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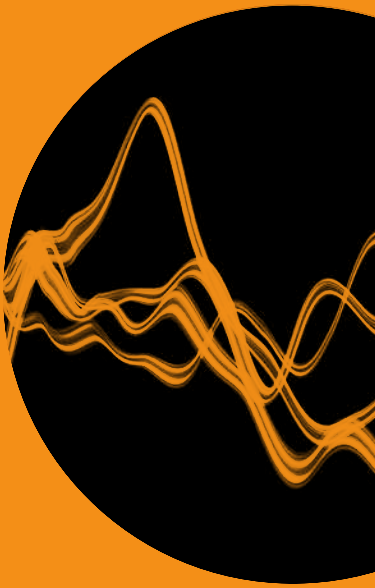

5G EVOLUTION
TOWARD 5G ADVANCED

ERICSSON

5G EVOLUTION TOWARD 5G ADVANCED:

An overview of 3GPP releases 17 and 18

Together with enhancements aimed at existing use cases such as mobile broadband, industrial automation and vehicle-to-everything, 3GPP release 17 introduces support for new ones including public safety, non-terrestrial networks and non-public networks. Meanwhile, the early planning of release 18 indicates that it will significantly evolve 5G in the areas of artificial intelligence and extended reality.

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The 3GPP has passed the midpoint in its work on its release 17 (Rel-17) specifications, with plans to publish them at the end of the first quarter of 2022. Meanwhile, the discussions on the scope of Rel-18 are well underway. In fact, 3GPP has already announced its decision to recognize Rel-18 as the first release of 5G Advanced to highlight the significant evolution of the 5G System (5GS) that it represents.

■ Several of the features in Rel-17 are intended to enhance network performance for existing services and use cases, while others address new use cases and deployment options. 5G Advanced will build on Rel-17, providing intelligent network solutions and covering numerous new use cases in addition to previously defined use cases and deployment options. *Figure 1* shows Ericsson's view on 3GPP's tentative time plan for releases up until 2028.

One key component of 5G Advanced is the use of artificial intelligence (AI) based on machine learning (ML) techniques. AI/ML is expected to trigger a paradigm shift in future wireless networks. AI/ML-based solutions will be used to introduce intelligent network management and solve multi-dimensional optimization issues with respect to real-time and non-real-time network operation.

AI/ML will also be used to improve the radio interface by further optimizing the performance of complex multi-antenna systems, for example. New use cases such as extended reality (XR) communication will use wireless networks to provide

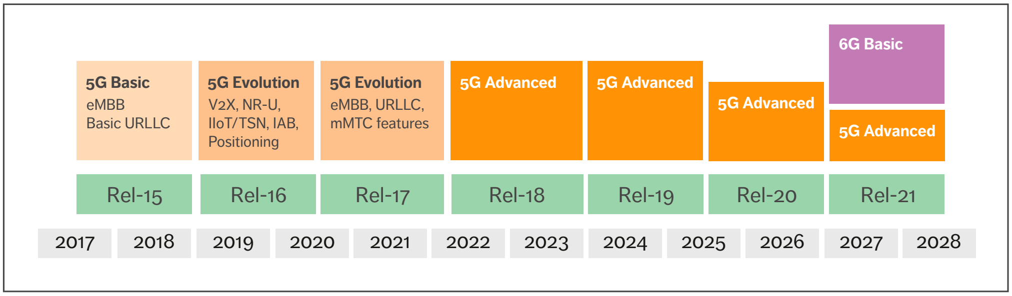

Figure 1 3GPP's 5G evolution tentative time plan

immersive experiences in cyber-physical environments and enable human-machine interactions using wireless devices and wearables.

Enhancements in 3GPP release 17

The path toward 5G Advanced begins with Rel-17, which includes significant enhancements to several radio access network (RAN) functionalities that are already deployed in live New Radio (NR) networks.

Beamforming and multiple-input, multiple-output (MIMO)

As shown in *Figure 2*, Rel-17 MIMO enhancements address four areas: beam management; multiple transmission and reception point (mTRP) for ultra-reliable, low-latency communication (URLLC); mTRP for enhanced mobile broadband (eMBB); and TDD and FDD reciprocity.

The multi-beam enhancements are intended to improve performance at high mobility by

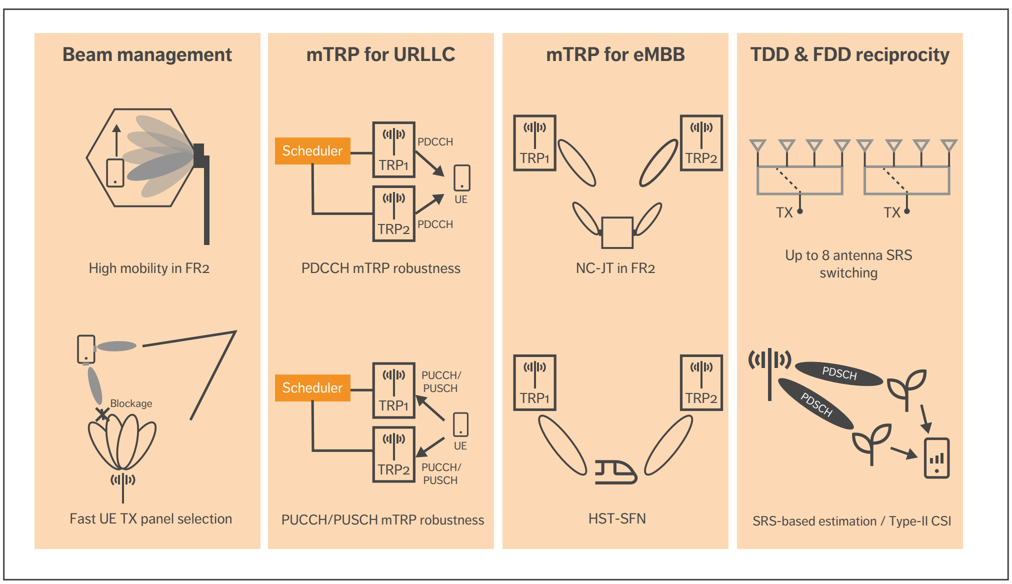

Figure 2 Rel-17 NR MIMO enhancement areas

streamlining signaling and to optimize performance for user equipment (UE) with multiple antenna panels. The mTRP enhancements increase robustness for the physical downlink control channel (PDCCH), physical uplink shared channel (PUSCH) and physical uplink control channel (PUCCH). They also enable richer channel state information (CSI) feedback for non-coherent joint transmission (NC-JT) and optimize performance for high-speed-train (HST) communication scenarios.

Finally, the enhancements to reciprocity-based operation include new codebooks with reduced feedback overhead, where partial channel knowledge is available at gNodeB (gNB), as well as improvements to the Sounding Reference Signals (SRSs).

Dynamic spectrum sharing

The dynamic spectrum sharing (DSS) included in Rel-15 already makes it possible to deploy an LTE cell and an NR cell on the same base station using shared spectrum, which enables an operator to provide 5G services by initiating a migration of spectrum from LTE to NR. Rel-16 primarily improved the capacity of the NR physical downlink shared channel (PDSCH). Enhancements in Rel-17 make it easier for operators to overcome PDCCH resource shortages in the NR cell, which can occur as the number of NR UEs increases. From Rel-17 onwards, cross-carrier scheduling allows for the data channels to be scheduled on the shared primary cell using the PDCCH of a downlink secondary cell.

User equipment power savings

Rel-17 includes power-saving enhancements for UEs in Radio Resource Control (RRC) connected, idle and inactive modes. Power-efficiency improvements are specified both for eMBB UEs and reduced-capability (RedCap) devices. The list of power-saving enhancements includes relaxed radio resource monitoring for devices operating at low mobility or in very good radio conditions, extended discontinuous reception (eDRX) for latency-tolerant devices, reduced PDCCH monitoring during active time, and power-efficient paging reception.

Positioning

NR has supported positioning since Rel-15 through the use of LTE positioning (for non-standalone deployments) and radio-access technology (RAT) independent positioning (Bluetooth, wireless LAN,

The 3GPP and 5G

The 3GPP published the first versions of the 5G standard in 2018. The work and specifications are divided into three main areas: System Architecture, Core and Terminal, and RAN. The 5G RAN is also known as NR (New Radio) and is part of the 5th Generation System.

The 3GPP organizes its work in releases with a continuous numbering scheme. The first version of the 5G specifications surfaced in 3GPP Rel-15 in 2018 and provided the base functionality as well as a large set of optional features. In subsequent releases, the 3GPP has added new functionality to the existing baseline. This is done with backwards compatibility, so that older terminals can still function in upgraded networks and vice versa.

The 3GPP adds functionality that is required to satisfy increasing demands on existing services (higher data rates for mobile broadband, for example) or to satisfy requirements of new services, use cases and deployment options (such as public safety applications and relaying). However, features are typically specified in a service- and use-case agnostic manner, which means that it is up to vendors and operators to decide how to use and combine the specified features.

pressure sensors and so on). Rel-16 introduced time-based positioning methods for NR standalone deployments (multi-round-trip time (RTT), Downlink and Uplink Time Difference of Arrival), as well as an angle-of-arrival and angle-of-departure-based positioning measurements, which can be used in combination with timing-based solutions to achieve higher accuracy.

In Rel-17, NR positioning is further improved for specific use cases such as factory automation by targeting 20-30cm location accuracy for certain deployments. Rel-17 also introduces further enhancements to latency reduction to enable positioning in time-critical use cases such as remote-control applications.

Aside from high-positioning accuracy, industrial Internet of Things (IIoT) and automotive use cases also demand integrity protection of the location information. From a higher layer point of view, Rel-17 introduces key performance indicators to indicate the reliability/integrity of the measurement report limited to the global navigation satellite system (GNSS) positioning procedure.

Ultra-reliable, low-latency communication

URLLC has been a key enabler for the 5GS to enter various verticals. Rel-15 established a solid foundation, and Rel-16 introduced further enhancements by the 3GPP's System Architecture (SA) and RAN groups to better serve various industry verticals such as factory automation, the transport industry and electrical power distribution. These enhancements included various user-plane redundancy schemes as well as enhancements to improve reliability, reduce latency and support time-sensitive communication (TSC).

The enhancements in Rel-17 aim to improve spectral efficiency and system capacity, support URLLC in unlicensed spectrum environments and strengthen the framework to support TSC. They include Hybrid Automatic Repeat Request-Acknowledgement (HARQ-ACK) enhancements, CSI enhancements, intra-UE multiplexing, time-synchronization enhancements and service survival time as an extension to TSC assistance information.

> “IN REL-17, NR POSITIONING IS FURTHER IMPROVED FOR SPECIFIC USE CASES SUCH AS FACTORY AUTOMATION”

NR coverage

The direct impact that coverage has on service quality, opex and capex makes it a key factor for both commercialization and competition. In Rel-17, the 3GPP has identified the PUSCH as a potential coverage bottleneck. To improve PUSCH coverage, the 3GPP is considering mechanisms for repetition and support for transport block processing over multiple slots. Moreover, Rel-17 specifies mechanisms to support demodulation reference signal (DMRS) bundling across PUSCH repetitions and signaling support for dynamic PUCCH repetition factor indication.

Small data transmission

To support power-efficient connection establishment, the existing NR RRC inactive mode enables a UE to resume a previously established RRC connection. To further enhance the UE power consumption at system access, Rel-17 specifies support for data transmission in RRC inactive mode. Not having to resume an RRC connection reduces the control plane signaling overhead, which is especially relevant for low-power devices that support traffic characterized by infrequent and small data transmissions.

Non-public networks

In Rel-16, the 3GPP specified support for non-public networks (NPNs), which provide access that is limited to a certain group of users such as the devices belonging to a given factory. To provide full support for industrial verticals, the 3GPP specified support for two NPN deployment options. The first, known as public-network-integrated NPNs, allows public operators to support NPNs by associating them directly to their networks. The second deployment

> A KEY ASPECT OF 5G NR IS THE CONTINUOUS DRIVE TO SUPPORT NEW VERTICALS AND DEPLOYMENT SCENARIOS

option is known as standalone NPN (SNPN). Broadly speaking, an SNPN has the same functionality and characteristics as a regular public network.

The 3GPP provides further enhancements for SNPNs in Rel-17. These enhancements include support for a UE accessing an SNPN using external credentials (such as those from a public network or those belonging to another SNPN), SNPN UE onboarding (to provision the UE with new NPN credentials and/or subscription parameters, for example) and support for emergency services.

Edge computing

Edge computing, which enables operator- and third-party services to be hosted close to the UE's access point of attachment, was supported in the initial 3GPP Rel-15 of 5GS. The baseline architecture enables efficient service delivery by reducing end-to-end latency and load on the transport network.

Rel-17 introduces mechanisms to discover edge application servers. For example, it defines an Edge Application Server Discovery Function (EASDF) primarily to support the session breakout connectivity model. The EASDF acts as a Domain Name System (DNS) resolver to the UE and can complement the DNS queries with UE location-related information. This enables the DNS system to resolve to application servers close to the UE location.

Rel-17 also clarifies and enhances the use of UE route-selection policy (URSP) rules for edge computing for the distributed anchor and multiple Protocol Data Unit (PDU) session connectivity models. The URSP rules configuration in the UE can take specific application server information into account. This in turn provides the UE with the ability to dynamically establish PDU sessions for specific application servers, eliminating the need to deploy support for complex session breakout solutions.

Furthermore, Rel-17 defines enhanced support for the relocation of the application server in case of UE mobility and includes new mechanisms to expose QoS monitoring results.

Data networks analytics

Several architectural enhancements and newly defined types of analytics in Rel-17 increase the scope and usability of network data analytics. Support for the aggregation of analytics enables use cases where a Network Data and Analytics Function (NWDAF) is able to collect data and analytic reports from other localized NWDAFs. The NWDAF has been disaggregated into two separate logical entities, which enables multiple NWDAF (analytics logical function) in the network to produce analytic reports according to a model distributed from the NWDAF model training logical function (MTLF).

Rel-17 also optimizes some procedures by including new network functions (NFs) that make it possible to process data closer to the data sources and enable lower signaling. The new data collection coordination function enables a single collection of data from 5G Core NFs, with the data being distributed by a non-standardized message bus. The analytics data repository function can store massive amounts of both data and analytic reports. Rel-17 also enhances the input to analytic reports by enabling the addition of information originating from UE applications.

New features in 3GPP release 17

A key aspect of 5G NR is the continuous drive to support new verticals and deployment scenarios. Rel-17 strengthens 5G support for new use cases primarily through new development in five areas: RedCap UE, non-terrestrial networks, frequency bands beyond 52GHz, and the multicast and broadcast service (MBS).

Reduced-capability user equipment

To further widen the range of use cases for NR, Rel-17 introduces support for RedCap UE. RedCap UE

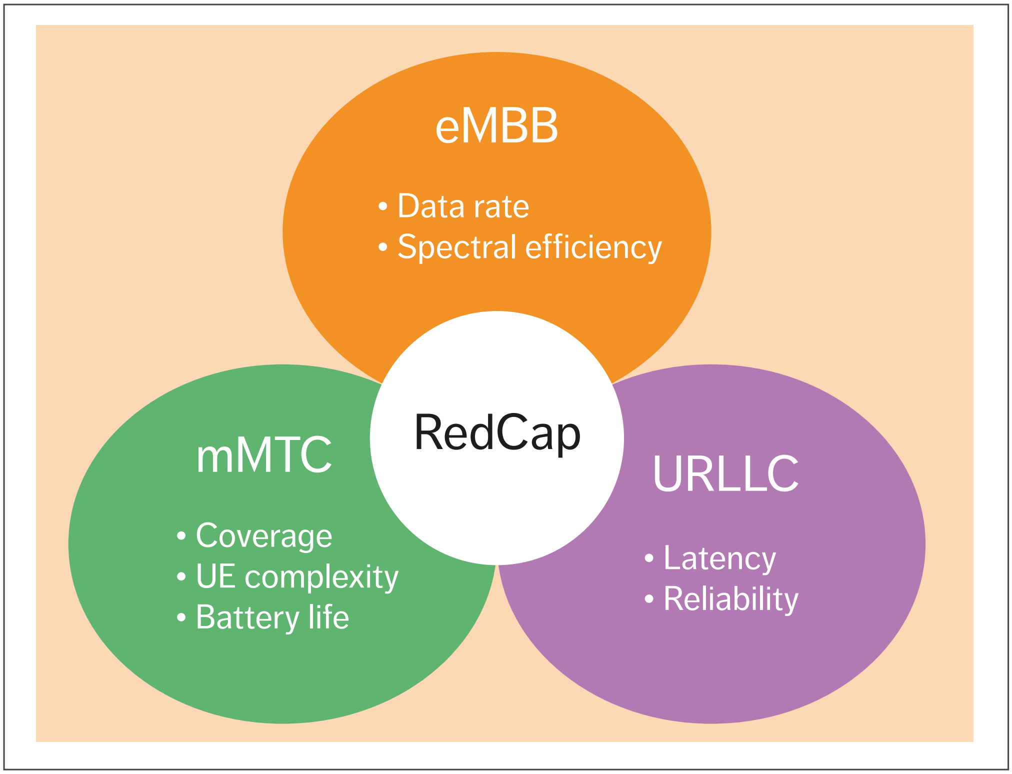

Figure 3 Rel-17 RedCap targets the requirement space between eMBB, mMTC and URLLC

will fulfill service requirements somewhere in between the relaxed massive machine-type communication (mMTC) requirements and highly stringent URLLC requirements, as shown in *Figure 3*. RedCap UE provides performance comparable to Rel-8 LTE UE but with additional benefits such as improved latency and the capability to operate in NR frequency bands ranging all the way up to 52GHz.

RedCap UEs are significantly less complex than regular NR UEs. This is thanks to a reduced number of radio receiver (RX) antenna branches, reduced RX and radio transmitter (TX) bandwidth and half-duplex operation, meaning that the UE is not required to transmit and receive at the same time. The reduced complexity is anticipated to result in a reduced device price point that will support the use of NR in new applications such as industrial sensor networks. The support of a single antenna branch will facilitate more compact device form factors, which is critical in popular wearable applications such as smart watches.

Non-terrestrial networks (NTN)

The NTN work in Rel-17 introduces new network topologies into the 3GPP specifications. These topologies are based on high-altitude platforms and low Earth orbit (LEO) and geosynchronous orbit satellites. NTN complements terrestrial networks with network coverage in remote areas over sea and

> THE MBS SUPPORT IN REL-17 REQUIRES SIGNIFICANTLY LESS OPERATIONS, ADMINISTRATION AND MAINTENANCE EFFORT

land where terrestrial coverage is absent. The work done by the 3GPP addresses NR, Narrowband-Internet of Things (NB-IoT) and LTE for Machine Type Communication (LTE-M), and it will thereby facilitate 3GPP NTN-based MBB and massive IoT services from Rel-17 onwards.

Rel-17 work builds on earlier studies performed in Rel-15 and Rel-16, where NTN channel models and necessary adaptations of the NR technology to support NTN were identified. The main challenges identified in Rel-16 and addressed in Rel-17 are related to the mobility and orbital height of the satellite. The height causes a high path loss and a large RTT. The mobility of an LEO satellite introduces a very high Doppler offset on the radio link, and it also inevitably requires all devices to frequently change their serving nodes. Rel-17 establishes basic mechanisms to manage these challenges and provides a first set of specifications to support NTNs based on NR, NB-IoT and LTE-M.

NR beyond 52.6GHz

Rel-16 supports operation in frequency range (FR) 1 and 2 covering the ranges 410MHz–7.125GHz and 24.25GHz–52.6GHz, respectively. In Rel-17, FR2 is extended beyond 52.6GHz all the way up to 71GHz using the existing NR downlink/uplink waveforms with the purpose of encompassing new licensed and unlicensed frequency bands in this range.

Operation in these bands does, however, affect several parts of the NR radio. It impacts the signal phase noise characteristics, the transmitter linearity, power efficiency and the receiver noise figure, among other things. However, the 3GPP has concluded that the use of new, advanced phase noise cancellation algorithms will make the Rel-15 physical layer (that is, the existing phase tracking reference signal and sub-carrier spacing of 120kHz) sufficiently robust to support this frequency range. Increased sub-carrier spacing of up to 960 kHz is still specified to allow the 3GPP to exploit even wider carriers of up to 2GHz and thereby unlock a new range of data rates.

Multicast and broadcast service

The MBS support in Rel-17 requires significantly less operations, administration and maintenance effort than its 4G predecessor, Evolved Multimedia Broadcast Multicast Service, as well as improving resource efficiency. 5G MBS is primarily intended to support important uses cases for public safety such as mission-critical push-to-talk, as well as enabling features like over-the-air software updates and live TV, video delivery and IoT solutions.

The 5G QoS framework is also applicable to 5G MBS traffic. It enables differentiated packet forwarding, which is crucial at high traffic load in the context of applications in the public safety domain.

Rel-17 also enables multicast sessions to UEs in RRC connected state, as well as broadcast sessions to UEs in RRC connected, inactive and idle states. The broadcast support for UEs in inactive and idle states is important to support maximum capacity for the broadcast service. Part of the feature is the support for group scheduling, mobility for service continuity and configurable feedback for reliability when needed.

Aside from those enhancements, to expedite the time to market, the MBS is facilitated by features and functionality that have already been specified. Implementation and configuration in a way that is transparent to the UEs is expected to enable the creation of single-frequency networks (SFNs).

3GPP release 18 – introducing 5G Advanced

The 3GPP RAN standardization team began discussing the scope of Rel-18 in June 2021 at the 3GPP RAN Rel-18 Workshop and aims for approval of the detailed scope by December 2021. Of the more than 500 proposals that were submitted to the workshop, Ericsson has identified what we consider to be the most important highlights and placed them in three categories.

Key enhancements for e-MBB use cases

Three of the most notable Rel-18 additions for eMBB use cases are beamforming/MIMO, mobility enhancements and network power savings.

Advanced antenna systems (AASs) are the main driver for increasing spectral efficiency of wireless networks, and they will continue to evolve due to factors such as enabling layer 1/layer 2 mobility, further improvements of uplink MIMO and enhancements related to fixed-wireless access applications.

DSS is extremely useful when transiting from 4G to 5G and many commercial networks already rely on it. To increase network efficiency during that transition, further enhancements are envisioned, such as improved NR performance when the number of LTE UEs decreases gradually, and reduced impact on NR performance due to interference from LTE broadcast signals.

Rel-18 also includes efforts to explore opportunities to further reduce network energy consumption.

Key enhancements for non-eMBB use cases

The most notable enhancements for non-eMBB applications (such as new or existing verticals) include RedCap, XR and national security and public safety (NSPS).

RedCap UEs are expected to play a significant role in many future applications. Based on Rel-17, Rel-18 RedCap solutions will further reduce device cost and power consumption. Solutions enabling energy harvesting, such as energy-efficient wake-up radios, will be investigated.

In Rel-17, the 3GPP RAN standardization team is studying various forms of augmented reality and virtual reality services and assessing their performance when operating through 5G. The main challenge is to simultaneously provide a very high data rate and low/bounded latency. In Rel-18, the 3GPP RAN group will look into traffic management

Terms and abbreviations

5GS – 5G System | **AAS** – Advanced Antenna System | **AI** – Artificial Intelligence | **CSI** – Channel State Information | **DNS** – Domain Name System | **DSS** – Dynamic Spectrum Sharing | **EASDF** – Edge Application Server Discovery Function | **eMBB** – Enhanced Mobile Broadband | **FR** – Frequency Range | **gNB** – gNodeB | **HST**– High-Speed Train | **IAB** – Integrated Access and Backhaul | **IIoT** – Industrial Internet of Things | **IoT** – Internet of Things | **LEO** – Low Earth Orbit | **LTE-M** – LTE for Machine Type Communication | **MBB** – Mobile Broadband | **MBS** – Multicast and Broadcast Service | **MIMO** – Multiple-Input, Multiple-Output | **ML** – Machine Learning | **MMTC** – Massive Machine-Type Communication | **mTRP** – multiple Transmission and Reception Point | **NB-IoT** – Narrowband-IoT | **NC-JT** – Non-Coherent Joint Transmission | **NF** – Network Function | **NPN** – Non-Public Network | **NR** – New Radio | **NR-U** – NR-Unlicensed | **NSPS** – National Security and Public Safety | **NTN** – Non-Terrestrial Networks | **NWDAF** – Network Data and Analytics Function | **PDCCH** – Physical Downlink Control Channel | **PDSCH** – Physical Downlink Shared Channel | **PDU** – Protocol Data Unit | **PHY** – Physical Layer | **PUCCH** – Physical Uplink Control Channel | **PUSCH** – Physical Uplink Shared Channel | **RAN** – Radio Access Network | **RAT** – Radio-Access Technology | **RedCap** – Reduced Capability | **RRC** – Radio Resource Control | **RTT** –Round-Trip Time | **RX** – Radio Receiver | **SFN** – Single-Frequency Network | **SNPN** – Standalone NPN | **SRS** – Sounding Reference Signal | **TRP** – Transmission and Reception Point | **TSC** – Time-Sensitive Communication | **TSN** – Time-Sensitive Networks | **TX** – Radio Transmitter | **UE** – User Equipment | **URLLC** – Ultra-Reliable, Low-Latency Communication | **URSP** – UE Route-Selection Policy | **V2X** – Vehicle-to-Everything | **XR** – Extended Reality

> 5G ADVANCED WILL ALSO INTRODUCE MORE INTELLIGENCE INTO WIRELESS NETWORKS

for resource-efficient and low-latency radio resource allocation, mobility support with consistent data rates, UE energy-efficient operation compatible with XR traffic and latency requirements.

Aside from automotive and industrial use cases, NSPS is the most prominent new vertical using 5GS. RAN enhancements for the remote control of drones and rogue drone detection are being considered to improve the situational awareness of first responders. Rel-18 will also further improve 5G's support for out-of-coverage scenarios by means of techniques such as UE-to-UE relaying.

Cross-domain functionalities for both MBB and non-MBB use cases

We also want to highlight three cross-domain functionalities that target both MBB and non-MBB use cases: AI/ML for physical layer (PHY) enhancements, AI/ML for RAN enhancements, and full duplex.

It is generally expected that AI/ML can significantly improve PHY performance. The RAN standardization will therefore explore the opportunities by setting up a general framework for AI/ML-related PHY enhancements, including proper AI/ML modeling, evaluation methodologies and performance requirements/testing. A first area for concrete AI/ML enhancement could be on beam management or channel estimation/prediction.

In Rel-17, one of the study items is to identify suitable use cases and corresponding AI/ML-based solutions for RAN. In Rel-18, enhancement for selective use cases from Rel-17 will be taken into the normative phase – that is, efficient traffic steering and load balancing. The focus will be on enhancements to current interfaces in the existing architecture. To incentivize vendor competitiveness, one goal is to ensure that AI models remain implementation-specific.

Despite the practical challenges and unclear performance potential, there is a proposal to study the feasibility of full duplex, where gNBs transmit and receive simultaneously on TDD frequency bands. The study will investigate the achievable gains and their dependency on cross-link interference and self-interference mitigation.

Conclusion

3GPP release 17 builds on previous releases with the aim of improving 5G System performance, supporting new use cases and verticals, and providing ubiquitous connectivity in different deployment conditions and scenarios. In the next phase, release 18 will create 5G Advanced, which will include new solutions and technology components that continue to boost network performance for mobile broadband and verticals.

5G Advanced will also introduce more intelligence into wireless networks by including suitable machine-learning-based techniques in different levels of the network. Future enhancements will also cover a wide variety of new verticals and use cases powered by artificial intelligence/machine learning technologies based on a single platform. As the work progresses, we are committed to ensuring that like 5G, 5G Advanced has the ability to support all use cases from one system design, focusing on forward compatibility and diverse configurability while ensuring maximum simplicity.

Further reading

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