Standardization

ITU-R IMT-2020 5G

Special Articles on 5G Standardization Trends Toward 2020

IMT-2020 Radio Interface Standardization Trends in ITU-R

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With international standardization of fifth-generation mobile communications systems (5G) in mind, ITU-R has set a new standard name called "IMT-2020," and begun work on IMT-2020 radio interface standardization. This article describes discussions leading up to this work and future plans.

1. Introduction

As shown in **Table 1**, The International Telecommunication Union-Radiocommunication sector (ITU-R)*1 has realized international radio interface standards (ITU-R Recommendations) in partnership with external organizations such as 3rd Generation Partnership Project (3GPP) for the International Mobile Telecommunications-2000 (IMT-2000), the 3rd generation mobile communications system,

Table 1 Mobile communications system standardization in ITU-R

Name	Positioning	Recommendation no., typical radio interfaces
IMT-2000	3rd generation mobile communications systems	Recommendation ITU-R M.1457 W-CDMA, HSPA, LTE, cdma2000, WiMAX etc.
IMT-Advanced	IMT-2000 successor systems	Recommendation ITU-R M.2012 LTE-Advanced, Wireless MAN-Advanced
IMT-2020	IMT-Advanced successor systems	(Recommendations will be formulated in 2020 with fifth-generation mobile communications systems (5G) standardization in mind)

*1 ITU-R: The Radiocommunication Sector of the ITU, which is an international organization in the telecommunications field. It conducts studies required to revise international regulations for radio communications and conducts research on radio communications technologies and operations.

and the IMT-Advanced system, the successor system of IMT-2000. In light of the rising global interest in fifth-generation mobile communications systems (5G) and advances in technical developments, ITU-R has defined IMT-2020*1 as a new standard name for the successor system for IMT-Advanced [1] and has begun work on international standardization of its radio interface. This article describes discussions to date and future plans in ITU-R Working Party 5D (WP 5D) overseeing detailed studies of this work.

2. Formulation of Vision Recommendation

Because 5G research and development has become active, ITU-R discussed a vision for mobile communications systems for 2020 and beyond. The results of these discussions are summarized in Recommendation ITU-R M.2083 published in September 2015 [2]. As shown in **Figure 1**, as typical usage scenarios for the IMT-2020 system, this recommendation summarizes (1) further mobile broadband advances (enhanced Mobile BroadBand (eMBB)), (2) machine-type communications enabling simultaneous multiple connections (massive Machine Type Communications (mMTC)), and (3) high-reliability, low-latency communications (Ultra-Reliable and Low Latency Communications (URLLC)). In addition, as shown in **Figure 2**, the key capabilities that IMT-2020 should have to enable these usage scenarios are shown as comparative improvements on IMT-Advanced. The key capabilities shown in this figure, such as the maximum data transmission rate (20 Gbps), multiple simultaneous connections (1,000,000 devices/km^2) and low latency (1 ms) are described in the IMT-2020 vision.

3. Schedule for IMT-2020 Radio Interface Standardization

With the completion of Recommendation ITU-R M.2083, ITU-R has developed a schedule for the

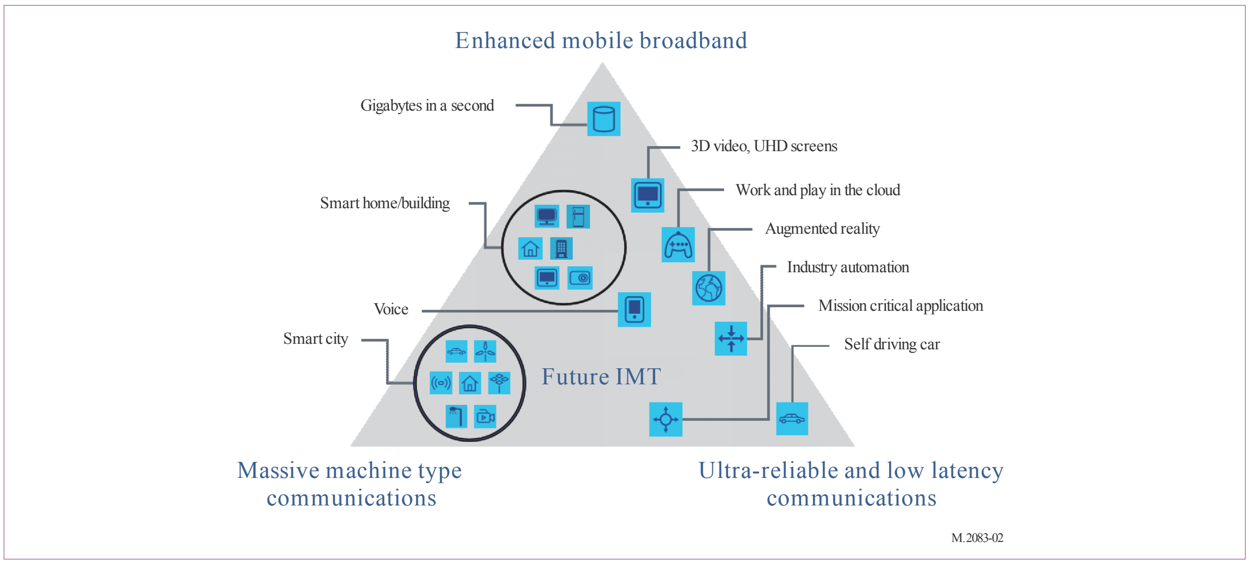

Figure 1 IMT-2020 typical usage scenarios (from Recommendation ITU-R M.2083, Figure 2)

*1 After discussions on IMT-Advanced, ITU-R has been avoiding the use of the name "Nth generation mobile communication system." However, ITU-R is working on the standardization of IMT-2020 radio interface with 5G international standardization in mind.

formulation of ITU-R Recommendations on the IMT-2020 radio interface to achieve the vision in M.2083, as shown in **Figure 3**. To formulate ITU-R Recommendations, it is agreed that studies should proceed in the following steps, as has been done in the past for the IMT-Advanced development.

(1) ITU-R to set requirements for the IMT-2020 radio interface, and solicit proposals from

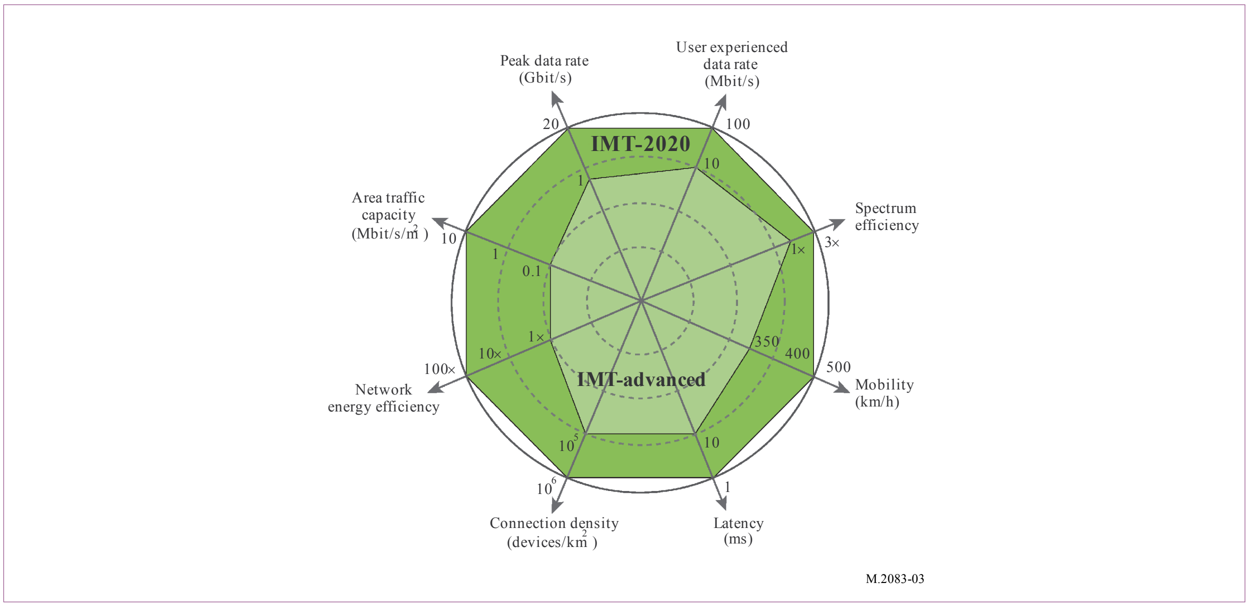

Figure 2 Capabilities that IMT-2020 should have (from Recommendation ITU-R M.2083, Figure 3)

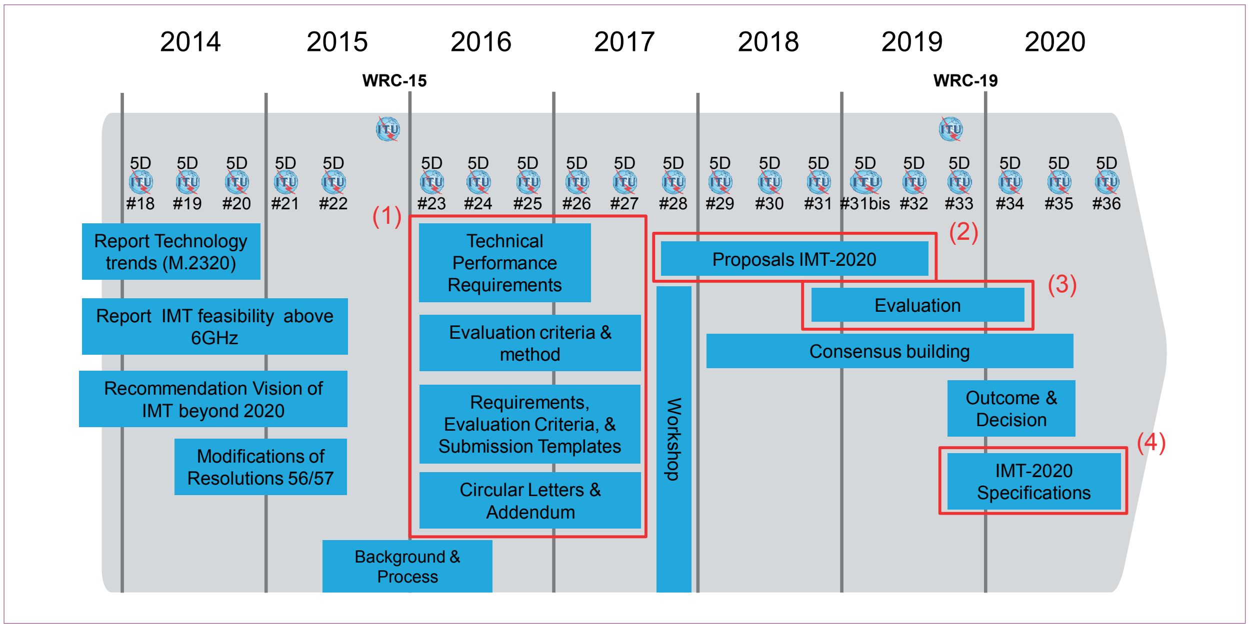

Figure 3 Work schedule for IMT-2020 radio interface developments (from ITU-R WP 5D Web site)

external organizations etc. (2016 to first half of 2017).

(2) External organizations etc. to make radio interface proposals to ITU-R. Proponents to submit self-evaluated results indicating that the details of their proposals satisfy the ITU-R requirements (second half of 2017 to first half of 2019).

(3) Based on proposal details and self-evaluated results information, external evaluation bodies registered in ITU-R are to conduct evaluations of whether the proposals satisfy the ITU-R requirements (second half of 2018 to first half of 2020).

(4) Agreement to be reached on recommendations for the radio interface in ITU-R in view of the evaluation results conducted by external evaluation bodies etc., and specific recommendation documents to be created (second half of 2019 to second half of 2020).

Accordingly, ITU-R plans to accept proposals from external organizations from October 2017 to June 2019. ITU-R Recommendations will be completed in the second half of 2020.

4. Documentation for IMT-2020 Radio Interface Standardization

ITU-R WP 5D has created three new ITU-R reports prescribing IMT-2020 radio interface requirements*2. External organizations and so forth making proposals to ITU-R must make their proposals in accordance with the contents of these ITU-R reports. In addition, documentation prescribing the details of the IMT-2020 radio interface proposal and the evaluation process has also been created.

4.1 Report ITU-R M. [IMT-2020. SUBMISSION]

This ITU-R report prescribes requirements for IMT-2020 radio interface proposals and templates for submitting proposals [3].

Firstly, multiple supports for the usage scenarios (eMBB, mMTC and URLLC) indicated in Recommendation ITU-R M.2083 are required as service requirements.

Also, as spectrum requirements, (1) usage of at least one frequency band identified for IMT in the ITU Radio Regulations must be supported, and (2) usage of frequency bands at or above 24.25 GHz must be supported. The latter of these requirements was formulated in view of the characteristics newly introduced in 5G.

In addition, technical performance requirements have also been prescribed, the details of which will be available by referring to Report ITU-R M. [IMT-2020. TECH PERF REQ] described in the next section.

4.2 Report ITU-R M. [IMT-2020. TECH PERF REQ]

This ITU-R report defines 13 items of technical performance requirements for the IMT-2020 radio interface and prescribes their required values [4]. Details are shown in **Table 2**. For example, with eMBB, the IMT-2020 spectral efficiency*2 requirement is approximately three times the required value for IMT-Advanced. In addition, for mMTC and URLLC, requirements are set for connection density, latency and reliability. Also, for a number

*2 These new reports were approved by Study Group 5 in November 2017, and will be published soon.

*2 Spectral efficiency: The number of data bits that can be transmitted per unit time and unit frequency band.

Table 2 IMT-2020 radio interface technical performance requirements, required values and evaluation methodology

	Requirement \ Test environment		Indoor Hotspot-eMBB	Dense Urban-eMBB	Rural-eMBB	Urban Macro-mMTC	Urban Macro-URLLC	Evaluation methodology
1	Peak data rate		Downlink: 20 Gbps, Uplink: 10 Gbps			–	–	Analytical
2	Peak spectral efficiency		Downlink: 30 bps/Hz, Uplink: 15 bps/Hz			–	–	Analytical
3	User experienced data rate		–	Downlink: 100 Mbps Uplink: 50 Mbps	–	–	–	Analytical for single band and single layer cell layout Simulation for multi-layer cell layout
4	5^{th} percentile user spectral efficiency		Downlink: 0.3 bps/Hz Uplink: 0.21 bps/Hz	Downlink: 0.225 bps/Hz Uplink: 0.15 bps/Hz	Downlink: 0.12 bps/Hz Uplink: 0.445 bps/Hz	–	–	Simulation
5	Average spectral efficiency		Downlink: 9 bps/Hz Uplink: 6.75 bps/Hz	Downlink: 7.8 bps/Hz Uplink: 5.4 bps/Hz	Downlink: 3.3 bps/Hz Uplink: 1.6 bps/Hz	–	–	Simulation
6	Area traffic capacity		10 Mbps/m^2	–	–	–	–	Analytical
7	Latency	User plane	4 ms			–	1 ms	Analytical
		Control plane	20 ms			–	20 ms	Analytical
8	Connection density		–	–	–	1,000,000 device/km^2	–	Simulation
9	Energy efficiency		Shall have the capability to support a high sleep ratio and long sleep duration.			–	–	Inspection
10	Reliability		–	–	–	–	$1-10^{-5}$ success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1 ms	Simulation
11	Mobility		Normalized traffic channel link data rates of 1.5 bps/Hz at 10 km/h in the uplink	Normalized traffic channel link data rates of 1.12 bps/Hz at 30 km/h in the uplink	Normalized traffic channel link data rates of 0.8 and 0.45 bps/Hz at 120 and 500 km/h, respectively, in the uplink	–	–	Simulation
12	Mobility interruption time		0 ms			–	0 ms	Analytical
13	Bandwidth		At least 100 MHz Shall support bandwidths up to 1 GHz for operation in higher frequency bands (e.g. above 6 GHz).					Inspection

of technical performance requirements, requirements and required values have been set for test environments (described later), as shown in the table.

3GPP have also defined requirements and target values prior to their studies on 5G radio interface specifications. Technical performance requirements defined by ITU-R are similar to their equivalent 3GPP requirements. However, ITU-R technical performance requirements [5] include items not in the 3GPP requirements (e.g., bandwidth to be supported).

4.3 Report ITU-R M. [IMT-2020. EVAL]

This ITU-R report prescribes details of evaluation methodology, test environments, and evaluation configurations, and the configurations of channel models used for evaluation for IMT-2020 radio interface requirements [6].

1) Evaluation Methodology, Test Environment and Evaluation Configurations

As shown in the right column of Table 2, there are three methods defined for evaluation methodologies for each requirement - inspection, analytical, and simulation. Also, to evaluate specified requirements, the following five test environments have been defined in consideration of the three typical usage scenarios (eMBB, mMTC, URLLC) described in Recommendation ITU-R M.2083.

- Indoor Hotspot-eMBB: Indoor environments assumed for eMBB usage scenarios
- Dense Urban-eMBB: Dense urban environments assumed for eMBB usage scenarios
- Rural-eMBB: Rural environments assumed for eMBB usage scenarios
- Urban Macro-mMTC: Urban environments assumed for mMTC usage scenarios
- Urban Macro-URLLC: Urban environments assumed for URLLC usage scenarios

Furthermore, one or more evaluation configurations, in other words, sets of evaluation parameters are defined for each of these test environments, as shown in **Tables 3** and **4**. For a proposed radio interface to be judged as having satisfied

Table 3 Evaluation configurations for eMBB test environments

Parameters	Indoor Hotspot-eMBB			Dense Urban-eMBB			Rural-eMBB		
	Spectral efficiency, mobility and area traffic capacity evaluations			Spectral efficiency and mobility evaluations		User experienced data rate evaluation	Spectral efficiency and mobility evaluations		Average spectral efficiency evaluation
	A	B	C	A	B	C	A	B	C
Carrier frequency for evaluation	4 GHz	30 GHz	70 GHz	4 GHz (Macro layer only)	30 GHz (Macro layer only)	4 GHz & 30 GHz (Macro + Micro layers)	700 MHz	4 GHz	700 MHz
Base station (BS) antenna height	3 m	3 m	3 m	25 m	25 m	25 m for Macro BSs and 10 m for Micro BSs	35 m	35 m	35 m
Inter-BS distance	20 m	20 m	20 m	200 m	200 m	200 m (Macro layer)	1,732 m	1,732 m	6,000 m
Number of antenna elements at BS	Up to 256 Tx/Rx	Up to 256 Tx/Rx	Up to 1024 Tx/Rx	Up to 256 Tx/Rx	Up to 256 Tx/Rx	Up to 256 Tx/Rx	Up to 64 Tx/Rx	Up to 256 Tx/Rx	Up to 64 Tx/Rx
Number of antenna elements at user terminal	Up to 8 Tx/Rx	Up to 32 Tx/Rx	Up to 64 Tx/Rx	Up to 8 Tx/Rx	Up to 32 Tx/Rx	4 GHz: Up to 8 Tx/Rx 30 GHz: Up to 32 Tx/Rx	Up to 4 Tx/Rx	Up to 8 Tx/Rx	Up to 4 Tx/Rx
User deployment	100% indoor 3 km/h	100% indoor 3 km/h	100% indoor 3 km/h	80% indoor 3 km/h, 20% outdoor (in-car) 30 km/h	80% indoor 3 km/h, 20% outdoor (in-car) 30 km/h	80% indoor 3 km/h, 20% outdoor (in-car) 30 km/h	50% indoor 3 km/h, 50% outdoor (in-car) 120 km/h, 500 km/h for mobility evaluation	50% indoor 3 km/h, 50% outdoor (in-car) 120 km/h, 500 km/h for mobility evaluation	40% indoor 3 km/h, 40% outdoor 3 km/h, 20% outdoor (in-car) 30 km/h

requirements for a particular test environment, requirements must be satisfied in at least one evaluation configuration under that test environment. The definition of multiple evaluation configurations under each test environment is due to the various frequency bands, deployment scenarios and usage scenes to be supported in IMT-2020, and is the result of the wide range of views submitted to ITU-R WP 5D.

2) Overview of Channel Models*3

Figure 4 describes channel model configurations used for a simulation-based evaluation method. The

Table 4 Evaluation configurations for mMTC and URLLC test environments

Parameters	Urban Macro-mMTC		Urban Macro-URLLC	
	Connection density evaluation		Reliability evaluation	
	A	B	A	B
Carrier frequency for evaluation	700 MHz	700 MHz	700 MHz	4 GHz
Base station (BS) antenna height	25 m	25 m	25 m	25 m
Inter-BS distance	500 m	1,732 m	500 m	500 m
Number of antenna elements at BS	Up to 64 Tx/Rx	Up to 64 Tx/Rx	Up to 64 Tx/Rx	Up to 256 Tx/Rx
Number of antenna elements at user terminal	Up to 2 Tx/Rx	Up to 2 Tx/Rx	Up to 4 Tx/Rx	Up to 8 Tx/Rx
User deployment	80% indoor 3 km/h, 20% outdoor 3 km/h	80% indoor 3 km/h, 20% outdoor 3 km/h	20% indoor 3 km/h, 80% outdoor 30 km/h	20% indoor 3 km/h, 80% outdoor 30 km/h

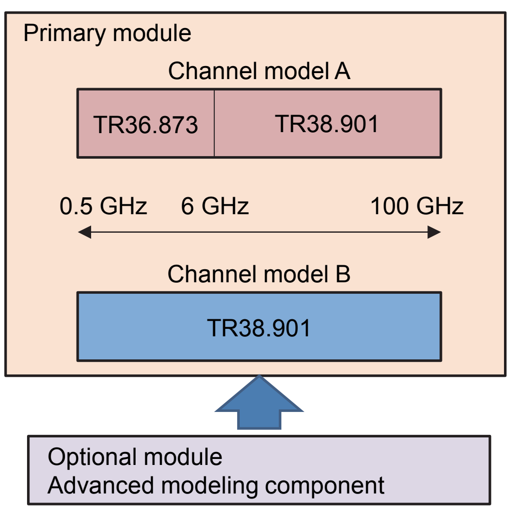

Figure 4 Channel model configurations

*3 Channel model: A model simulating the behavior of radio waves, used for evaluating the performance of radio communications systems.

basic system simulation model is called the "primary module," and consists of a path loss model, (Line Of Sight) LOS probability model and fast fading model. The unification of the primary module in one model was vigorously discussed in ITU-R WP 5D, although finally two models, channel model A and B, were prescribed. For channel A, the 0.5 to 6 GHz model described in 3GPP TR36.873 [7] and the 6 to 100 GHz model described in TR38.901 [8] newly prescribed by 3GPP for evaluating 5G have been adopted. For channel B, the model described in TR38.901 was adopted for the entire 0.5 to 100 GHz frequency range. Both channels A and B have models defined for indoor hotspots*4 (InH_x), urban macrocells*5 (UMa_x), urban microcells*6 (UMi_x) and rural macrocells (RMa_x), and enable evaluation in the aforementioned test environments. When proponents of radio interfaces perform self-evaluation with simulations, they have to perform the evaluation by selecting the same channel model, A or B, for all their evaluated test environments.

Additionally, a range of new technologies are anticipated for application with IMT-2020 such as Massive Multiple Input Multiple Output (Massive MIMO)*7, Multiuser MIMO*8, and to evaluate these technologies, an optional model called "advanced modeling component" has been prescribed. This has been created based on the additional modeling component prescribed in TR38.901.

4.4 Document IMT-2020/2 (Rev.1)

This documentation prescribes details of the IMT-2020 radio interface proposal and evaluation process [9].

The document assumes two cases – the case when proposals are received and finally included in recommendations as single Radio Interface Technologies (RIT) and the case when proposals are received and finally included in recommendations as combined Sets of Radio Interface Technologies (SRIT).

Moreover, this document prescribes specific requirements that must be satisfied in all of the aforementioned five test environments as requirements for recommendations as IMT-2020 radio interface technologies.

5. Conclusion

This article has described standardization trends for IMT-2020 radio interfaces ongoing in ITU-R in view of the rising global interest in 5G, and advances in related technical developments. To date, requirements and so forth necessary for IMT-2020 have been agreed upon, and ITU-R has moved to a stage of acceptance of specific proposals from external organizations going forward.

As a member of the Japan delegation, proactively contributing to the activities of ITU-R WP 5D, NTT DOCOMO intends to continue to be active in ITU-R while coordinating with 3GPP studies.

REFERENCES

[1] Resolution ITU-R 56-2: "Naming for International Mobile Telecommunications," Nov. 2015.

[2] Recommendation ITU-R M.2083-0: "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond," Sep. 2015.

[3] Draft new report ITU-R M. [IMT-2020.SUBMISSION]: "Requirements, evaluation criteria and submission templates for the development of IMT-2020," Jun. 2017.

[4] Draft new report ITU-R M. [IMT-2020.TECH PERF REQ]: "Minimum requirements related to technical performance for IMT-2020 radio interface(s)," Feb. 2017.

*4 Hotspot: A place where communications traffic is concentrated such as a plaza or square in front of a train station.

*5 Macrocell: In mobile communications systems, a cell is an area covered by a single base station antenna. A macrocell is a relatively large area with radius of 500 m or more.

*6 Microcell: A communications area of radius from several tens to several hundreds of meters, covered by a single base station.

[5] A. Benjebbour et al.: “3GPP Defined 5G Requirements and Evaluation Conditions,” NTT DOCOMO Technical Journal, Vol.19, No.3, pp.13–23, Jan. 2018.

[6] Draft new report ITU-R M. [IMT-2020.EVAL]: “Guidelines for evaluation of radio interface technologies for IMT-2020,” Jun. 2017.

[7] 3GPP TR36.873 V12.4.0: “Study on 3D channel model for LTE (Release 12),” Mar. 2017.

[8] 3GPP TR38.901 V14.0.0: “Study on channel model for frequencies from 0.5 to 100 GHz (Release 14),” Mar. 2017.

[9] Document ITU-R IMT-2020/2 (Rev.1): “Submission, evaluation process and consensus building for IMT-2020,” Feb. 2017.

*7 Massive MIMO: In MIMO systems that transmit radio signals overlapping in space by using multiple antenna elements for transmission and reception, these Massive MIMO systems aim to achieve high-speed data communications with greater numbers of simultaneous streaming transmissions while securing service areas by using antenna elements consisting of super multi-element arrays to create sharply formed radio beams to compensate for the radio propagation losses that accompany high-frequency band usage.

*8 Multiuser MIMO: A technology that improves spectral efficiency by using MIMO technologies to simultaneously transmit (multiplex) signals for multiple users.