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Special Articles on 5G Standardization Trends Toward 2020

5G Standardization Trends at 3GPP

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NTT DOCOMO is conducting a variety of technical studies and joint experiments with the aim of launching the fifth-generation mobile communications system (5G) in 2020. The 3rd Generation Partnership Project (3GPP), the international body that formulates international standards and specifications for 5G, has been promoting studies since 2015 on 5G service requirements and component technologies for radio access and the core network. This article describes the overall 5G standardization schedule, 5G requirements and use cases, features of 5G radio and the core network for achieving those requirements, and deployment scenarios.

1. Introduction

The 3rd Generation Partnership Project (3GPP), the international body that formulates standards for mobile communications systems, is moving forward with studies on the fifth-generation mobile communications system (5G).

In addition to high data rates and large capacity as taken up in LTE and LTE-Advanced, new requirements and required values for 5G are being studied from a variety of perspectives such as low latency and high reliability, diverse terminal connectivity, and diverse industry support. Specific use cases applying 5G can be envisioned, such as Virtual Reality (VR)*1, advancement and automation of industry through a massive number of Internet

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*1 VR: Technology that creates a virtual space using computer graphics on a PC or other computer.

of Things (IoT) devices, and wireless communications for vehicles known as Vehicle-to-Everything (V2X)*2 as in autonomous driving.

In this article, we introduce the 5G standardization schedule centered about 3GPP and describe 5G requirements and use cases at 3GPP, the features of 5G radio and the core network*3 for achieving those requirements, and deployment scenarios.

2. 5G Standardization Schedule

2.1 ITU-R

The International Telecommunication Union Radiocommunication Sector (ITU-R)*4 began preparing 5G technology performance requirements in 2016 and will be accepting proposals for a radio interface satisfying those requirements from 2017 to 2019. Then, on the basis of these radio-interface proposals, the plan is to prepare ITU-R Recommendations for the radio interface from 2019 to 2020. We note here 5G standardization trends at ITU-R are described in more detail elsewhere in these Special Articles [1].

2.2 3GPP

At 3GPP, the plan is to proceed alongside the ITU-R schedule and formulate 5G standards in a stepwise manner through multiple Releases up to the end of 2019. Studies for Release 14 were conducted from 2016 to the beginning of 2017. These included a basic study or Study Item (SI)*5 on a new 5G-specific radio communication system called New Radio (NR) having no backward compatibility with the existing LTE and LTE-Advanced systems and a study and evaluation of candidate component technologies. Next, Release 15, which is scheduled for completion by the middle of 2018, will include a detailed specifications study or Work Item (WI)*6 and formulation of the initial 5G standard called Phase 1. In addition, the plan for Release 15 is to complete basic specifications for Non-Standalone*7 operation combining LTE and NR by December 2017 and basic specifications for Standalone*8 operation based only on NR by June 2018. The assumption here is that Release 15 specifications will enable countries around the world to proceed with 5G deployment.

Continuing on, the plan for Release 16 scheduled for completion by the end of 2019 is to continue with a detailed specifications study and to prepare the second version (Phase 2) of the 5G standard.

At 3GPP, the systematic submission of radio interface proposals to ITU-R based on these stepwise specifications studies is being studied.

3. Main Requirements for 5G

In addition to high data rates and large capacity as required of existing mobile communications technologies, 5G requirements have been studied at 3GPP taking into account the creation of new markets. The following describes main use cases and requirements studied with 5G in mind.

3.1 5G Use Cases

At 3GPP, main 5G features consist of enhanced Mobile BroadBand (eMBB), massive Machine Type Communications (mMTC), and Ultra-Reliable and Low Latency Communications (URLLC). At ITU-R, these three features are taken to be key usage scenarios of the IMT-2020 system [1]. Moreover, in

*2 V2X: Generic name for vehicle-to-vehicle and vehicle-to-infrastructure communications.

*3 Core network: A network consisting of switches and subscriber-information management equipment. Mobile terminals communicate with the core network via the radio access network.

*4 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 technology and operation.

keeping with these 5G usage scenarios, use cases are also being established at the service level. For example, use cases for which reduced latency is a requirement as in telemedicine and autonomous driving have been newly specified for 5G. A total of 74 use cases including the above and requirements for each use case are summarized in 3GPP Technical Report (TR) 22.891 [2]. These use cases can be grouped into the five categories listed in **Table 1**.

3.2 5G Requirements

1) Radio Access Technology Requirements for Each Usage Scenario

Main requirements for 5G radio access technology (5G NR) for each usage scenario have been determined at 3GPP as listed in **Table 2** [3]. For eMBB, the peak data rate has been set to 20 Gbps and 10 Gbps in the downlink and uplink, respectively as target values. Furthermore, in comparison with LTE-Advanced, the goal here is to achieve a three-fold gain in spectrum efficiency*9, higher mobility speeds, and low-latency radio transmission. Next, for mMTC, the distance from the base station at which a data rate of 160 bps can be provided on the uplink is taken to be the cell radius, which can be defined in terms of propagation losses*10 according to distance from the base station (maximum coupling loss*11 of 164 dB). Other targets include a battery life beyond 10 years and a radio system that can accommodate an even greater number of devices. Finally, for URLLC, a very low latency of 0.5 ms (one-way radio transmission delay) has been set as a target value.

Table 1 Requirements and main use cases grouped by category

Category	Related specifications	Requirements	Main use cases
eMBB	TR22.863 TS22.261	High data rate, high traffic density, diverse coverage, high user mobility	Indoor, hotspots, wide area
CriC	TR22.862 TS22.261	High reliability and low latency, high reliability, high availability, and low latency, very low latency, high accuracy positioning	Virtual presence, tactile Internet, remote control, telemedicine, remote first-aid, drone control
MIoT	TR22.861 TS22.261	Improved operation, diversified connectivity, and improved resource-usage efficiency in relation to IoT	Improved IoT device initialization, large-capacity support, wearable device communication, bio-connectivity, wide area monitoring
NEO	TR22.864 TS22.261	System flexibility, scalability, mobility, efficient content delivery, and improved security, plus diverse backhaul/access considerations and migration/interworking considerations	*Common system requirements independent of services
eV2X	TR22.886 TS22.186	High data rate, high reliability, high availability and low latency, wide area coverage	Autonomous driving, convoy driving, remote driving

CriC: Critical Communications
MIoT: Massive IoT
TS: Technical Specification
eV2X: enhanced V2X
NEO: NEtwork Operation

*5 SI: The work of "studying feasibility and broadly identifying functions that should become specifications."

*6 WI: The work of "deciding the functions that should become specifications and preparing detailed specifications for those functions."

*7 Non-Standalone: An operation format in which terminals connect to a mobile communications network via multiple radio technologies.

*8 Standalone: An operation format in which terminals connect to a mobile communications network via a single radio technology.

Table 2 5G NR main requirements

Use-cases	Key performance indicator	NR DL	NR UL	LTE-Advanced DL	LTE-Advanced UL	LTE (Release 8) DL	LTE (Release 8) UL
eMBB	Peak data rate	20 Gbps	10 Gbps	1 Gbps	500 Mbps	100 Mbps	50 Mbps
	Peak spectral efficiency	30 bps/Hz	15 bps/Hz	30 bps/Hz	15 bps/Hz	3~4 ×HSDPA (Release 6)	2~3 ×HSUPA (Release 6)
	C-plane latency	10 ms		Less than 50 ms		Less than 100 ms	
	U-plane latency	4 ms		Reduced U-plane latency compared to Release 8		Less than 5 ms	
	Cell/TRxP spectral efficiency (bps/Hz/TRxP)	3 times higher than LTE-Advanced		—		—	
	Area traffic capacity(bps/m^2)	3 times higher than LTE-Advanced		—		—	
	User experienced data rate (bps)	3 times higher than LTE-Advanced		—		—	
	5% user spectrum efficiency (bps/Hz/user)	3 times higher than LTE-Advanced		Cell edge user throughput (bps/Hz/cell/user)		User throughput	
				0.12 (2×2 ANT)	0.04 (1×2 ANT)	2~3 ×HSDPA	2~3 ×HSUPA
	Target mobility speed (relates also to URLLC, mMTC)	500 km/h		350 km/h		350 km/h	
	Mobility interruption time (relates also to URLLC, mMTC)	0 ms		—		—	
mMTC	Coverage	Max coupling loss 164 dB		Max coupling loss 164 dB (NB1)		—	
	UE battery life	Beyond 10 years		Up to 10 years		—	
	Connection density	1,000,000 devices/km^2		60,680 devices/km^2		—	
URLLC	U-plane latency	0.5 ms		—		—	
	Reliability	10^{-5} for 32 bytes with U-plane latency of 1 ms		—		—	

2) Overall Performance Requirements for the 5G System

Performance requirements for the system on the whole including 5G NR and the core network have been specified for different use cases [4]. These requirements include data rate, latency, reliability, traffic density, and connection density. For example, the experienced data rate on the downlink has been set to 1 Gbps, but very high requirements have been set for end-to-end latency such as 10 ms for intelligent transport systems as in V2X, 5 ms for remote control, and 0.5 ms for tactile Internet.

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*9 Spectrum efficiency: The number of data bits that can be transmitted per unit time per unit frequency.

*10 Propagation losses: The amount of attenuation in the power of the signal emitted from the transmitting station till it arrives at the reception point.

*11 Coupling loss: The propagation loss according to distance from the base station used to define the cell radius, which is the distance from the base station at which a certain data rate can be provided.

In addition, the following three requirements are representative of those specified for the 5G system overall.

(a) Network slicing*12 support

A network can be composed of one or more network slices in which each network slice has the functionality of a complete, independent network. Each network slice can satisfy different functional or performance requirements and accommodate a specific group of users or type of service. One terminal will be able to connect to multiple network slices simultaneously.

(b) Diverse access support

The 5G core network shall be able to accommodate satellite and fixed broadband access in addition to Evolved Universal Terrestrial Radio Access (E-UTRA)*13 and 5G NR.

(c) Efficient provision under diverse conditions

To provide 5G, consideration is also being given to making essential equipment more power efficient and using network resources more efficiently. In 5G, particular attention is being given to the provision of low-latency services and studies are being made on network configurations that arrange gateway*14 equipment at the edge of the network close to mobile terminals. Low-cost provision is also being considered for markets requiring only minimal service levels as in areas with limited access to power.

3.3 Recent Trends in Studies on 5G Service Requirements

To meet the demands of industry, 3GPP Service and System Aspects 1 (SA1) has been conducting studies in Release 16 towards addition or revision of use cases and requirements related to railways and power. At the same time, coordination with the automobile industry is progressing through information exchanges and discussions with the 5G Automotive Association (5GAA)*15. Coordination with fixed networks, meanwhile, is moving forward at 3GPP SA2 through discussions with Broadband Forum*16 and other organizations in anticipation of Release 16 specifications.

4. Features of NR and 5G Core Network

The following describes the respective features of NR and the 5G core network for satisfying the 5G requirements described above.

4.1 NR Features

One key feature of NR is support of Non-Standalone operation, which is an operation format that provides service in combination with an LTE/LTE-Advanced area without having to provide an NR area by itself.

Existing LTE/LTE-Advanced networks are already providing services over broad areas using the 2 GHz and 800 MHz frequency bands. In contrast, it is assumed that 5G in its initial deployment stage will be rolled out using new high-frequency bands such as the millimeter wave band. A scenario consisting of local rollouts from areas with high demand is therefore being considered. If such a network using new spectrum for NR can be operated together with an LTE/LTE-Advanced network using existing frequency bands, it should be possible to provide more satisfying communications

*12 Network slicing: One format for achieving next-generation networks in the 5G era. Architecture that optimally divides the core network in units of services corresponding to use cases, business models, etc.

*13 E-UTRA: An air interface used for advanced wireless access schemes in 3GPP mobile communication networks.

*14 Gateway: A node having functions such as protocol conversion and data relaying.

*15 5GAA: An association founded by automotive and telecommunications players to promote studies on connected car services using 5G.

for the user than providing services locally by NR only. Furthermore, from the viewpoint of an operator expanding its service area, Non-Standalone operation providing 5G in combination with LTE/LTE-Advanced enables NR to be added on locally within an existing service area and to be expanded gradually according to demand. This is the most promising provision format at the 5G initial deployment stage. Against this background, Non-Standalone operation is attracting attention from NTT DOCOMO and other operators around the world studying early deployment of 5G. A consensus has been reached on formulating specifications for Non-Standalone operation by December 2017 ahead of those for Standalone operation. Technical details of Non-Standalone operation are described elsewhere in these Special Articles [5].

4.2 Features of 5G Core Network Accommodating NR

Both a system that extends Evolved Packet Core (EPC)*17 and a system for deploying a newly specified 5G core network are being studied as core networks accommodating NR. In particular, studies on the 5G core network with the aim of achieving the 5G service requirements described above have begun with the plan of completing specifications as 3GPP Release 15 in June 2018. The 5G core network has the following four main features:

- Reorganization of functions among terminals, the Radio Access Network (RAN) *18, and the core network
- Introduction of service-based architecture
- Support of network virtualization
- Introduction of network slicing and simultaneous connection of multiple gateways

These component technologies are described elsewhere in these Special Articles [6].

5. NR and 5G Core Network Deployment Scenarios

Scenarios for deploying and expanding NR and the 5G core network against the existing fourth-generation mobile communications system (4G) are being studied at 3GPP. We point out here that 3G and LTE deployment was achieved by a single scenario that newly introduced both the RAN and core network (the scenario directly connecting scenario (0) to scenario (3) in **Figure 1**). In contrast, the deployment of NR and the 5G core network can leverage the capability of providing NR by Non-Standalone operation as described above and the capability of accommodating LTE by the 5G core network. These features make it possible to provide multiple deployment scenarios as shown in Fig. 1.

Among the scenarios shown in Fig. 1, scenario 1 that accommodates Non-Standalone NR by EPC is the most promising at the time of initial 5G deployment. As a result, the strong demand from telecom operators in countries aiming for an early NR deployment has led to a consensus on drafting the standards and specifications needed for scenario 1 as early as possible. Non-Standalone NR accommodated by EPC is also the method initially proposed by NTT DOCOMO for providing NR with an eye to early 5G deployment. This format of accommodating Non-Standalone NR by EPC has the following advantages:

- Maintains the stable quality of the coverage area already serviced by LTE/LTE-Advanced

*16 Broadband Forum: An international organization that aims to promote the spread of broadband networks.

*17 EPC: An IP-based core network standardized by 3GPP for LTE and other access technologies.

*18 RAN: The network situated between the core network and mobile terminals consisting of base stations and other equipment for controlling the radio layer.

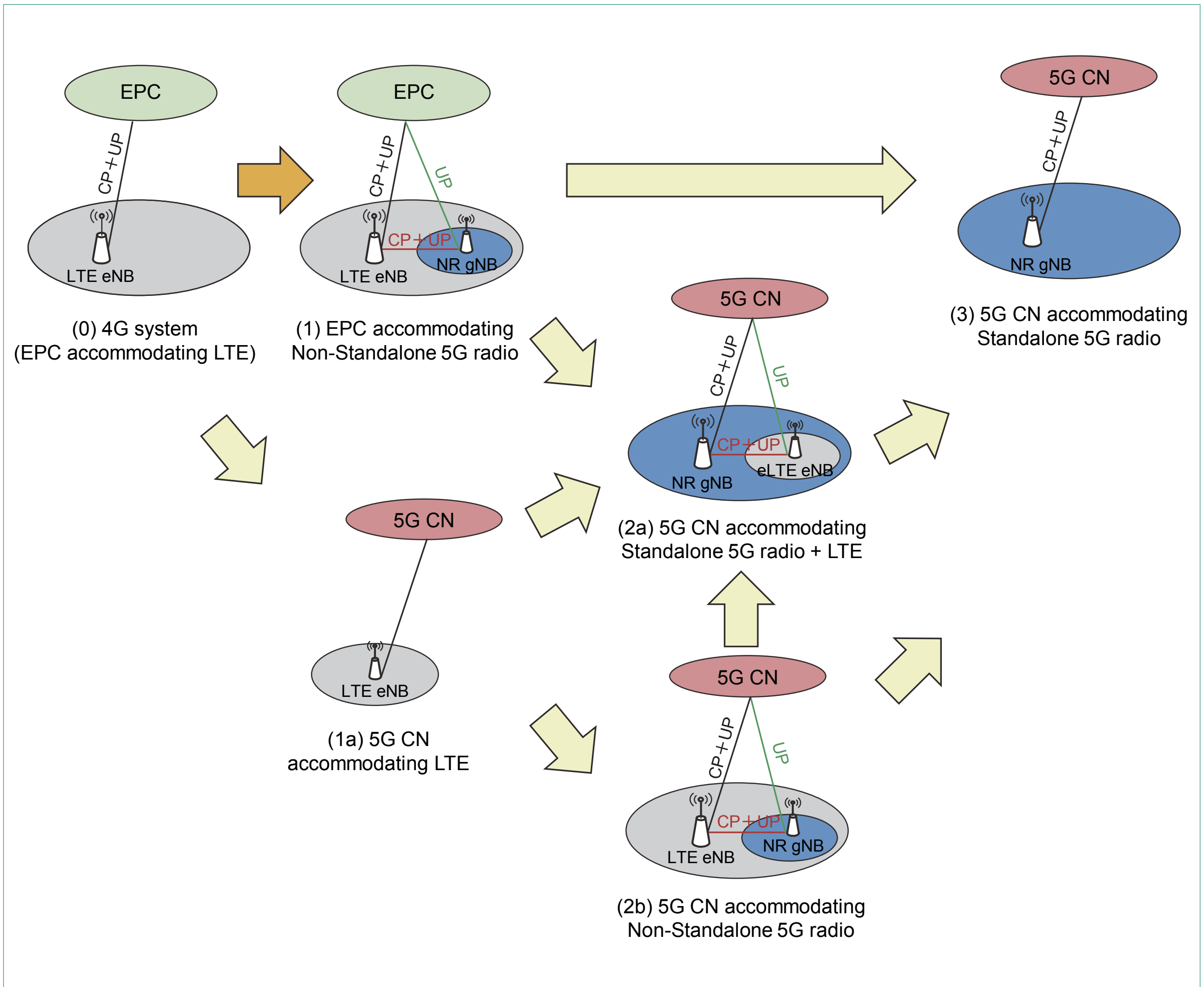

Figure 1　5G Radio/core network deployment scenarios

- Uses EPC having stable operation appropriate for achieving eMBB
- Minimizes the number of new design items and test items at time of 5G deployment

This approach is expected to lower the hurdle to NR deployment while enabling early and stable deployment to an extent not possible with a totally new deployment of the 5G core network. With Non-Standalone NR accommodated by EPC, we can expect the scale of changes to be limited by using EPC in its existing state for the most part. In addition, recent studies at 3GPP are including support for functions that will enable low latency even with EPC accommodation.

After NR provision by EPC-accommodated Non-Standalone operation (scenario (1)), the 5G core network can be introduced and a variety of scenarios can be provided in terms of LTE and NR area expansion as shown in Fig. 1 (scenarios (1a), (2a), (2b), and (3)). In this way, telecom operators can deploy NR and the 5G core network using an optimal set of scenarios in line with their business plans.

6. Conclusion

In this article, we described the overall 5G standardization schedule, 5G requirements and use cases, and the features of NR and the 5G core network for achieving those requirements. Component technologies of NR and the 5G core network are also described in these Special Articles [5] – [7].

At present, studies are proceeding at 3GPP toward the provision of functions specified by Phase 1 in the form of Release 15. The plan is to study functional extensions for some of these functions as Phase 2 in Release 16 and beyond.

NTT DOCOMO is contributing to 5G standardization efforts at 3GPP and aims to contribute to further development of 5G standards into the future.

REFERENCES

[1] A. Benjebbour et al.: "IMT-2020 Radio Interface Standardization Trends in ITU-R," NTT DOCOMO Technical Journal, Vol.19, No.3, pp.55–63, Jan. 2018.

[2] 3GPP TR22.891 V14.2.0: "Feasibility Study on New Services and Markets Technology," Sep. 2016.

[3] 3GPP TR 38.913 V14.2.0: "Study on Scenarios and Requirements for Next Generation Access Technologies," Mar. 2017.

[4] 3GPP TS22.261 V15.0.0: "Service requirements for the 5G system," Mar. 2017.

[5] A. Umesh et al.: "5G Radio Access Network Standardization Trends," NTT DOCOMO Technical Journal, Vol.19, No.3, pp.36–47, Jan. 2018.

[6] A. Minokuchi et al.: "5G Core Network Standardization Trends," NTT DOCOMO Technical Journal, Vol.19, No.3, pp.48–54, Jan. 2018.

[7] K. Takeda et al.: "Status of Investigations on Physical-layer Elemental Technologies and High-frequency-band Utilization," NTT DOCOMO Technical Journal, Vol.19, No.3, pp.24–35, Jan. 2018.