Mobile Communication Forum have been established and the 863 Program and other 5G projects have been launched as national pro-

jects. In the Republic of Korea, the 5G Forum has been established as a collaborative effort among industry, academia, and government. It released a 5G white paper in March 2015.

- Activities in Japan

As 5G studies gain momentum throughout the world, Japan has been preparing its vision for mobile communications and technologies in the 2020s. It has initiated 5G promotional activities both inside and outside Japan by contributing to ITU-R WP5D and collaborating with 5G study groups in various countries and regions. Activities have been particularly active among industry, academia, and government toward a 2020 deployment of a 5G mobile communications system in conjunction with the 2020 Summer Olympics and Paralympics in Tokyo. In September 2013, the 2020 and Beyond Ad Hoc (20B AH) group was established under the Advanced Wireless Communications Study Committee of the Association of Radio Industries and Business (ARIB)^{*16}. This group has released a white paper summarizing the results of its studies [9]. In addition, 5GMF was established in September 2014 under the leadership of the Ministry of Internal Affairs and Communications (MIC) to promote studies in radio access technologies, network technologies, and 5G applications [10].

^{*15} **European Commission:** The executive body of the European Union. It submits bills, implements decisions, upholds treaties, and otherwise carries out the day-to-day operations of the European Union.

^{*16} **ARIB:** An organization subordinate to the MIC that sets standards for systems that use the radio spectrum in the fields of communications and broadcasting in Japan.

5GMF plans to hold integrated trials beginning in 2017.

5.2 Activities at NTT DOCOMO

NTT DOCOMO has been conducting studies on 5G since 2010, the year in which it launched LTE commercial services, and has been participating actively in some of the 5G-related projects described above. It has also been developing a real-time simulator since 2012 to evaluate the capacity-enhancement effects of candidate technologies in the 5G system, which should also help visualize NTT DOCOMO’s 5G technical

concept. As shown in **Figure 10**, the combination of 5G RAT, band enhancement, and small cell*17 technology in a model simulating an actual Tokyo urban environment was able to increase capacity by more than 1000 times compared with an LTE macro cell*18 environment. NTT DOCOMO received the Minister of Internal Affairs and Communications Award at CEATEC Japan*19 2013 for an exhibition presenting this study.

Additionally, NTT DOCOMO achieved a bit rate of 10 Gbps as a world’s first in an outdoor mobile environment as part of a 5G transmission experiment

conducted jointly with Tokyo Institute of Technology in December 2012 [11]. It has also been conducting 5G experiments through separate collaborations with major vendors in the world since 2013. All in all, it has concluded agreements on collaborative experiments with a total of 13 companies as of November 2015 [12]. At the same time, NTT DOCOMO has been conducting its own experiments including the evaluation of indoor/outdoor transmission using NOMA technology [4] and the measurement of radio propagation in high frequency bands [13], this in ad-

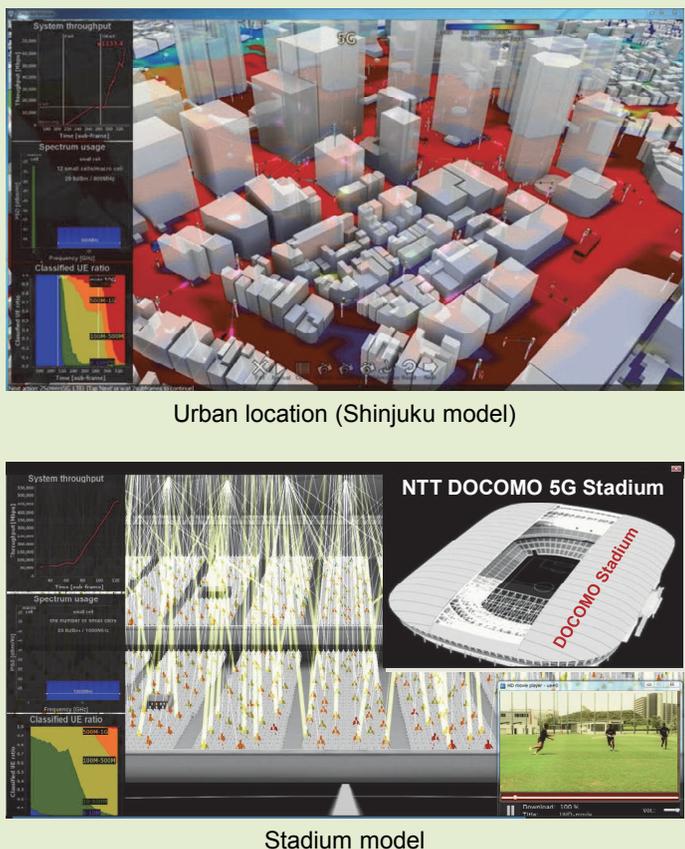


Figure 10 Screenshots of demonstration by 5G simulator

*17 **Small cell**: General term for a cell covering a small area compared with a macro cell and having low transmission power.
 *18 **Macro cell**: A cellular communication area with a radius of from several hundred meters to several tens of kilometers used mainly to provide

outdoor communications. Macro cell antennas are usually installed on towers or roofs of buildings.
 *19 **CEATEC Japan**: The largest international exhibition of imaging, information, and communications technologies in Asia.

dition to studying the core network in the 5G era [14]. These activities are introduced in more detail in other special articles in this issue.

6. Conclusion

This article focused on the 5G next-generation mobile communications system that is slated to provide a variety of new services including enhanced MBB for higher speeds and greater capacity and IoT connecting all kinds of things to the network by wireless means. It described research and development activities at NTT DOCOMO and world trends toward 5G. At NTT DOCOMO, we will continue to conduct transmission experiments and promote 5G standardization activities (scheduled to intensify next year) with the aim of launching 5G services in 2020 and supporting the continuous enhancement of 5G (5G+) in the years to come.

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