Technology Reports 5G NR LTE

Special Articles on Release 15 Standardization
—Advancements in the Completed Initial 5G and LTE/LTE-Advanced Specifications—

Technical Overview of the 3GPP Release 15 Standard

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3GPP Work items on detailed specifications for RAN and CN have progressed toward commercialization of 5G, and non-standalone specifications for providing services combining LTE and NR areas were completed in December 2017. Then, in June 2018, the Release 15 standards were completed, including standalone specifications for providing NR-only areas and for advances to LTE/LTE-Advanced. This article gives an overview of the NR and LTE specifications from the 3GPP, completed in Release 15.

1. Introduction

The 3rd Generation Partnership Project (3GPP), which is an international standardization organization for mobile communications systems, completed its Release 15 specifications in June 2018. This included the first complete specification for 5th Generation (5G) mobile communications systems. The specifications set regulations for the New Radio (NR) communication system, satisfying 5G use cases and requirements and not backward-compatible with earlier LTE/LTE-Advanced systems, and for the new 5G Core Network (5GC). At the same time, it also sets new specifications for LTE/LTE-Advanced, continuing to extend functionality and increase performance. This article gives an overview of the main radio and core network functionality specified in Release 15, and discusses background considerations for the release.

2. Release 15 Specification Functional Overview

3GPP Release 15 contains new NR and 5GC specifications, and extended specifications for LTE/LTE-Advanced. These include enhanced Mobile BroadBand (eMBB) technologies for achieving higher speed and capacity as with earlier mobile communications technologies, but also actively studies technologies for implementing Ultra-Reliable and Low Latency Communications (URLLC). Technical extensions to LTE/LTE-Advanced for massive Machine-Type Communications (mMTC), to accommodate large numbers of Internet of Things (IoT) terminals are also included. **Figure 1** shows functionalities specified for the three usage scenarios: NR, 5GC and LTE/LTE-Advanced.

3. New Radio Access Functionality Defined in the Release 15 Specification

3.1 Functionality for NR

For NR, technologies to provide for non-standalone[*1] and standalone[*2] operation of eMBB are specified [1]. The main technology for providing non-standalone operation is Dual Connectivity[*3] for LTE and NR. Technology to provide URLLC on NR is also specified.

1) Functionality for eMBB

The main NR features for realizing eMBB are (a) high-frequency/ultra-wideband transmission, (b) Massive Multiple Input Multiple Output (Massive MIMO)[*4] transmission, and (c) flexible frame[*5] structure and physical channel[*6] structure. These features are described below.

(a) High frequency/ultra-wideband transmission

NR in Release 15 anticipates high-frequency bands up to 52.6 GHz and radio performance is specified for frequency range 1 (FR1) from 450 to 6,000 MHz and frequency range 2 (FR2) from 24,250 to 52,600 MHz. As with LTE/LTE-Advanced, FR1 is specified assuming conducted testing, but FR2 is assumed to only be used Over The Air (OTA)[*7] [2]. For ultra-wideband transmission, up to 100 MHz per Component Carrier (CC)[*8] is specified for channel bandwidth in FR1, while up to 400 MHz per CC is specified in FR2. The physical layer[*9] specifications also support Carrier Aggregation (CA)[*10] and dual connectivity, to realize ultra-high-data rate transmission by bundling up to 16 NR CCs. This support for large channel bandwidth and extremely high frequency bands is a major difference between NR and LTE/LTE-Advanced.

NR also supports multiple Orthogonal

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

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

*3 Dual Connectivity: A technology that achieves wider bandwidths by connecting two base stations in a master/secondary relationship and performing transmission and reception using multiple component carriers supported by those base stations.

*4 Massive MIMO: MIMO systems transmit radio signals overlapping in space by using multiple antenna elements for transmission and reception. Massive MIMO systems aim to achieve high-speed data communications with greater numbers of simultaneous streaming transmissions while securing service areas. They achieve that aim 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.

*5 Frame: The period in which an encoder/decoder operates or a data signal of length corresponding to that period.

*6 Physical channel: A generic term for channels that are mapped onto physical resources such as frequency or time, and transmit control information and other higher layer data.

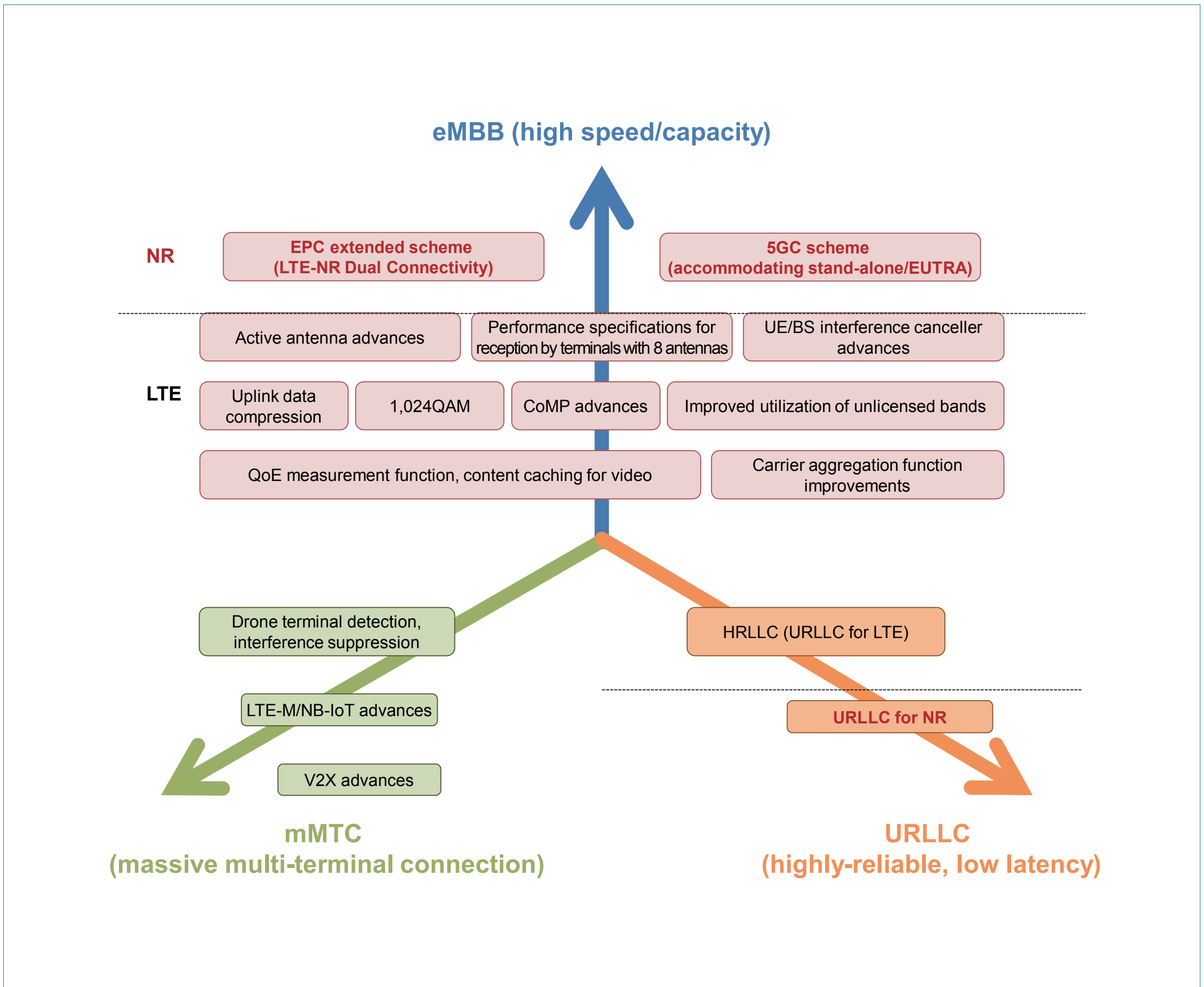

Figure 1　Main functions specified in Release 15 for NR, 5GC, and LTE/LTE-Advanced

Frequency Division Multiplexing (OFDM)*11 sub-carrier*12 spacings, of 15, 30, 60, and 120 kHz, for data transmission. This is because generally if OFDM sub-carrier spacings are the same at all frequencies, high frequency bands have significantly degraded resistance to multipath fading*13 and phase noise*14, compared with lower frequency bands.

OFDM based technology was also adopted as the multiple access*15 system because it has good affinity with MIMO technology and strong resistance to frequency-selective fading*16. OFDM is supported on both the uplink and the downlink. To ensure coverage

*7　OTA: A method for setting specified points and measurement points in a radiowave-propagation space, specifying wireless performance (including antenna emission and reception characteristics), and measuring those parameters.

*8　CC: Term denoting each of the carriers used in Carrier Aggregation.

*9　Physical layer: First layer of the OSI reference model; for example, "physical-layer specification" expresses the wireless interface specification concerning bit propagation.

*10　CA: A technology that achieves high-speed communication while maintaining backward compatibility with existing LTE, by using multiple component carriers simultaneously to expand bandwidth for transmission and reception.

*11　OFDM: A digital modulation method where the information is transmitted over multiple orthogonal carriers and sent in parallel. It allows transmission at high data rates.

*12　Sub-carrier: Individual carrier for transmitting signals with multi-carrier transmission such as OFDM.

*13　Multi-path fading: A phenomenon whereby a radio wave is subjected to repeated reflection and diffraction due to geographical features and buildings, and thus reaches to a receiver as multiple radio waves.

on the uplink, in addition to OFDM, Discrete Fourier Transform-spread (DFT-spread) OFDM*17, which has low Peak-to-Average Power Ratio (PAPR)*18, is also supported for single stream transmission.

(b) Massive MIMO transmission

The Release 15 physical layer specification specifies component technologies such as the reference signal structure and beam management, which assume Massive MIMO transmission in high frequency bands with up to 256 antenna elements on base stations and up to 32 antenna elements on terminals. To realize high data rate and capacity, the downlink supports single user MIMO*19 transmission with up to 8 layers and multi-user MIMO*20 transmission with up to 12 layers, and the uplink supports single-user MIMO transmission with up to four layers.

With high frequency bands, beam forming*21 is usually an important technology to compensate for reduced coverage due to propagation losses*22. Since LTE/LTE-Advanced did not anticipate use of high frequency bands, it assumed a digital beam forming implementation, with beam forming generated in the digital domain. However, it is difficult to implement high-frequency-band Massive MIMO in this way, so NR assumes a hybrid implementation that combines both digital and analog beam forming. As a result, major NR functions in the standard specification, such as initial access, scheduling, and Hybrid Automatic Repeat reQuest (HARQ)*23 retransmission, give consideration to the new high-frequency-band hybrid type of beam forming as well as the current, low-frequency-band digital beam forming [2].

(c) Flexible frame structure/physical channel structure

As mentioned earlier, NR supports multiple sub-carrier spacings, and with a wide subcarrier spacing in the frequency direction, OFDM symbols*24 are shorter in the time direction. For example, with a 120 kHz subcarrier spacing, the OFDM symbols are 1/8 the length of with a 15 kHz sub-carrier interval, as with LTE/LTE-Advanced. Using wide sub-carrier spacings in this way makes low-latency transmission possible. The number of OFDM symbols in an allocation unit for control and data channels can be changed flexibly [2], and the uplink and downlink slot ratio in the frame structure can be changed flexibly, according to the traffic ratios on the uplink and downlink.

2) Functionality for URLLC

URLLC supports and assists usage scenarios for mission critical services*25 that require near-real-time and high reliability. These are a type of IoT that includes self-driving vehicles, industrial robots, and remote medicine. As mentioned earlier, low latency is implemented by using a wide sub-carrier spacing, and reducing the number of OFDM symbols used for data assignment. On the other hand, to implement high reliability, new Channel

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*14 Phase noise: Phase fluctuation that occurs due to frequency components other than those of the carrier frequency in a local oscillator signal.

*15 Multiple access: Indicates methods in a radio system in which channels are assigned from among multiple vacant radio channels for communication, when multiple UE are communicating within the system.

*16 Frequency selective fading: A phenomenon in which the received level is not uniform along the frequency axis of the received signal because signals (frequencies) arrive through various paths due to reflection from buildings, etc.

*17 DFT-spread-OFDM: A digital modulation format. It is able to reduce PAPR by multiplying the signal from a user by a DFT precoder before performing OFDM modulation.

*18 PAPR: The ratio of the maximum power to the average power. If this value is large, the amplifier power back-off has to be large to avoid signal distortion, which is particularly problematic for mobile terminals.

*19 Single-user MIMO: Technology that uses MIMO transmission at identical temporal frequencies for a single user.

*20 Multi-user MIMO: A technology that uses MIMO to transmit signals to multiple users at the same time using the same frequency.

Quality Indicator (CQI)*26 and Modulation and Coding Scheme (MCS)*27 tables for URLLC are specified to support lower signal ratios than eMBB.

3.2 Functionality for LTE/LTE-Advanced

Release 15, also extends earlier specifications, with technologies that extend LTE/LTE-Advanced to implement eMBB, including support for 1024 Quadrature Amplitude Modulation (QAM)*28 to further improve the frequency utilization, enhanced OTA regulation for the active antenna system*29, and technical extensions to use unlicensed bands.

1) eMBB Technology for Increasing Bandwidth Utilization

Technologies to extend LTE/LTE-Advanced and increase frequency utilization are described below.

(1) 1024QAM support

To increase the peak data rate further, 1024QAM and DeModulation Reference Signal (DM-RS)*30 overhead*31 reduction are specified.

(2) Coordinated Multi-Point transmission/reception (CoMP)*32 advances

Non-coherent joint transmission, in which two base stations transmit different data sequences without knowing Channel State Information (CSI)*33 of the other base station is supported. With this, extensions were made to QCL, control information, and CSI feedback functions.

(3) Performance specifications for reception by terminals with eight antennas

Radio performance is specified for realizing expanded cell coverage with terminals having eight receiver antennas and maximum transmission speed using eight layers on the downlink is increased.

(4) Expansion of OTA based requirements for active antenna systems

Only two items for OTA based requirements were specified in Release 13 (Equivalent Isotropic Radiated Power (EIRP)*34 and Equivalent Isotropic Sensitivity (EIS)*35) for active antenna system radio performance, and these basically assumed conducted testing. In Release 15, all the conducted based requirements other than the two in Release 13 are replaced with those based on OTA, introducing specifications that enable end-to-end performance to be guaranteed, including the antennas. With these requirements, it is now possible to require performance to be guaranteed based on 3GPP specifications, for active antenna systems that do not have antenna connectors. For equipment with this type of structure, power losses within the equipment are reduced, and multiple transceivers and antennas can be implemented with high density, forming tighter beams (high gain), and compensating for the higher radio wave propagation losses in high frequency bands.

(5) Technologies to reduce various types of interference

Several functions to extend LTE/LTE-Advanced have been specified, to suppress

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*21 Beamforming: Technology for generating a directional pattern for transmission and/or reception by using multiple antennas (by means of controlling amplitude and phase of each of multiple antennas) and increasing or decreasing antenna gain in regard to specific directions.

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

*23 HARQ: A technique that compensates for errors in received signals through a combination of error-correcting codes and retransmission.

*24 OFDM symbol: A unit of transmission data consisting of multiple subcarriers. A Cyclic Prefix (CP) is inserted at the front of each symbol.

*25 Mission critical service: A type of communications service defined for 3GPP mobile communications networks, provided for public safety; mainly police and fire prevention.

*26 CQI: An index of reception quality measured at the mobile station expressing propagation conditions on the downlink.

*27 MCS: Combinations of modulation scheme and coding rate decided on beforehand when performing AMC.

*28 QAM: A modulation method that uses patterns of both amplitude and phase for modulation, with varieties according to the number of such patterns such as 16QAM and 64QAM.

interference from other cells and increase user throughput. A function has been specified to reduce the amount of Cell-specific Reference Signal (CRS)*36 transmitted by base stations during times and in areas where the volume of data traffic is low, reducing both interference due to CRS and base station power consumption. An interference canceller*37 function for uplink reception on base stations has also been specified. Performance of interference suppressing technologies for low cost terminals with only one receiver antenna, such as IoT terminals, has also been specified.

2) Other Technologies for eMBB

Besides technologies to improve frequency utilization, other improvements have been made based on experience operating LTE/LTE-Advanced networks. The main such technologies are described below.

(1) Improving utilization of unlicensed bands

The uplink function for Licensed Assisted Access (LAA)*38 that was specified in Releases 13 and 14 has been extended. Specifically, it is possible to change the position of the first and last symbols more flexibly when transmitting uplink data. Autonomous UL transmission is also supported, enabling terminals to begin uplink transmission autonomously.

(2) CA functionality improvements

With earlier CA, delay for the following required terminal processing occurs before the Secondary Cell (SCell)*39 can be configured.

- The time required to measure the quality of candidate carriers increases, depending on the number of SCell candidate-measurement carriers.
- When communication with the SCell begins, several tens of milliseconds are needed to start up the Radio Frequency (RF) channel.

To solve these issues, a mechanism has been specified to measure radio signal quality of SCell candidates while a terminal is in the Idle state, along with the new dormantSCell state, in which an SCell is configured with an initialized RF circuit before the SCell starts communication.

(3) Uplink data compression

For Time Division Duplex (TDD)*40, the ratio of uplink to downlink usually emphasizes the downlink, so the radio resources available for transmission on the uplink are limited. To transmit uplink user data using the radio resources efficiently, a mechanism for Uplink Data Compression (UDC) is specified, which compresses headers for packets at the IP level and above (IP, User Datagram Protocol (UDP)*41, Real-time Transport Protocol (RTP)*42, etc.). Headers are compressed at the Packet Data Convergence Protocol (PDCP)*43 layer, using the DEFLATE*44 algorithm standardized by the Internet Engineering

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*29 Active antenna system: A system that integrates antenna elements and RF circuits that have traditionally been separated thereby providing a more efficient system.

*30 DM-RS: A user-specific reference (pilot) signal known by the base station and mobile station for estimating the fading channel used for data demodulation.

*31 Overhead: Control information needed for transmitting/receiving user data, plus radio resources used for other than transmitting user data such as reference signals for measuring received quality.

*32 CoMP: Technology which sends and receives signals from multiple sectors or cells to a given UE. By coordinating transmission among multiple cells, interference from other cells can be reduced and the power of the desired signal can be increased.

*33 CSI: Information describing the state of the radio channel traversed by the received signal.

*34 EIRP: The transmission power at the reference point in radio radiation space.

*35 EIS: The received power at the radiated requirement reference point in radio reception space.

*36 CRS: A reference signal specific to each cell for measuring received quality in the downlink.

Task Force (IETF)*45.

(4) QoE measurement functionality/content caching for video

With the recent rise of services for viewing video on for smartphones, increasing the image quality and Quality of Experience (QoE) for video in mobile communication environments has become an issue for operators. To measure QoE on real networks, a mechanism enabling the network to collect QoE measurements from terminals, called Minimization of Drive Test (MDT)*46, has been specified. A mechanism which places a video content cache servers near base stations has also been studied, to reduce delay when downloading video. With this mechanism, terminals download data from the content server by connecting and communicating through the base station directly with the content server, rather than communicating through the Evolved Packet Core (EPC)*47.

3) Technologies for mMTC

In response to recent increasing anticipation in the market for IoT, the 3GPP has also specified technologies for machine communication and inter-vehicle communication. Advancements in these functionalities have been implemented in Release 15, specifying enhancements for drones and URLLC.

(1) Drone terminal detection/interference suppression

With the spread of services using drones, demand has also increased for mobile communication systems to provide wide-area communication for drone terminals. To meet this anticipation in the market, the 3GPP has studied whether providing communication for drone terminals using LTE/LTE-Advanced is feasible, and found that even existing specifications have the necessary and sufficient functionality to provide communication for drone terminals.

On the other hand, a problem of increasing uplink interference from overhead drone terminals to the base station has been identified. Some countries and regions also require a license for drone terminals to fly, so the issue of how the network can determine if a drone is licensed or not was also studied.

For the issue of uplink interference, a mechanism has been specified to adjust the open-loop*48 transmit-power control parameters for individual terminals, setting them to control the target Signal to Interference Ratio (SIR)*49 even when propagation losses from the base station are small.

To determine whether a drone terminal is licensed, a mechanism is specified to link with the Home Subscriber Service (HSS)*50 within the network and determine the license status from subscriber information.

(2) LTE-M*51/NarrowBand (NB)-IoT*52 advances

Release 15 also adds extensions to TDD support and low-power features for IoT terminals through LTE networks.

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*37 Interference canceller: A method for separating multiple combined signals received at the same time, by successively detecting and then cancelling each signal from the received signal. It generally yields better performance than Minimum Mean Square Error (MMSE) detection.

*38 LAA: A generic name for radio access methods in which terminals obtain configuration information from an LTE carrier using a licensed band, and then use an unlicensed band for radio communication.

*39 SCell: Carriers other than the PCell with multiple carriers in CA. Also referred to as the secondary cell.

*40 TDD: A format in which downlink and uplink communication is segmented in time, with transmission and reception alternating.

*41 UDP: A standard Internet protocol above the IP layer. In contrast to TCP it does not provide functions to establish a connection between server and terminal or to retransmit data that does not reach the destination.

*42 RTP: A real-time multimedia transport protocol used on IP networks. Defined by the Internet Engineering Task Force (IETF, See *43).

*43 PDCP: A sublayer of layer 2. A protocol for ciphering, validation, ordering and header compression, etc.

*44 DEFLATE: A data compression algorithm standardized by the IETF.

(a) Idle mode power conservation technology (Wake-up signal)

To reduce power consumption in Idle mode, a new Wake-up signal has been specified. Normally, terminals in Idle mode attempt to decode the downlink control periodically to obtain paging*53 information. They do not know whether there is paging information to obtain until the channel has been decoded, so it must be done periodically, increasing power consumption. Release 15 introduces a simple process for detecting a Wake-up signal. This provides a way to determine whether there is paging information and should reduce terminal power consumption.

(b) Reduced latency for small-packet communication

In use cases such as smart meters, data transmissions are expected to use relatively small packets. For such cases, a procedure for starting transmission of small amounts of data has been added within the random access*54 procedure, which normally cannot be used to start data transmission. This promises to reduce latency for small-packet communication.

(c) TDD support

In Releases 13 and 14, LTE-M and NB-IoT were specified, targeting operation in Frequency Division Duplex (FDD)*55 bands. Release 15 also enables operation in TDD bands.

(3) Vehicle to Everything (V2X) communication advances

Release 15 adds extensions to the V2X communication functionality specified in Release 14. Specifically, to increase the data rate and bandwidth of V2X communication, CA has been introduced to Mode 4*56, which enables terminals to select transmission resources autonomously from a resource pool*57. Support for the 64QAM modulation scheme has also been added for V2X. New terminal performance specifications have also been added to satisfy low latency requirements.

4) Highly-Reliable Low-Latency Communication (HRLLC, URLLC for LTE)

There has been increasing demand recently for services requiring real-time performance, such as self-driving vehicles, industrial robots, remote medicine and virtual reality (VR), and mission-critical services requiring high reliability. As such, functionality implementing low latency and highly reliable communication on LTE/LTE-Advanced has been specified.

(a) Technologies for highly-reliable communication

For highly-reliable communication, functionality has been introduced to improve transmission quality on the downlink control channel, and uplink and downlink data channels.

For the downlink control channel, in conventional LTE/LTE-Advanced, the Physical Control Format Indicator Channel (PCFICH)*58

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*45 IETF: A standardization organization that develops and promotes standards for Internet technology.

*46 MDT: A technology standardized by the 3GPP for gathering QoE information. Terminals send information to the network regarding incidents such as interruption of communication or failed handover as they occur, such as location and cause of the incident.

*47 EPC: The core network on 3GPP mobile communication networks, mainly accommodating E-UTRA.

*48 Open loop: A type of control that operates on the input, without using the output for feedback.

*49 SIR: The ratio of desired-signal power to interference power.

*50 HSS: A subscriber information database that manages authentication and current location information in a 3GPP mobile network.

*51 LTE-M: An LTE communication specification for terminals that communicate at low speed using narrow bandwidth, for IoT devices (sensors, etc.).

*52 NB-IoT: An LTE communication specification for terminals that communicate at even lower speed and narrow bandwidth than LTE-M, for IoT devices (sensors, etc.).

*53 Paging: A method and signal for calling a visiting UE that is on standby when a call is received.

was detected and the number of PDCCH OFDM symbols was identified. However, in this case, the quality of the entire downlink control channel is constrained by PCFICH detection errors and error detection. As such, a method to improve the quality of the downlink control channel has been specified, avoiding earlier effects of PCFICH detection errors and error detection by notifying of the number of PDCCH OFDM symbols using higher layer signaling.

To improve the quality of transmission on the uplink and downlink data channels, new functionality was introduced to repeat transmission of the same data over multiple Physical Downlink Shared Channels (PDSCH), Short Physical Downlink Shared Channels (SPDSCH)*59, Semi-Persistent Scheduling Physical Uplink Shared Channels (SPS-PUSCH)*60 or Semi-Persistent Scheduling Short Physical Uplink Shared Channels (SPS-SPUSCH)*61.

(b) Technologies for low-latency communication

For low-latency communication, the signal processing times for the 1 ms Time-To-Interval (TTI)*62 was reduced from earlier values, and a new short TTI was specified.

Functionality has been specified to reduce the signal processing times from when data is received on the downlink till when HARQ feedback is sent, and from receiving on the downlink control channel, which schedules uplink data, till data is sent on the uplink, by 25%, from the prior minimum of 4 ms to 3 ms.

To also reduce the size of the 1 ms TTI itself, which is composed of 14 OFDM symbols, slots composed of 7 OFDM symbols and sub-slots composed of 2 or 3 symbols have been specified as short TTIs. Accordingly, functionality has also been specified for scheduling resources using these units of data on the downlink SPDSCH and uplink SPUSCH. To implement Short TTI data allocation, uplink and downlink control channels, Short Physical Downlink Control Channel (SPDCCH) and Short Physical Uplink Control Channel (SPUCC) are also specified.

4. Core Network Specified for Release 15 NR

Figure 2 shows the two methods for providing NR as specified in Release 15 from the core network perspective. They are the extended EPC scheme, which extends the existing EPC to provide NR in non-standalone operation, and the 5GC scheme, which introduces the newly specified 5G core network (5GC) to provide NR in standalone operation [1].

4.1 Features of Extended EPC Scheme

1) EPC Dual Connectivity

Cases of NR operation, such as deployment in localized areas or limited coverage, are expected because NR has features such as use of high-frequency bands. On the other hand, the quality of existing services such as Voice over LTE (VoLTE) and IoT

*54 Random access: A procedure executed by mobile terminals and base stations for connecting uplink signals and synchronizing their transmission timing.

*55 FDD: A method for implementing simultaneous transmission and reception with radio communications etc, in which transmission and reception are done using different frequencies.

*56 Mode 4: A type of resource allocation method used with LTE V2X.

*57 Resource pool: A set of resources achieved by bundling together many units of hardware each possessing certain types of resources (CPU, memory, HDD, etc.). Various types of virtual machines can be created from a resource pool.

*58 PCFICH: A physical channel used to notify of the number of symbols for PDCCH transmission on LTE.

*59 SPDSCH: PDSCH with a short TTI.

*60 SPS-PUSCH: A method for periodically sending different uplink data based on demodulation of downlink control information.

*61 SPS-SPUSCH: PUSCH with a short TTI.

*62 TTI: Transmission time per data item transmitted via a transport channel.

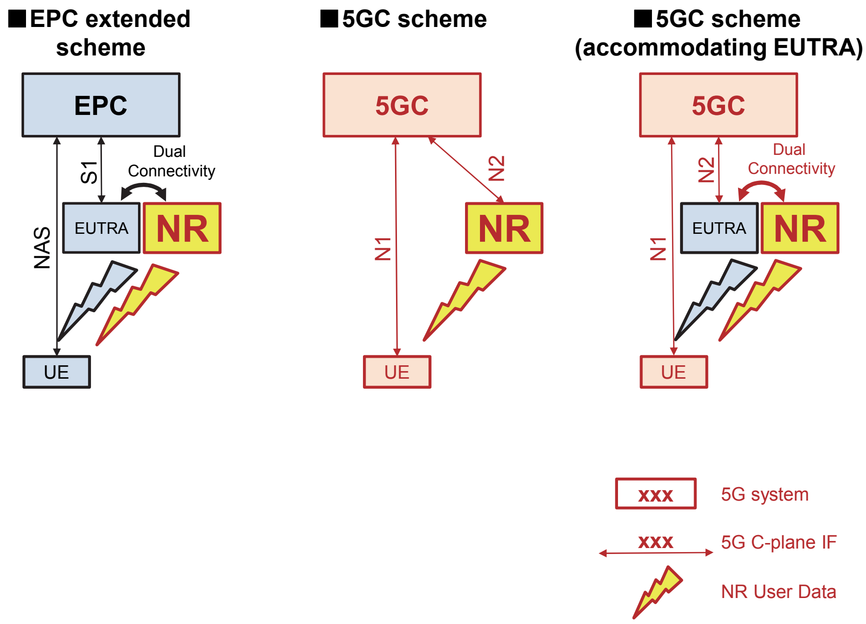

Figure 2 Provision of NR from the core-network perspective

must be maintained and require adequate area coverage, so operation will need to vary according to the service and environment. Existing EPC facilities and coverage provided by LTE/LTE-Advanced will be used for these services, and NR will be used for specialized services such as viewing high-definition video. The main feature of EPC Dual Connectivity is that various settings on existing EPC equipment, the S1 Interface (S1-IF)*63 with evolved NodeB (eNB)*64, and the Non-Access Stratum interface (NAS-IF)*65 are used with the terminal to minimize any effect on core network equipment. This enables NR to be introduced relatively quickly.

2) 5G NR Service Identification (Control) Functionality

In addition to the Dual Connectivity function described above, various other functions have been specified for providing NR much more appropriately and flexibly, considering roaming and various other types of contract and forms of operation.

- 5G area notification function: When the core network receives from a terminal, as during the attach*66 procedure, the core network sends 5G subscriber information to the terminal. The terminal then notifies the user

*63 S1-IF: The functional layer between eNB and EPC.
*64 eNB: A base station for the LTE radio access system.
*65 NAS-IF: The functional layer between the mobile terminal and core network through the Access Stratum (AS).
*66 Attach: The process of registering a mobile terminal to a network when the terminal's power is turned on, etc.

whether it is in an NR area and whether a 5G NR connection is possible using an icon or other means, based on the subscriber information and cell configuration information from the base station.

- 5G NR connection decision function: As described above, this notifies the terminal and the base station regarding the subscriber's 5G contract. This allows control of network operation such as enabling or disabling 5G and making NR connections while roaming, or only allowing specific terminals used for testing to make NR connections.
- 5G Gateway (GW*67) selection function: When providing GW equipment optimized for throughput and capacity, which are 5G features, this function gives priority to terminals capable of using NR when connecting to the GW equipment.
- 5G-Data Reporting function: With Dual Connectivity, the base station allocates transmission of user data to either Evolved Universal Terrestrial Radio Access (E-UTRA)*68 or NR, according to factors such as the radio environment. This function counts and reports the amount of user data transmitted by NR and reports it from the base station so that the core network can know how much user data was actually transmitted by NR.

4.2 New 5G Core Network Features

5GC is the new 5G core network equipment specified in Release 15. See reference [1] regarding the main features of 5GC.

One of the main features of 5GC is that it is able to accommodate E-UTRA together with NR in a Next Generation Radio Access Network (NG-RAN)*69. eNB that are able to connect to 5GC are called ng-eNB, and use the same NG-AP interface when connecting to 5GC as they do when connecting to NR. A fallback technology is also provided, so that when a terminal is in a 5GC area and starts IP Multimedia Subsystem (IMS)*70 voice services, the terminal will be connected to EPC, and these services will be provided through EPC. This enables radio equipment built with E-UTRAN, and its settings and coverage to be used on 5GC, preserving the quality and area of existing services while providing new 5G services and implementing migration smoothly.

5. Conclusion

This article has given background and described the main functionality in the Release 15 specifications for NR, 5GC and LTE/LTE-Advanced. For more details regarding NR and related network management specifications introduced here, please see other articles of this special feature, references [2] to [5]. The 3GPP began work creating the Release 16 specifications in October 2018. With respect to NR, the intention is to create specifications that will advance multi-beam/MIMO for millimeter wave and expand application areas for URLLC and IoT. Regarding the core network, the intention is to study improvements to various platform functions

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*67 GW: A node having functions such as protocol conversion and data relaying.

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

*69 NG-RAN: A RAN connecting to the 5G core network using NR or E-UTRA as radio access technology.

*70 IMS: A subsystem that provides IP multimedia services (e.g., VoIP, messaging, presence) on a 3GPP mobile communications network.

for commercial introduction of 5GC, and new services such as URLLC, V2X and IoT, enhancing and applying them on 5GC.

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