3GPP Highlights

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NEWS

Crossing the bridge to 6G

Release 19 is all about 5G Advanced, with work continuing apace in the groups to ensure that the functional freeze of features is achieved by September, with the ASN.1 & Open API freeze completed by December 2025.

Looking beyond, from the new year, Release 20 (Rel-20) will take centre stage, with its emphasis on projects for both 5G Advanced and 6G. This dual-track framework will allow 3GPP groups to innovate within 5G-Advanced, while simultaneously initiating the research phase for 6G.

Rel-20 is therefore more than just an incremental upgrade — it is the bridge between today's networks and the transformative potential of 6G.

Following on from the 3GPP 6G workshop - in Incheon (March 10 – 11), studies in WG SA1 on the 6G Use Cases and Service Requirements (SP-241391) and in TSG RAN on 6G Scenarios and Requirements (RP-243327) are underway. Further Rel-20 technical 6G studies will start in June 2025 (under discussion at the time of writing).

Rel-21 will be the official start of normative work on 6G, producing the first 3GPP technical specifications. The Rel-21 timeline is expected to be finalized by June 2026, with the ASN.1 & Open API freeze projected no earlier than March 2029.

FORE - WORD

Welcome to the tenth issue of 3GPP Highlights, a newsletter that depends on contributions from the membership and the partners, via articles that are intended for a readership of fellow experts in the technical groups as well as newcomers to 3GPP - who might be inspired to come in for a closer look

There is no single technical theme to an issue of Highlights, the content comes from across the groups, documenting the quarterly progress towards the completion of the last release, the work on the current release and the march forward to the next. In this issue we cover a variety of projects across Rel-18, Rel-19 and Rel-20.

At the recent TSGs#107 plenaries in Incheon, I looked around me and thought back to Issue 1 of Highlights, published in September 2020. Then, the focus was on Rel-16 work, but there was a bigger story to cover. In that first issue we were mirroring the concerns of the community and documenting the way that delegates were coping with a new work / life balance which involved working in isolation, attending e-meetings across time zones and dealing with a variety of local restrictions due to the COVID pandemic.

On March 10, 2025 things were so much better. Over one thousand experts were able to sit together in Incheon for the Rel-20 6G workshop, mask-less and in 'normal' proximity. The cover photo of this issue includes an image of that room. Five years on from the start of the pandemic, we are in a good place. Each issue of Highlights has covered this steady return to F2F meetings and normality, as well as covering the last release, the work on the current release and the march forward to the next.

As always, we hope that you enjoy this new issue of 'Highlights'. If so, please tell a friend to subscribe. If not, please tell me and I will work to be better next time.

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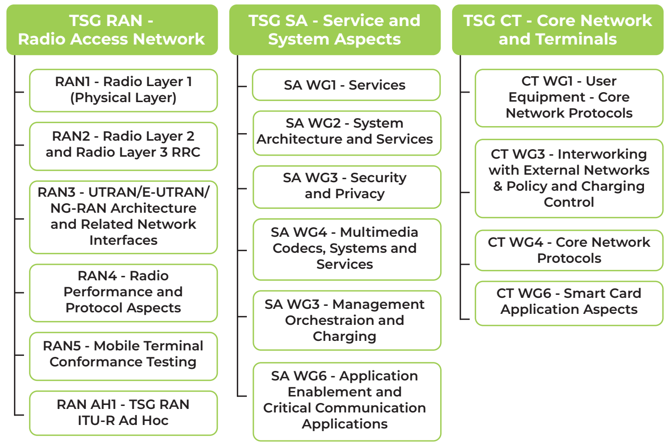
SA2 Roles & Responsibilities

By Andy Bennett, 3GPP WG SA2 Chair

3GPP, and WG SA2, is at a critical point, planning what will be done in the next two years in the continuation of 5G Advanced development and the start of work on 6G. For the first time in ten years SA2 will face the challenge of enhancing the architecture of one generation while developing the architecture of a new one.

SA2 is the Working Group responsible for the overall System Architecture of the Core Network part of the 3GPP system. The group defines the functionality of Network Functions (NFs) and how they interact with other NFs. Each release of the specifications brings new functionality and services, requiring updates to existing NFs, or new NFs, and new or updated interactions between them.



▾ Relationships with other groups

3GPP's waterfall model of specification development involves three stages: Stage 1 (service requirements), Stage 2 (architecture) and Stage 3 (protocols). For the Core Network there is one Stage 1 group, SA1, that provides requirements that define what the system does, but not how this is achieved.

The 'how' is the responsibility of the Stage 2 and Stage 3 groups. The Stage 2 groups (SA2, SA3, SA4, SA5, SA6) work on different aspects of the architecture required to support the Stage 1 requirements. The Stage 3 groups (CT1, CT3, CT4, CT6) take the Stage 2 architecture and define the protocols required to support this architecture.

That is the simple view of how 3GPP works. In practice there are exceptions to the above. For example, CT1 specifies some Stage 2, and SA6, SA3, SA4 also have Stage 3 responsibilities). In addition, the differences between Stage 1, Stage 2 and Stage 3 can sometimes be uncertain, and of course alignments between the specifications owned by different groups are needed.

For these reasons there is a need for frequent communication between the working groups and with the parent bodies (TSG SA and TSG CT).

▾ Release 19 - Maintenance

The Release 19 Stage 2 freeze milestone was in December 2024. Beyond that point new Stage 2 functional changes by SA2 were only permitted with the approval of the SA Plenary. Some work items have continued with limited new work allowed - until March 2025. In addition, a decision was made in December to do some normative work on Ambient power-enabled Internet of Things in Release 19. This work will complete in June 2025.

Since December 2024 SA2's focus has shifted to Release 19 maintenance work (correction of the specifications, alignment between specifications) and preparation for Release 20.

Rel-19 SA2 work items: There is always a broad range of work carried out by SA2 and the work items listed below show that Release 19 is no exception.

Work Items		TEI19 / Mini-WIDs	
Acronym	**Title**	**Acronym**	**Title**
EnergySys	Energy Efficiency and Energy Saving	TEI19_OBGAD	On-demand broadcast of GNSS assistance data
AIML_CN	Core Network Enhanced Support for Artificial Intelligence (AI)/Machine Learning (ML)	TEI19_MINPA	Stage 2 of Minimize the Number of Policy Associations
5GSAT_Ph3-ARC	Integration of satellite components in the 5G architecture Phase III	TEI19_SLUPiR	Spending Limits for UE Policies in Roaming scenario
XRM_Ph2	Extended Reality and Media service (XRM) Phase 2	TEI19_IP_SP_EXP	Enhancing Parameter Provisioning with static UE IP address and UP security policy
UPEAS_Ph2	UPF enhancement for Exposure And SBA Phase 2	TEI19_MLR4RTR	Multiple Location Procedure for Emergency LCS Routing
eEDGE_5GC_Ph3	Enhancement of support for Edge Computing in 5G Core network - Phase 3	TEI19_HSBO	Roaming traffic offloading via session breakout in HPLMN
MASSS	Multi-Access (ATSSS_Ph4)	TEI19_DLPMR	Deferred 5GC-MT-LR Procedure for Periodic Location Events based NRPPa Periodic Measurement Reports
NG_RTC_Ph2	System architecture for Next Generation Real time Communication services Phase 2	TEI19_NetShare	Indirect Network Sharing
UAS_Ph3	UAS, UAV and UAM Phase 3	TEI19_RVAS	Architecture support of roaming value-added services
5G_Femto	System aspects of 5G NR Femto	TEI19_ProSe_NPN	ProSe support in NPN
5G_ProSe_Ph3	Proximity-based Services in 5GS Phase 3	TEI19_QME	QoS monitoring enhancement
VMR_Ph2	Vehicle Mounted Relays Phase 2	TEI19_TIME_SUB_EPS	Subscription control for reference time distribution in EPS
UIA_ARC	Identifying non-3GPP Devices Connecting behind a UE or 5G-RG	TEI19_VLANSUB	Providing per-subscriber VLAN instructions from UDM and DN-AAA
MPS4msg	MPS for IMS Messaging and SMS services	TEI19_NFsel_by_tPLMN	NF discovery and selection by target PLMN
AmbientIoT-ARC	Architecture support of Ambient power-enabled Internet of Things	TEI19_SliceSel	Network Controlled Network Slice Selection
		TEI19_PRUE	PRU Usage Extension supported by Core Network

▾ Release 20 – A question of time

For recent releases SA2 has planned based on a capacity of 36 Time Units (TUs) per working group meeting. This requires three WG Streams to run in parallel for most of the first three days of each meeting. After day three (Wednesday) the meeting works only on revisions of input documents opened in the first three days. These revision sessions are not included in the capacity calculation.

Session	Stream	Monday	Tuesday	Wednesday
Q0	1		Drafting	Drafting
	2		Drafting	Drafting
	3		Drafting	Drafting
Break				
Q1	1	Opening of meeting	TU 13	TU 28
	2		TU 14	TU 29
	3		TU 15	TU 30
Break				
Q2	1	TU 1	TU 16	TU 31
	2	TU 2	TU 17	TU 32
	3	TU 3	TU 18	TU 33
Lunch				
Q3	1	TU 4	TU 19	TU 34
	2	TU 5	TU 20	TU 35
	3	TU 6	TU 21	TU 36
Break				
Q4	1	TU 7	TU 22	Revisions
	2	TU 8	TU 23	Revisions
	3	TU 9	TU 24	Revisions
Break				
Q5	1	TU 10	TU 25	Work Planning (30.x)
	2	TU 11	TU 26	
	3	TU 12	TU 27	

All work for the new release and all maintenance work for previous releases must be planned within the 36 TUs per meeting.

The overall capacity available during a release is therefore the number of meetings in the release timeframe multiplied by the capacity per meeting. This is split between new release work, maintenance work, and a buffer.

Between March 2025 (start of Release 20 work in SA2) and September 2026 (Stage 2 freeze for Release 20) there are 9 meetings of SA2 planned and the split of TUs is shown below.

	Time Units (TUs) Planned
TU Count (9 meetings X 36 TUs)	324
TUs for pre Rel-19 Maintenance	29
TUs for Rel-19 Maintenance	62
YUs for Rel-20 Study & Work Items	156
Buffer TUs	77

Determining what comprises the new release work is a joint effort between TSG SA Plenary and WG SA2. The SA Plenary discusses potential work areas and decides on a list of them, to go forward. SA2 is then asked to draft, discuss and agree Study Item or Work Item Descriptions (SIDs or WIDs) that contain a list of Work Tasks that are required in each case, and an estimate of the TUs required for the work.

These SIDs and WIDs are discussed by SA Plenary and approved, or not. Even if SA Plenary approve a SID or WID it might be down-scoped. At the end of the SA Plenary meeting that determines the overall release content (June 2025 for Release 20) there will be a set of SA2 SIDs and WIDs that fit within the TU budget.

Rel-20 5GA Stage 2 SID planning

For Release 20 SA Plenary decided on a list of 5G Advanced topics in December 2024 and sent this list to SA2:

Rel-20 5G Advanced Topics

Integration of satellite components in the 5G architecture Phase 4	AI/ML Enhancements
Integrated Sensing and Communication	Energy Efficiency Enhancements
Enhancements for ePDG based access to 5GC	Industrial network enhancements
XR and Media Services	Indirect Network Sharing Phase 2
Mission Critical Services, Multimedia Priority Services	NG_RTC continuation
Ambient IoT	User Identities and Authentication Architecture – Phase 2
SMS to Emergency Centre	

WG SA2 has used a variety of means (face to face sessions, drafting sessions, conference calls and moderated discussions via email or the New Working Methods tool (NWM) to draft, discuss and agree SIDs and WIDs in the first half of 2025. Four SIDs were agreed by SA2 in February and approved by SA Plenary in March, and technical work started in the SA2 meetings in April and May. SA2 will discuss SIDs and WIDs related to the other topics in May, and any agreed will be sent to the June SA Plenary for discussion.

A difference for Release 20 compared to recent releases is that there will be two categories of new work: 5G Advanced study and normative work, and 6G study work. The final content for 5G Advanced will therefore be dependent on how many TUs are allocated for 5G Advanced and how many for 6G.

This division of TUs is yet to be determined.

Rel-20 SA2 6G SID - what we know so far

A workshop attached to the TSG meetings in March 2025 gave a chance for companies to share their ideas and priorities for 6G, across RAN and SA. Following the workshop SA2 invited companies to submit their priority work areas for the Working Group, include technical descriptions of Work Tasks that would be required (at the level of detail that would be needed for inclusion in a 6G SID).

During the April 2025 SA2 meeting intensive discussion of a summary of these inputs resulted in a document that has now been used as the basis for starting a moderated discussion ahead of the SA2 meeting in May. Analysis of the company inputs to this moderated discussion will lead to at least one draft 6G SID being submitted to the May 2025 WG SA2 meeting. During that meeting SA2 will aim to agree a 6G SID and submit it to the TSG SA Plenary meeting in June.

The following potential work areas have been identified for further discussion in the May 2025 WG SA2 meeting, in Fukuoka:

Rel-20 6G Potential Topics

System architecture requirement, principle and assumption	QoS framework
System Architecture	Policy framework
Migration and interworking	IMS enhancement
AI aspects	Legacy service
Common Data framework	Immersive service
Sensing	NTN
Computing	Non 3GPP access
Distributed Autonomous Network	User consent framework
NAS and other UE-Core network interaction	6G IoT
SBA enhancement	System aspect for security

Once the 6G SID is approved by SA Plenary the technical work can start. The TU budget available for this will depend on the split between 5G Advanced and 6G as mentioned above. Because only study work will be carried out in the Release 20 timeframe, the 6G study can continue beyond the Stage 2 freeze (September 2026) and so there will be more meetings available for the work. The date for completion of the study is yet to be finalized by SA Plenary, but will be no later than March 2027. SA Plenary will review the SA2 6G SI completion date in December 2025 and make a final decision on whether finalization will be in December 2026 or March 2027.

The additional TU budget and number of meetings compared to a typical item (study work, followed by normative work) should allow time at the start of the study to discuss concepts, use cases, key issues and architectural assumptions in more detail and provide a solid platform for the later part of the study.

Release 21

The 6G work in Release 20 is critical to the development of 6G, but is only the first stage. As the SA2 6G study approaches completion, preparation work (discussion of candidate Work Item Description(s)) will start for the normative work in Release 21 so that this can start in a timely way. By the middle of 2026 SA2 is expected to be hard at work on the normative 6G specifications.

Release 21 normative 6G specification work is expected to align with the IMT-2030 submission window. To that end the timeline for Release 21 is anticipated to be finalized no later than June 2026 (the ASN.1/OpenAPI freeze is projected to be by March 2029).

In addition to the 6G normative work in Release 21 there may also be further development and enhancement of the 5G Advanced architecture, and continued maintenance of previous releases, so planning complexities similar to Release 20 can be expected.

In Summary

The planning of a 3GPP release is a complex process involving much effort within and across the Working Groups and TSGs. This is especially so, and especially important, as we start the development of a new 3GPP generation. The above gives a brief insight into WG SA2's part in this.

For more from WG SA2: **www.3gpp.org/3gpp-groups**

Split rendering over IMS

By Shane He (WI Rapporteur, Nokia), Srinivas Gudumasu (InterDigital), Saba Ahsan (SA4 RTC SWG Chair)

In Release 19, 3GPP provides enhanced split rendering support over the IP Multimedia Subsystem data channel for a wider range of XR media applications and with new features for optimization

Split rendering is a technique where the processing of XR content is distributed between the user device (e.g., AR glasses) and the network (e.g., edge or cloud servers) in order to reduce the computational load on the device. Split rendering can improve the user experience for devices with limited computation by leveraging the network's processing capabilities as well as reduce battery consumption on the end device.

With Rel-18, IMS-based AR real-time communication (TS 26.264) introduced support for split rendering. In Rel-19, SA4 has defined a generic split rendering service for XR media, including real-time and non-real-time XR, in TS 26.567. The new specification utilizes the IMS data channel for providing the split rendering service and adds new features for improved performance.

Key use cases enabled by this specification include XR services in industrial (e.g., for monitoring, maintenance, collaboration, and teleoperation), enterprise and educational environments; entertainment use-cases, including cloud-gaming, and shared and collaborative entertainment and productivity XR services, where users gather in a shared space and interact with each other and with the environment.

Figure 1 illustrates how the split rendering functions are mapped to a generalized IMS DC (Data Channel) architecture. A Split Rendering DCMTSI Client (SR-DCMTSI) is an MTSI client, as specified in TS 26.114, that additionally supports IMS data channel for split rendering capabilities. The Media Function (MF) is responsible for interacting with clients during the split-rendering process, managing resources, and running the rendering process.

The DC Application Server (AS) controls split-rendering services, including session media control and capability negotiation. TS 26.567 provides codecs and media transport protocols for delivery of split-rendered media and metadata of the split rendered content. Furthermore, it contains procedures of split rendering session establishment, modification and adaptation. In addition, the specification provides the list of QoE metrics that can be collected and reported from an SR-DCMTSI client and the configuration information required for enabling QoE metrics collection and reporting feature.

Overall, 3GPP TS 26. 567 serves as a comprehensive guide for network operators, service providers, media application providers and equipment manufacturers to develop and deploy IMS-based multimedia telephony services for split rendering, ensuring consistent performance and interoperability across the ecosystem. It is expected to bring several significant impacts and benefits for the operators as well as users, e.g.:

- **Enhanced User Experience:** Split rendering allows for more efficient processing and rendering of multimedia content by distributing the workload between the client and the server. This can lead to smoother and higher-quality multimedia experiences for end-users, particularly in applications like augmented reality (AR), virtual reality (VR) and extended reality (XR). Adaptation of rendering tasks between the end device and network ensures the final rendering is optimized based on network conditions and capabilities.
- **Reduced Latency:** By offloading some of the rendering tasks to the server, split rendering can reduce the latency experienced by users. This is crucial for real-time applications such as gaming, video conferencing, and interactive media, where low latency is essential for a seamless experience. The MF can adjust the processing delay involved in the split-rendering processing tasks based on the end-to-end latency metrics and provides better quality of experience to the users.
- **Optimized Network Utilization:** Split rendering can efficiently use the network resources by offloading the complex processing tasks to servers and can optimize the network resources usage by reducing the amount of data that needs to be transmitted over the network. This is achieved by sending only the necessary data for rendering, rather than the entire multimedia content, especially by split adaptation. This can lead to more efficient use of bandwidth and reduced network congestion.
- **Device Accessibility:** Operators can enable running XR services on devices with lower processing power by leveraging server-side rendering capabilities where the server renders the full XR scene. This can lower the cost of devices for end-users and make advanced multimedia services more accessible for new lightweight devices like the AR glasses.
- **Interoperability and Standardization:** the deployment of split rendering functions in current IMS systems can lead to improved performance, efficiency, and user satisfaction, while also providing operators with opportunities for innovation and differentiation in the competitive telecommunications market.

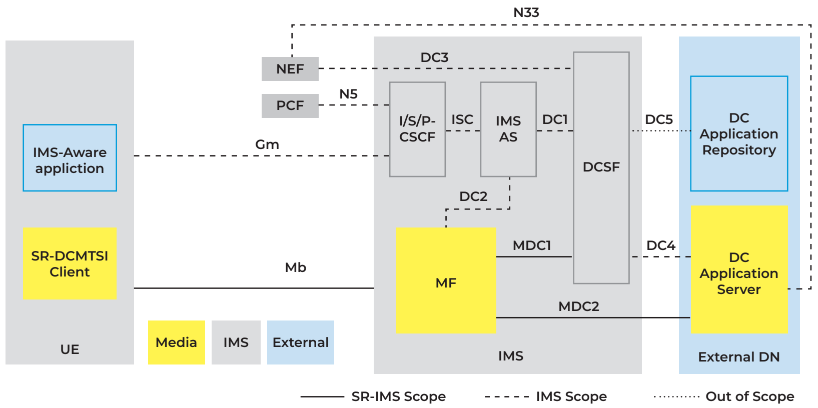


Figure 1: Generalized IMS DC Architecture to support split rendering

Avatar Communications in 3GPP: Enabling Immersive AR Calls

By Imed Bouazizi and Thomas Stockhammer (Qualcomm)

In recent years, Augmented Reality (AR) has witnessed a transition from a niche technology into a mainstream phenomenon, significantly enhancing real-time communications (RTC) with richer and more engaging user experiences.

As AR services proliferate across various devices and form factors, integrating avatars into real-time AR calls has emerged as a critical advance. Recognizing this potential, 3GPP has recently completed the FS_AVATAR study in Release 19, laying essential groundwork for the standardized deployment of avatars within immersive AR communications.

Following this foundational study, the AvCall-MED normative work item was approved to advance avatar integration specifically within IMS-based AR calls. This targeted initiative aims to standardize the representation, animation, and signaling protocols essential for enabling both 2D and 3D avatar communications, thus ensuring broader interoperability among service providers, developers, and end users.

Foundations from FS_AVATAR Study

The FS_AVATAR study, documented in 3GPP TR 26.813, extensively explored the technical landscape necessary for effective avatar communication. Key insights included defining robust avatar representation formats, efficient methods for streaming avatar animations, and establishing essential signaling mechanisms. The study emphasized the necessity of achieving seamless compatibility with existing AR-capable devices such as smartphones, AR glasses, and head-mounted displays (HMDs).

Due to the complexity of this feature, the study's conclusions recommended Release 19 work to focus initially on enabling 1-to-1 avatar communications. This approach will expedite implementation and adoption, providing a robust foundation upon which more complex multi-party scenarios can subsequently be developed.

Avatar Representation Format (ARF)

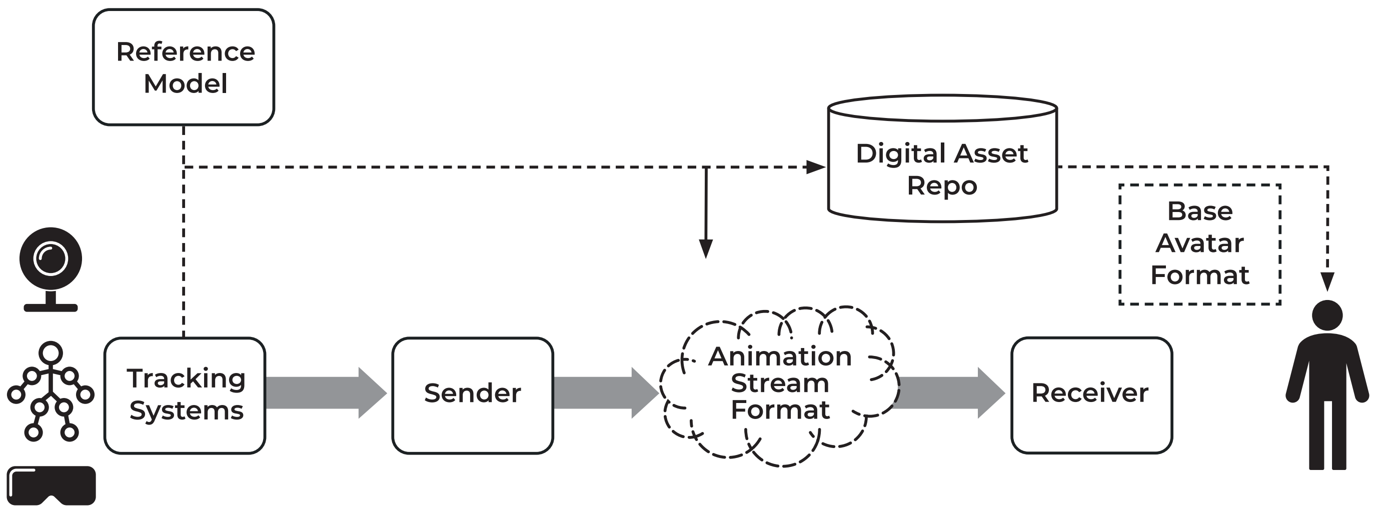
A central element of this initiative is the introduction of the MPEG Avatar Representation Format (ARF), standardized as ISO/IEC 23090-39. ARF defines a structured and interoperable framework for avatar data representation, including geometric models, skeletal structures, blend shapes for facial expressions, textures, and animation data. This standard ensures avatars are consistently rendered and animated across diverse devices and services, enhancing user experience and service consistency.

ARF supports two container formats: ISOBMFF (ISO Base Media File Format) and ZIP-based containers, enabling efficient and partial access to avatar components.

Objectives of AvCall-MED

In alignment with FS_AVATAR findings and 3GPP WG SA2 architectural enhancements, AvCall-MED targets three main deployment scenarios for avatar communication: Receiver-driven, Sender-driven, and Network-driven avatar rendering and animation.

For Receiver-driven avatar communication, AvCall-MED will extend TS 26.264 by specifying the essential formats, signaling protocols, and animation streams tailored for IMS-based AR calls. The animation streams are designed in a way to interoperate with XR runtimes, such as OpenXR [2]. This approach is depicted by the figure below.



In the case of Sender-based avatar communication, AvCall-MED will leverage existing TS 26.114 and TS 26.264 standards. Here, sender devices animate avatars locally, transmitting a final rendered stream. Guidelines will be established to optimize this method, including optional pose data exchange mechanisms. These will be crucial when the receiver's viewpoint or interactions directly influence avatar rendering on the sender's side.

For scenarios utilizing Network-based avatar rendering, AvCall-MED will introduce additional extensions to TS 26.264. These will define formats and signaling required for base avatars and animation streams, alongside capabilities for signaling and format negotiation to facilitate Media Function (MF)-based animation and rendering within the network. Network-driven rendering offers distinct advantages, especially for thin AR glasses or other resource-constrained devices, by shifting computational demands onto the network infrastructure.

IMS Architecture Extensions in TS 23.228

To fully support avatar communications, extensions to the IMS architecture have been introduced by 3GPP WG SA2 in TS 23.228. These enhancements define additional signaling and session management capabilities required for handling avatar-related information flows within IMS-based services. These architectural updates ensure the seamless integration of avatar communication functionalities, allowing avatars to be efficiently exchanged, animated, and managed within existing IMS frameworks.

An important enhancement to the architecture is the Base Avatar Repository (BAR) element, which is reposible for the secure storage and management of base avatars, allowing participants in an AR call to access the sender's base avatar for animation.

AvCall-MED is considering the development of an interface to the BAR to facilitate secure management and controlled access to avatar assets. This interface will enable service providers and users to store, retrieve, and dynamically update their avatar data securely and efficiently, significantly streamlining asset management across diverse AR applications and platforms.

Conclusion and Future Work

The AvCall-MED work item represents a significant advancement in 3GPP's ongoing efforts to enrich RTC through immersive technologies. By addressing core technical requirements for avatar representation, animation, and management using the ARF format and IMS architectural enhancements, AvCall-MED establishes a robust foundation for the future proliferation of immersive communication services.

As follow-up to this work, we anticipate studying the aspects and traffic characteristics of more advanced Avatar representation and animation. The focus will be on the quality of experience, security, and UE characterization for a realistic looking avatar communication experience.

[1] 3GPP TS 26.813: "Study of Avatars in Real-Time Communication Services".
[2] The OpenXR™ Specification 1.1, The Khronos® OpenXR Working Group
[3] 3GPP TS 26.264, "IMS-based AR Real-Time Communication"
[4] 3GPP TS 23.228, "IP Multimedia Subsystem (IMS); Stage 2"
[5] ISO/IEC 23090-39:2025 Information technology, Avatar Representation Format.

For more from WG SA4: www.3gpp.org/3gpp-groups

Release 19 Ambient IoT

By RAN1 A-IoT Rapporteurs; Xiaodong Shen (CMCC) and Matthew Webb (Huawei)

3GPP is developing new IoT technologies supporting passive devices - battery-less or with limited energy storage - powered by harvesting ambient energy from the environment, with ultra-low complexity and small form factor.

The new IoT technology will provide complexity and power consumption orders-of-magnitude lower than the existing 3GPP LPWA technologies (e.g. NB-IoT and eMTC) and will address use cases and scenarios that cannot otherwise be fulfilled based on existing 3GPP LPWA IoT technologies.

In Release 18 WG SA1 and TSG-RAN analyzed use cases, deployment scenarios, traffic, connectivity topologies, device constraints, service requirements, KPIs, design targets, and required functionalities for Ambient IoT solutions. A follow-up Study Item (SI) in Rel-19 explored more-detailed radio aspects. It is worth noting that WGs SA2 (Architecture) & SA3 (Security and Privacy) are also carrying out studies in their areas.

The WG RAN1 Rel-19 A-IoT Work Item (WI) focuses on two representative use cases, i.e. indoor inventory (rUC1) and indoor command (rUC4) defined in TR38.848. Deployment scenario 1 with Topology 1 (D1T1) is considered, where D1 refers to device and base station reader (BS) indoors, and T1 refers to device directly and bidirectionally communicates with the BS reader. The targeted spectrum is FR1 licensed FDD spectrum, with R2D in DL spectrum and D2R and carrier-wave in UL spectrum.

The overall Rel-19 objective is to standardize the so-called A-IoT 'device 1', which has ~1 μW peak power consumption, energy storage, RF envelope detector receiver, initial sampling frequency offset (SFO) up to 105 ppm, neither R2D nor D2R amplification in the device. The device's D2R transmission is backscattered on a carrier wave (CW) provided externally.

Rel-19 A-IoT supported traffic types include Device-terminated (DT) and Device-originated device-terminated triggered (DO-DTT). Device-originated autonomous (DO-A) is not supported due to active transmission in D2R not being supported.

The A-IoT devices envisioned for Rel-19 consume tiny amounts of power, at very low cost. This will be achieved using components with wide manufacturing tolerances and variability under environmental conditions e.g. by temperature profile. They will contain no active RF components with their device-to-reader (D2R) transmissions done via passively modulating an external RF carrier wave using simple circuitry - powered for a short time from stored energy.

The stored energy can be harvested from ambient RF, thermal or dedicated energy supply nodes. This aspect is unspecified in Rel-19. The device's receiver, for R2D, is typically a very simple envelope detector, which can detect how the overall power of the signal varies, but cannot detect any detailed structure of it, unlike conventional UEs which can decode complicated OFDM signals.

The Study Item generated a reference architecture for device 1, shown in Figure 1. More advanced devices were also studied, which included adding a reflection amplifier to the passive device (2a), and also very low-cost active devices (2b). The standardization of some of those concepts is targeted for Rel-20.

Such a device architecture requires the simplest modulations. In R2D, square-wave on-off keying (OOK) is used, and in D2R the device chooses from OOK or BPSK, both based on square wave signals. Although the R2D design is based on OFDM from the reader transmitter's point of view, this is to allow convenient co-generation with NR. Many steps of the conventional 3GPP L1 are removed to accommodate the device's low power: in both R2D and D2R, there is no scrambling, interleaving, MIMO, separate control channels, L1 HARQ, nor use of complex numbers in designing signals. There is no channel coding in R2D, to avoid device processing load, but the LTE convolutional code is used in D2R, to benefit from the sophisticated reader's receiver.

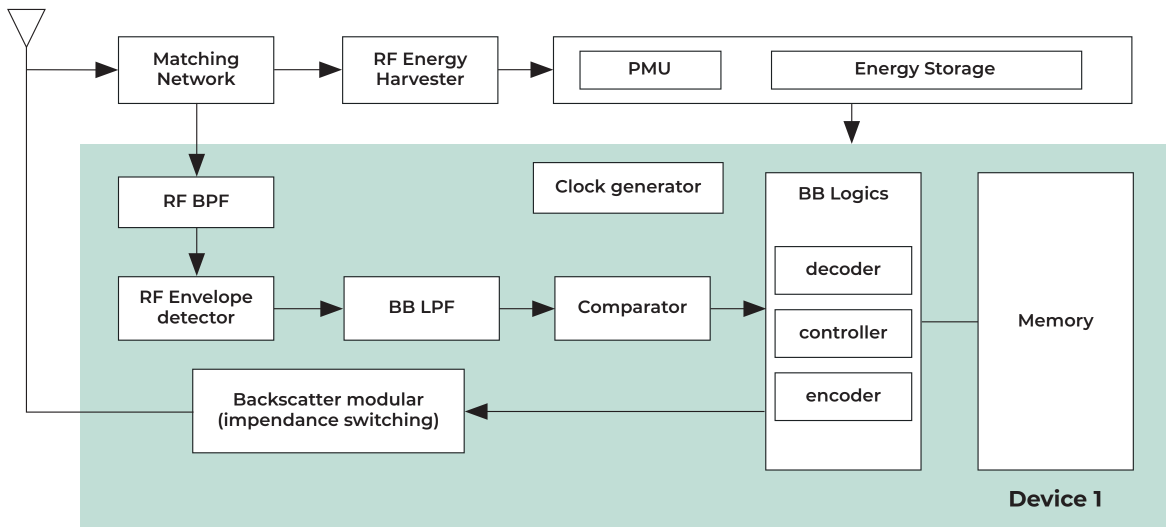


Figure 1: Architecture of Ambient IoT device 1

Manchester line-coding is used in R2D and D2R, which does not have a comparable step in NR. This takes the square-wave modulation and inserts additional frequent ON-OFF signal transitions. In R2D the device's receiver can use these edges as a timing reference of the high-quality timing reference in the BS transmitter to adjust its internal receiver clock to maintain tracking. This removes any need for absolute synchronization between reader and device. In D2R transmissions, a binary sequence-based preamble and periodic midamble (e.g., m-sequence) are inserted to allow the reader to keep track of the device's clock drift.

R2D multiplexing is only TDMA. The reader can vary the R2D data rate by modulating the OOK square wave at different rates – this does not permit FDMA, due to the wideband envelope detector in the device. For D2R, the line-code can be used to effectively repeat an information bit at a faster rate, and create a higher-frequency square wave, allowing devices to be frequency-separated according to their repetition rates i.e., FDMA. This provides higher capacity during an inventory procedure with hundreds of devices to read in a few seconds.

The overall access scheme of A-IoT is network-triggered, so a device only responds to a transmission from the reader. D2R access is based on slotted-ALOHA, a long-known protocol providing simple randomization and back-off among multiple addressed nodes contending for resources in the time domain. There is also a contention-free access when a particular device is targeted. The protocol layers for A-IoT remove the vast majority of L2 and L3: there is no RRC, PDCP, SDAP, ARQ, mobility, AS security, and other traditional higher-layer functions. The concept of paging is retained, by which the network indicates the beginning of e.g. an inventory process.

There is a new network architecture, shown in Figure 2, introducing the 'A-IoT Function' (AIOTF) which can communicate directly with the RAN, or indirectly via an AMF. The AIOTF is the termination of the NAS protocol with the device. It manages the services relating to triggering RAN operations, and other aspects relating to transfer of information between an application and the RAN or device

A globally unique A-IoT permanent device identifier is allocated to each device. The identifier has several parts to it, which can correspond to e.g. a PLMN ID, information type ID, electronic product code (EPC) etc.

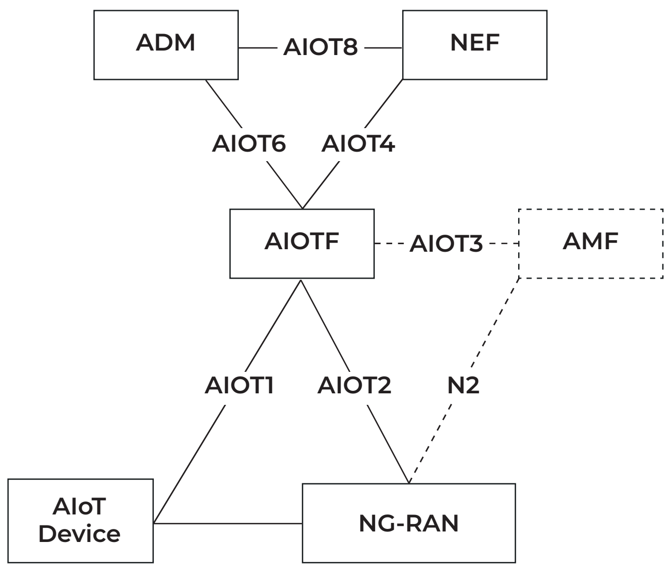


Figure 2: Non-roaming Ambient IoT System architecture in reference point notation

The CN can indicate different matching 'masks' to address subsets of the devices based on those parts of the ID, and only matched devices respond with e.g. their EPC or other stored information. The structure of a permanent device ID is shown in Figure 3.

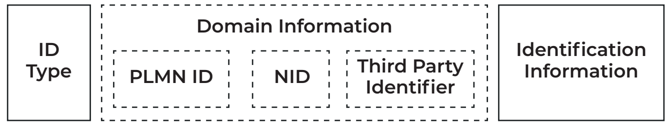


Figure 3: Ambient IoT Device Permanent Identifier Structure

In Rel-19, WG RAN4 studied the RF requirements impact, CW interference cancellation feasibility, testability issues for an A-IoT device, and co-existence between A-IoT and NR. RAN4 first discussed the deployment scenario for co-existence and decided to focus on macro BS outdoor and A-IoT system indoor. Depending on different spectrum usage and interference conditions, RAN4 evaluated co-existence between A-IoT and NR for 36 interference cases. According to the evaluation results, co-existence between NR and A-IoT system is feasible. In some cases, the interference from another system (NR or A-IoT) is negligible, while in other cases, interference is observed and some potential mechanisms to mitigate the interference are required. Details can be found in TR38.769.

Finally, evolution targeting more advanced devices is expected to significantly enhance key performance metrics including coverage, capacity, and data rates. With higher permitted device power consumption and complexity, whilst remaining orders of magnitude below 3GPP's LPWA technologies, active D2R transmission with internally generated signals can provide superior coverage performance, and Zero-IF/IF receivers exhibit better link performance compared to RF envelope detectors.

Although Topology 2 - which enables intermediate UEs to function as a reader by relaying to a BS - is not included in Release 19, its potential incorporation in Release 20 could expand the application scope of A-IoT. It is expected that the deployment of A-IoT solutions on licensed spectrum will introduce novel capabilities and create new market opportunities in the future.

AI/ML for NG-RAN & 5G-Advanced towards 6G

By 3GPP RAN3 Leadership: Yin Gao, Angelo Centonza, Gen Cao

Working Group RAN3 completed Rel-18 normative work in Q4 2023, while Rel-19 work items started in Q2 2024 and normative work is ongoing. Data collection enhancements and signaling support over existing 5G network interfaces are specified in the Rel-18 AI/ML for NG-RAN Work Item (WI) based on the study carried out in 3GPP Rel-17 and optimization.

A framework for RAN intelligence has been described in 3GPP TR 37.817, as shown in Figure 1. The Data Collection function provides input data to Model training and Model inference functions. Examples of input data may include measurements from UEs or different network entities, feedback from Actor, output from an AI/ML model. Achieving efficient and valid data collection and management is the key to guaranteeing good performance of AI/ML training and inference in both 5G and 6G.

After the completion of Rel-18 AI/ML WI, a new study item is launched in Rel-19 to investigate AI/ML support for new use cases, namely Network Slicing, Coverage & Capacity Optimization (CCO). The study also considers the support of objectives that were not fulfilled in Rel-18; including continuous MDT collection - targeting the same UE across RRC states, mobility optimization for NR-DC and split architecture support.

A new Work Item was triggered in RAN3 for Rel-19 on AI/ML for NG-RAN, resulting from the related Rel-19 study. It concentrates primarily on three key objectives: AI/ML-assisted Network Slicing, AI/ML-assisted CCO and the Rel-18 leftovers identified during the study phase. For AI/ML-assisted Network Slicing, RAN3 has specified predicted slice-level information within the Data Collection procedure as well as collection of per slice UE performance feedback information. Regarding AI/ML-assisted CCO, enhancements have been made by introducing future CCO states and associated predicted CCO issues into the Xn and F1 interfaces. Additionally, concerning split architecture support, an agreement has been reached to transfer measured EC from the gNB-DU to the gNB-CU, while discussions are ongoing on how to enable transferring of UE performance feedback from the gNB-DU and gNB-CU-UP to the gNB-CU-CP. Furthermore, an identifier has been incorporated into the Dual Connectivity procedure to trigger the collection of UE performance metrics in support of NR-DC use cases.

On Continuous MDT, RAN3 triggered a Liaison Statement (LS) exchange with WG SA5, continuing the discussion on solution design. RAN3 emphasized that solutions developed for continuous MDT should minimize the impacts on the existing Management-Based MDT framework and should enable correlation of MDT measurements collected form the same UE while moving across different RRC states.

There have been some discussions on the potential Rel-20 AI/ML for NG-RAN for 5G-A during RAN#106 (Madrid, December 2024). A Way Forward was endorsed stating that Rel-20 AI/ML for NG-RAN for 5G-A should be based on the current 5G architecture and interfaces. While potential new AI/ML based use cases including QoE Optimization, Network energy saving and Mobility (including Multiple-hop target node UE trajectory) need to be down-scoped in the June 2025 RAN plenary (RAN#108), taking the 5GA Rel-20 RAN3 available Time Units (TUs) into account.

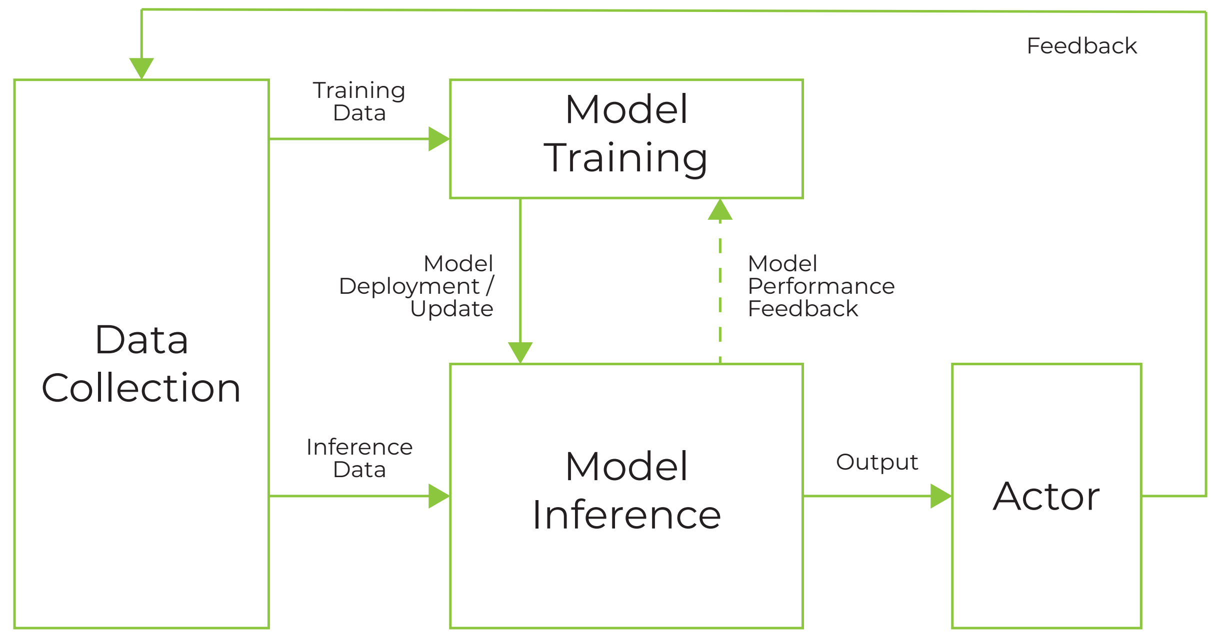


Figure 1: Functional Framework for RAN intelligence

AI for the Network or a Network for AI?

In general, there are two aspects discussed: AI for Network (AI4Net) and Network for AI (Net4AI). AI4Net pertains to the scenario where AI/ML serves to empower the network. In this context, AI technologies are harnessed to enhance and optimize the performance and management of wireless networks. The overarching objective of AI4Net is to capitalize on AI to boost network efficiency, stability and ultimately the network performance and user experience.

The above RAN3 led AI/ML for NG-RAN projects aim to fulfill such purpose. On the other hand, Net4AI refers to the situation where the network plays a role in empowering AI/ML. Here, wireless networks are employed to support and enhance the operation and performance of AI/ML services. Through the optimization of network architecture, data collection and transmission technologies, the intention is to offer robust network support for AI/ML services. Those two aspects will guide the design principles of 6G networks integrated with AI/ML.

As we look to the future of 6G networks, from mobile connectivity to the Internet of Everything, and ultimately to the intelligent connectivity of all things, 6G will signify a considerable leap forward. It will transcend the basic connection of people and things to empower the efficient interconnection of intelligent entities. This includes not only robots but also a wide array of intelligent devices, thereby ushering in a new era of seamless and intelligent communication anytime and anywhere, paving the way for autonomous systems such as smart city, smart low-altitude economies, smart transportation, smart education & healthcare, smart homes, as shown in Figure 2.

An example, to demonstrate the advances to be seen in the 6G era, warehouses will be a part of the smart city scenario, with warehousing robots across different types of categories, e.g., AGV(Automated Guided Vehicles) robots, palletizing robots, sorting robots, AMRs (Autonomous Mobile Robots), all adapting to different scenarios. Due to their different capabilities and the different requirements in warehousing, these robots will work together, making task related real-time judgments about environmental changes affecting their work.

Another example is smart healthcare at home and hospital. Personal wearable devices can continuously monitor health status and interact with devices like blood pressure monitors and weighing scales, while also integrating with XR-based remote healthcare. In hospital settings, it will extend to more specialized medical equipment, such as in smart wards, where intelligent hospital beds will work in conjunction with advanced diagnostic and treatment devices, intelligent medical communication systems, and automated caregiving robots. Flexible selection and management of variants of intelligent devices in a collaborative way for on-demand medical treatment request can be imaged in the future.

It is worth noting that how to integrate developing AI technologies, such as Agentic AI with 6G network, is a promising topic to be investigated when 3GPP starts the discussion on the overall 6G RAN architecture, with related use cases and solutions. How to achieve cross-layer data collection and management within the 3GPP system including UE/RAN/CN and enable information exchange between the application layer and the 3GPP system is also a promising topic to be studied.

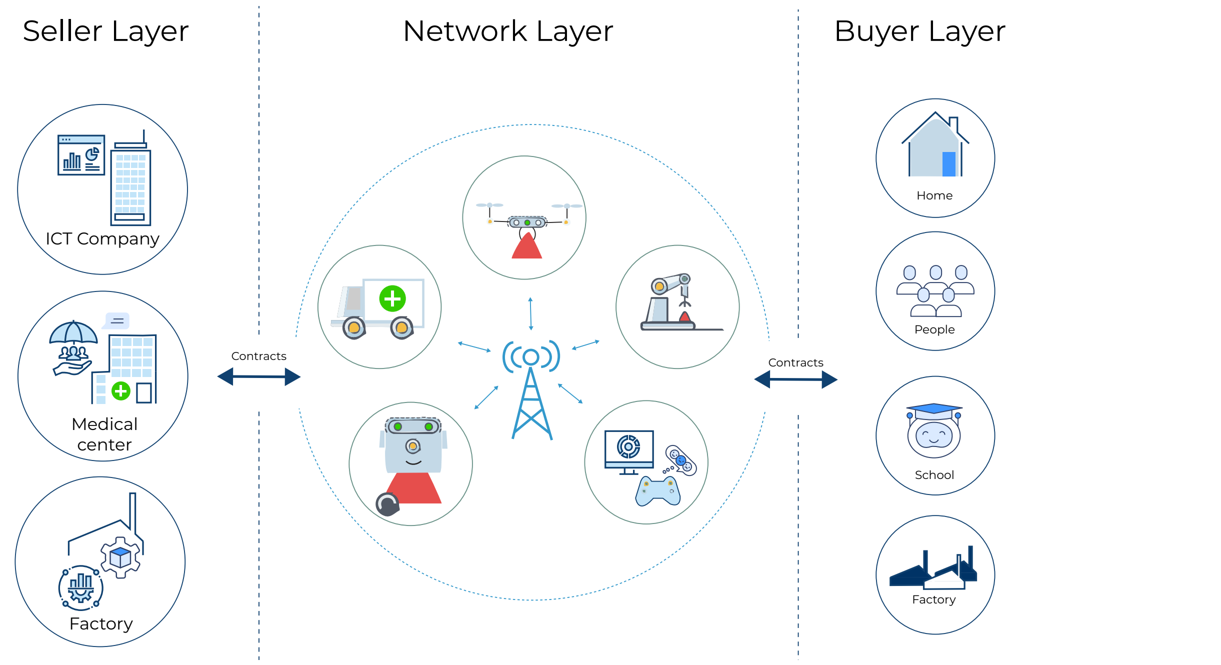


Figure 2: Potential AI/ML applications of 6G

In conclusion, during the 5G era, we transitioned from the traditional reactive paradigm, such as Self-Organizing Networks (SON), to a more proactive AI/ML approach. As we stand on the cusp of the 6G era, AI/ML is to be further integrated with wireless communication technologies so as to permeate different protocol layers and support multiple functionalities. 6G networks will enable interactions and collaboration among a collection of AI aware entities which will have the potential to bring tangible benefits to our society.

Simultaneously, it is crucial to acknowledge the challenges that lie ahead, particularly data security and system energy efficiency. These issues are not confined to RAN3 alone, all 3GPP WGs will play an active role in addressing these challenges.

AM and UE Policy Management in 5G

By CT WG3 Delegates Abdessamad El Moatamid (Huawei), Zhenning Huang (China Mobile), Yue Sun (China Telecom)

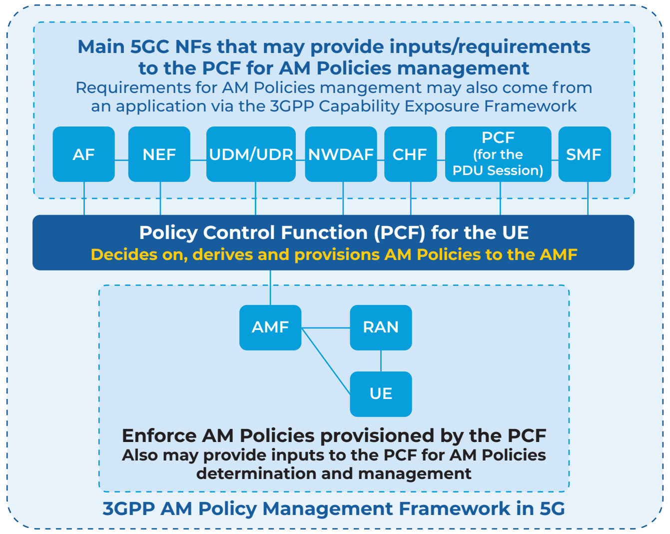
Access and Mobility (AM) Policy Management and UE (User Equipment) Policy Management are the key components of the so called "non-session management" related policy control framework in 5G. They enable policies to be derived and enforced that control how UEs access the network, how UEs interact with both the network and each other and how both the users and the network manage their mobility within and when roaming outside of the boundaries of the network of a Mobile Network Operator (MNO).

5G AM Policy Management

The management and enforcement of policies is ensured primarily by the Policy Control Function (PCF), specifically called the "PCF for the UE", and the Access and Mobility Function (AMF). The main AM Policy management functionalities are the following:

- **Service Area Restrictions** management, which consists basically on a list of areas within the network (e.g., list of (non-) allowed Tracking Areas) within which the UE is restricted access to network services.
- **RFSP Index** (RAT/Frequency Selection Priority Index) management, which enables the network to control and influence how the UE performs radio resource management.
- **UE-AMBR** (UE Aggregate Maximum Bitrate) and UE-Slice-AMBR (UE per-slice Aggregate Maximum Bitrate) management and enforcement, i.e., control the usage of network resources (and per network slice resources) by a particular UE.
- **Network Slice Replacement** management, which consists on allowing the replacement of a network slice with another network slice, e.g., when the initial network slice becomes unavailable or congested, and based on a local decision at the PCF and/or using inputs from e.g., the O&M system, the NWDAF, etc.
- **SMF selection management information** management, which allows the PCF to interact and control/influence to some extent the SMF selection functionality of the AMF so as to achieve an overall optimized data traffic management.

The requirements related to all these functionalities may be part of the user's network subscription, provisioned by an application through the 3GPP Network Capability Exposure framework (see [1]) and/or be derived or updated by the PCF based on operator policies and/or other information available to the PCF such as UE location information, network analytics data provided by the Network Data Analytics Function (NWDAF), etc. The control of these functionalities is achieved via the establishment (e.g., during UE registration) and management by the AMF of an "AM Policy Association" (on a per-UE basis) at the PCF, which enables the latter to provision AM policies to the AMF, which in turn provisions these policies to the RAN and/or UE that take care of enforcing them and reporting the related events to the AMF and PCF.



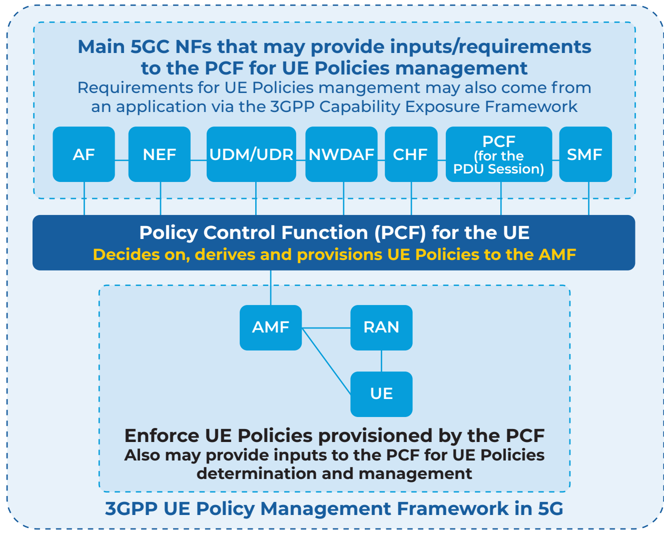
For more details, see also [2], [3], [7], [5] and [6].

5G UE Policy Management

UE Policy management is a framework to control how UEs access and interact with the network and how UEs may interact with each other. The management and enforcement of these policies is ensured primarily by the Policy Control Function (PCF), also specifically called the "PCF for the UE", and the Access and Mobility Function (AMF). The main UE Policy management functionalities are the following:

- **ANDSP** (Access Network Discovery & Selection Policy) management, which consists on the rules and policies to control how the UE selects non-3GPP accesses (e.g., WiFi, WLAN).
- **URSP** (UE Route Selection Policy) management, i.e., the rules and policies to control how the UE routes outgoing traffic, e.g., to an established PDU Session, offloading to a non-3GPP access (e.g., WiFi) outside the scope of a PDU Session, using a new PDU Session to be established, via a ProSe Layer-3 UE-to-Network Relay outside the scope of a PDU Session.
- **V2XP** (V2X Policy) management, which enables to provision the configuration parameters and policies for the UE to manage V2X (Vehicle-to-Everything) communications.
- **ProSeP** (ProSe Policy) management, which enables to provision the configuration parameters and policies for the UE to manage ProSe (Proximity based Services) services.
- **RSLPP** (Ranging/Sidelink Positioning Policy) management, which enables to provision the configuration parameters and policies for the UE to manage Ranging/Sidelink Positioning services.
- **A2XP** (A2X Policy) management, which enables to provision the configuration parameters and policies for the UE to manage A2X (Aircraft-to-Everything) communications.

The requirements related to all these functionalities may be derived based on existing UE Policies at the UE (e.g., pre-configured at the UE side), provisioned requirements by an application through the 3GPP Network Capability Exposure framework (see [1]) and/or be derived or updated by the PCF based on operator policies and/or other information available to the PCF such as network analytics data provided by the Network Data Analytics Function (NWDAF), etc. The control of these functionalities is achieved via the establishment (e.g., during UE registration) and management by the AMF of an "UE Policy Association" (on a per-UE basis) at the PCF, which enables the latter to provision UE policies to the AMF, which in turn provisions these policies to the UE that takes care of enforcing them and reporting the related events to the AMF and PCF.



For more details, see also [4], [3], [7], [5] and [6].

Unlocking the potential of 5G AM and UE Policy Management – Examples & Use Cases

Use case #1: AM/UE Policy control based on spending limits

In 3GPP Rel-18, a new functionality was introduced to allow the PCF for the UE to perform AM/UE policy decisions based on the available spending limits information (e.g., the daily/weekly/monthly spending limits for mobile data are reached or are close to be reached for a subscriber) in non-roaming scenarios. This functionality exemplifies how the operator policies at the PCF for AM/UE Policy Management can be implemented.

For this purpose, the PCF interacts with the CHF (Charging Function) to request and/or subscribe to receive spending limits related reporting for one or several "policy counters" (i.e., spending limits indicators). Once this is in place, the CHF notifies the PCF of any changes in the current or pending statuses of the subscribed policy counter(s), and optionally the activation time(s) for the case of pending statuses (e.g., due to a billing period that will expire). The PCF then uses all these dynamically collected statuses of policy counter(s) and the related information as inputs to its internal policy decisions to apply related pre-configured operator-defined actions.

With this functionality, operators can dynamically configure, establish and enforce AM/UE Policy decisions (e.g., downgrade or upgrade the UE-AMBR, change the URSP rules, update the service area restrictions) based on the spending limits information. In 3GPP Rel-19, this functionality was further extended to roaming scenarios to enable dynamic change of UE Policies based on spending limits related information.

Use case #2: Network assisted performance level upgrade using frequency management suggestions

AM Policy management can play a highly important role in enhancing network performance by acting on the improvement of the RFSP Index management. The PCF can enable by that more dynamic and differentiated mobility control strategies. The PCF can provision RFSP Index values to the AMF to assist with frequency selection and enable more specific radio resource management at the UE. The PCF determines the RFSP Index values to be provisioned based on various factors such as the accumulated usage information (e.g., used volume, used time or both), network analytics data from the NWDAF on the current load levels at the concerned network slice instance or the UE Communication related information, UE communication behavior information, user data congestion information, the perceived service experience, etc.

This flexible Policy framework for frequency selection and mobility management enhances user experience, optimizes network efficiency, and supports differentiated service delivery across various users' segments and network conditions.

> With the introduction of 5G-Advanced and AI technologies, these capabilities will be further enhanced to enable more autonomous, dynamic and intelligent network management.

Conclusion

With the introduction of 5G-A (3GPP Rel-18 onwards) and AI technologies, these capabilities will be further enhanced to enable more autonomous, dynamic and intelligent network management, thus paving the way for the enhanced control of how UEs are treated by the network, e.g., real-time policy management based on an AI-Native network architecture and intent-driven automation, finer-grained UE differentiation for tailored experiences, efficient connecting of more and more types of UEs with greatly more massive numbers (e.g., IoT devices, sensors), etc. We look forward to the introduction of these exciting new functionalities and use cases in the future.

For more from WG CT3: **www.3gpp.org/3gpp-groups**

[1] "3GPP Capability Exposure Frameworks and APIs", Pages 08-09, 3GPP Highlights Newsletter, Issue 09, December 2024

[2] 3GPP TS 29.507: "Access and Mobility Policy Control Service; Stage 3"

[3] 3GPP TS 29.513: "5G System; Policy and Charging Control signalling flows and QoS parameter mapping; Stage 3"

[4] 3GPP TS 29.525: "5G System; UE Policy Control Service; Stage 3"

[5] 3GPP TS 23.501: "Technical Specification Group Services and System Aspects; System Architecture for the 5G System"

[6] 3GPP TS 23.502: "Procedures for the 5G System; Stage 2"

[7] 3GPP TS 23.503: "Policy and Charging Control Framework for the 5G System"

Engineering intelligence: How 3GPP SA5 is shaping AI/ML management for the 5G System

By Hassan Al-Kanani (NEC, Rapporteur) & Yizhi Yao (Intel, Co-rapporteur)

The rapid integration of Artificial Intelligence and Machine Learning (AI/ML) into the 5G System has brought exciting possibilities for a wide range of enhancements, including intelligent automation and optimisation.

As AI/ML functionalities take shape within 5G networks, in addition to RAN groups and WG SA2 (Architecture), nearly all 3GPP working groups are advancing specification work to enable AI/ML-enhanced features in their respective domains. These parallel efforts reflect a growing emphasis on intelligent automation and data-driven operations across the entire system, highlighting the need for consistent and scalable AI/ML support - spanning all domains.

Within 3GPP, the SA5 working group plays a central role in ensuring that these capabilities can be managed, trusted and deployed reliably at scale. SA5's work focuses on the domain-agnostic management and orchestration of AI/ML features, ensuring alignment and lifecycle support across the system.

WG SA5 is specifying how AI/ML functionalities can be managed efficiently and effectively, through a domain-independent AI/ML management and orchestration framework that supports the full lifecycle of AI/ML workflows—including model training, validation, testing, emulation, deployment, and inference execution.

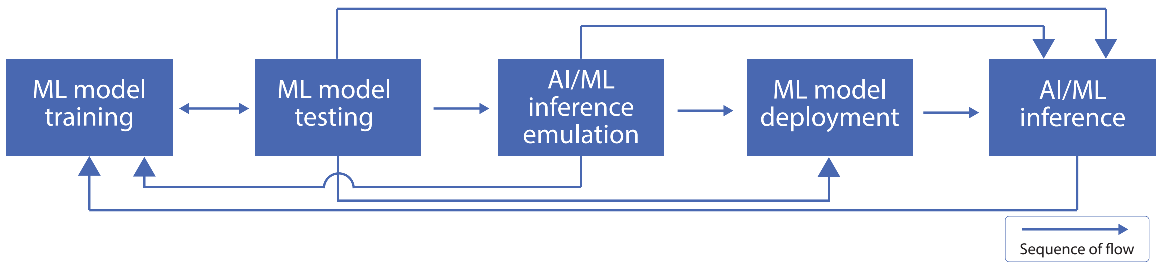
While other working groups address AI/ML integration from their respective areas, SA5's management centric approach ensures standardized coordination and lifecycle support across the 5G system. This includes RAN, Core Network, Management and Orchestration, and applications establishing a unified and extensible foundation for cross-domain AI/ML deployment.

Together, these aligned efforts provide a scalable platform for enabling intelligent network behaviour, reinforcing automation, adaptability, and intelligence in current and future 3GPP releases.

Rel-19 work: Expanding AI/ML management to support evolving enhancements in 5GS

The AIML Rel-18 specifications development project achieved significant milestones, including the development of a domain-agnostic AI/ML lifecycle management framework that covers all main phases (steps) of AI/ML operations in the 5GS. A Wide range of management capabilities, supported by detailed corresponding use cases, requirements and NRM-based APIs, were developed and documented in TS 28.105.

AI/ML LCM framework:



AI/ML LCM management capabilities:

Lifecycle step	Capability name	Description
ML model training	Training management	Allows the MnS consumer to request, control, and monitor ML model training or re-training, including training performance management and policy setting
	Validation management	Supports evaluation of model performance on validation data and identification of performance variance to determine if re-training is necessary.
ML model testing	Testing management	Enables MnS consumer to request testing of a trained ML model, select performance metrics, receive results, and potentially trigger re-training based on outcomes.
AI/ML Inference emulation	Inference emulation	Provides capability to emulate ML inference for specific models in a test environment, enabling evaluation before actual deployment.
ML model deployment	Model loading management	Enables the MnS consumer to trigger, control, and monitor the loading of ML models into the appropriate functions.
AI/ML inference	Inference management	Allows the MnS consumer to activate/deactivate inference functions or models, configure output parameters, and monitor or update inference performance as needed.

Building on the solid foundation established in Rel-18, the on-going work in Rel-19 further enhances the framework to provide consistent, scalable, and extensible support for AI/ML integration across the 5G System.

Overview of AI/ML management progress

Release 18 Accomplishments:

Terminologies	Developed a comprehensive set of terms relevant to AI/ML management.
Lifecycle Management Framework	Defined a framework for managing the entire lifecycle of ML models and AI/ML inference functions, ncluding; training, testing, emulation, deployment and inference.
Operational Capabilities	Defined detailed AI/ML management capabilities across all lifecycle phases/steps. Supported by specific use cases, requirements and solutions.
Interfaces and APIs	Specified stage 2 Network Resource Models (NRMs) and stage 3 (OpenAPIs) to support AI/ML management functionalities across the 5GS (management systems, 5GC and NG-RAN).
Functional Scenarios	Documented scenarios describing potential locations and operational contexts for ML training and AI/ML inference functions within the 5G system.

Release 19 Progression (Study completed, Normative work ongoing):

Enhaned Management Capabilities	For AI/ML across the 5GS (management system, 5GC, NG-RAN) – All are being assessed in the normative phase, building on the foundational work from Rel-18 with new use cases' and corresponding requirements and solutions.
ML Model training enhancements	• Support for knowledge-based transfer learning, distributed training, Federated Learning, Reinforcement Learning, pre-training and fine-tuning – All are under further evaluation during normative discussions. • Capabilities for monitoring training data statistics, model confidence and ensuring explainability are being explored for normative specification. • Energy-efficient training practices to enable sustainable AI/ML continue to be discussed as part of ongoing normative work.
AI/M Inference Emulation	Energy-efficient training practices to enable sustainable AI/ML continue to be discussed as part of ongoing normative work.
ML Model deployment	Inference emulation capabilities, including customer requested emulation and environment selection, are being further assessed for inclusion in normative specifications.
AI/ML Inference	• Management aspects related to ML model loading, transfer /delivery and deployment in live networks are under active normative consideration. • Mechanisms for improving coordination of AI/ML inference, latency optimization and remedial action are being refined as part of normative efforts. • Sustainable AI/ML practices for live network inference and model management are also under ongoing normative assessment.

The ongoing AI/ML management project in SA5 strengthens the 5G System's ability to support increasingly complex AI/ML-based functionalities being introduced across other domains such as those developed by SA2 and RAN work groups. Building on the lifecycle framework defined in Rel-18, the Rel-19 project enhances operational capabilities aligned with the following advanced techniques:

- **Federated Learning (FL)** and **Vertical Federated Learning (VFL)** techniques for decentralized and privacy-preserving training, supporting both Core and RAN use cases and capabilities.
- **Reinforcement Learning (RL)** and **distributed training** methods, enabling adaptive and scalable learning across diverse network environments.
- **Sustainable AI/ML**, incorporating energy-efficient mechanisms to ensure responsible and resource-aware model development.
- **Flexible inference emulation** and **optimized model deployment** for NG-RAN and 5GC, ensuring efficient coordination of AI/ML functionalities across live and test environments.

These capabilities ensure that SA5 provides the necessary lifecycle support to manage and operate intelligent network features introduced by the RAN work groups including for example those considered by RAN3 (e.g. AI/ML-based network slicing and capacity optimization) and SA2-defined AI/ML functions within the 5G Core.

This forward-looking work ensures that the AI/ML management framework remains robust, flexible, and future proof, paving the way for intelligent automation and optimization in advanced 5G and beyond systems.

Rel-18: AI/ML functionalities and management scenarios

The key functional components involved in AI/ML deployment are the ML training function, which is responsible for training the model, and the inference function, which hosts the trained model to perform inference. These functionalities offer deployment flexibility and can be distributed across various domains in the 5GS to enable AI/ML capabilities effectively.

The ML training and AI/ML inference functions may reside in different parts of the 5G system, depending on the deployment scenario, including:

- RAN or CN Management Systems,
- Network Functions (e.g., gNB, NWDAF),
- Cross-domain Management Systems.

Scenarios of AI/ML functional arrangements:

Scenario 1: Both in Management System – ML training and inference functions reside in the RAN or CN domain-specific management function (eg. MDAF).

Scenario 2: Split between Management and gNB – ML training is in the RAN management function; inference runs in the gNB.

Scenario 3: Both in gNB – both ML training and inference occur directly in the gNB, enabling localized intelligence.

Scenario 4: Both in the NWDAF – For Core Network domain, both functions are hosted in NWDAF (training in MTLF, inference in AnLF).

For more from WG SA5: www.3gpp.org/3gpp-groups

Intent Driven Management enabling highly autonomous networks

By WG SA5 Authors: Ruiyue Xu (Huawei), Mark Scott (Ericsson)

Compared to earlier networks - 5G and 5G Advanced systems bring more operational complexities, largely due to the growing number of devices online and their increased diversity.

Network autonomy is one of the important topics for 5G systems, for reduced OPEX through efficiency and an improved service experience - for various vertical industries – through a variety of intelligence and automation mechanisms.

As networks continue to evolve the level of complexity can explode, as scenarios such as design & planning, deployment, maintenance and optimization are considered. The need for abstraction of the operational requirements, such as is supported by intents, becomes more apparent. 3GPP SA5 started the intent driven management work for mobile networks back in June 2018. The effort is continually evolving as new capabilities and scenarios come to light, to support highly autonomous networks.

Intent concept

An intent is a set of expectations including requirements, goals and constraints given to a 3GPP system, without specifying how to achieve them. Intents allow customers to request networks and services without detailed knowledge of how they will be provided. Inherently, this assumes that the system can learn the behaviour of networks and services and use intelligence and automation mechanisms to fulfil the requests expressed via intents.

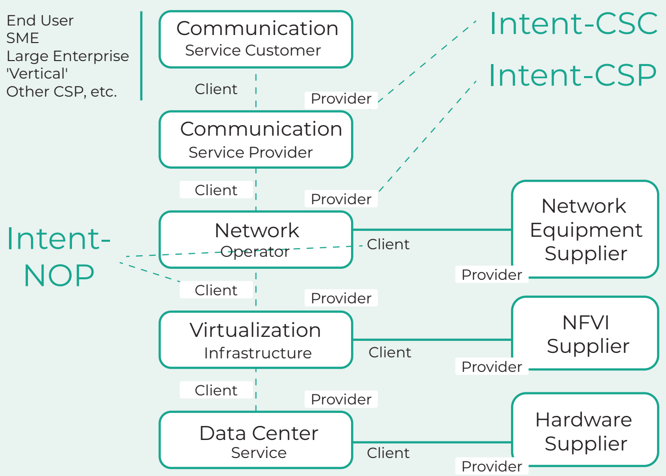
This not only relieves the consumer of the burden of knowing implementation details but also provides flexibility allowing the system to explore alternative options, to find optimal solutions.

Intent based on user types

To support different roles related to 5G networks and network slicing management defined in 3GPP, different intents could be considered, being used for supporting different interactions, specifically:

- Intent-CSC: from Communication Service Customer (CSC) to the Communication Service Provider (CSP) to express properties of a communication service, e.g. 'Enable a V2X communication service for a group of vehicles in certain time with low latency'.
- Intent-CSP: from CSP to a Network Operator (NOP) to express properties of the CSP's desired network, e.g., 'a network slice supporting V2X communications.
- Intent-NOP: from NOP to a Network Equipment Provider (NEP) to express characteristics of a RAN and/or 5GC network, e.g., specifying 'coverage requirements and UE throughput requirement in certain area'.

Figure 1:



Intent management functionalities for different phases

The intent management functionalities for different phases include:

Intent Investigation
In this phase, the MnS Consumer finds out what intent content (a list of expectations) is feasible before expressing the intent expectations to be fulfilled by the Intent Handling Function (i.e. MnS Producer). This has two aspects:

- **Intent handling capability**. The MnS Consumer finds the Intent Handling Function which has the necessary domain responsibilities and supports their required intent expectations.
- **Intent pre-evaluation**. The MnS Consumer finds out whether their wanted intent expectations and wanted values are feasible. The MnS Consumer can use negotiation procedures to help determine suitable intent information for the Intent Handling Function. The network (including NFs) will not be changed during the intent pre-evaluation phase. Supported procedures include a Feasibility Check to allow the MnS Consumer to confirm that the proposed intent is supported by the Intent Handling Function, and exploration procedures such as requesting the best values.

Intent Generation and Activation
In this phase, the MnS Consumer generates the intent content (a list of expectations) and sends it to the Intent Handling Function for fulfilment.

Intent Fulfilment
The Intent Handling Function fulfils the given intent within its domains of responsibility. Intent Reports generated by the Intent Handling Function are used by the MnS Consumer to observe the fulfilment. The MnS Consumer may identify a need to modify the intent content based on the intent report content. Intent negotiation procedures can be used by the MnS Consumer to improve the fulfilment by modifying the intent to better align with the Intent Handling Function's ability to fulfil the intent.

Intent driven management service (IDMS)

Intent support in 3GPP is provided via an Intent Driven Management Service (IDMS) defined as an MnS per 3GPP Service Based Management Architecture (SBMA). The Intent Handling Function provides the MnS Producer (a logical function with intent handling capabilities that provides the intent driven management service) which allows its MnS Consumer to express intents for managing the network and services.

The intent driven MnS solution uses the "model driven approach" in SBMA, which decouples the operations from the intent model. The intent driven MnS solution specified by 3GPP TS 28.312 is a flexible interface and allows for extensions to support new scenarios/services.

In TS 28.312, the following are defined:

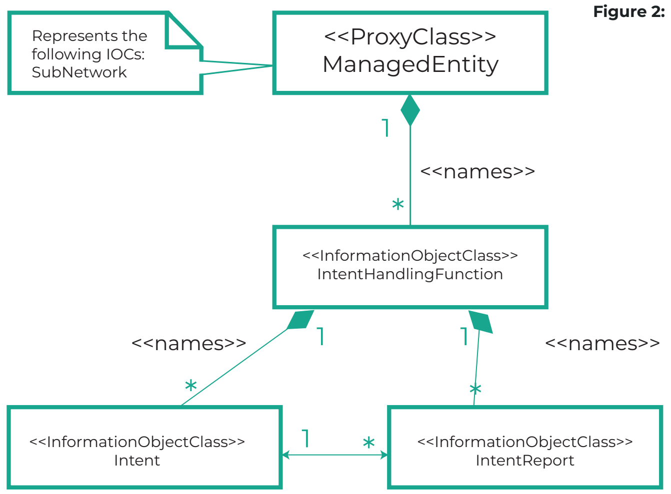
A unified set of management operations, including:

- Intent lifecycle management, including create an intent, modify an intent, delete an intent, query an intent, activate an intent and deactivate an intent.
- Intent report management, including query an intent report, subscribe to an intent report, unsubscribe from an intent report, notify an intent report.
- Intent handling capability query, including query intent handling capability.
- Intent negotiation management, including intent feasibility check, intent exploration and intent fulfilment negotiation procedures.

A generic intent information and data model defined in a common intent model framework to support intent management. The generic intent information model includes:

- Intent HandlingFunction model, represents the intent handling capabilities (i.e., supported expectation object information and expectation target) supported by a specific Intent Handling Function.
- Intent model, contains one or multiple IntentExpectation(s) which includes MnS Consumer's requirements, goals and contexts.
- IntentReport model, represents intent report information containing one or any combination of intentFulfilmentReport, intentConflictReports, intentFeasibilityCheckReport, intentExplorationReport and intentFulfilmentNegotiationReport.

Figure 2:



Scenario specific intent Expectation instances. The following scenario specific intent instances are defined by utilizing the constructs of the generic IntentExpectation to support some typical intent driven scenarios:

- RadioNetworkExpectation, which can be used to represent MnS Consumer's expectations for radio network delivering and performance assurance.
- Radio Service Expectation, which can be used to represent MnS Consumer's expectations for radio service delivering and assurance in the specified area.
- 5GC Network Expectation, which can be used to represent MnS Consumer's expectations for 5GC network delivering.
- End-to-end Network Resource Optimization Expectation, which can be used to represent MnS Consumer's expectations for the resource optimization of network resources across multiple network domains.
- Edge Service Support Expectation, which can be used to represent MnS Consumer's expectations for edge service deployment.
- Network Maintenance Expectation, which can be used to represent MnS consumer's expectation for maintaining a network.

Guidelines for using scenario specific intent expectation for intent driven scenarios. Table 1 describes guidelines for using the 3GPP standardized scenario specific intent expectations defined in TS 28.312 to satisfy the intent driven scenarios defined in TS 28.312.

The intent driven MnS solution is a flexible interface, which not only provides support for the scenario specific intents defined in TS 28.312, but can also support scenarios which are not standardized. TS 28.312 contains guidelines for using the intent Generic Information Model to support new scenarios using vendor defined extensions to the generic ExpectationObject(s) and vendor defined ExpectationTarget(s):

- Standardized Intent Expectation with vendor specific combination of standardized ExpectationObject(s) and ExpectationTarget(s).
- Standardized Intent Expectation with standardized ExpectationObject(s) and ExpectationTarget(s) and additional vendor defined ExpectationObject(s) and/or ExpectationTarget(s).
- Vendor defined Intent Expectation by utilizing generic IntentExpectation. The Vendor defined Intent Expectation includes vendor extension ExpectationObject(s) and/or ExpectationTarget(s).

Use case	Scenario specific IntentExpectation	ExpectationObject. ObjectContext	ExpectationTarget	ExpectationContext
Intent containing an expectation for delivering radio network (clause 5.1.1)	Radio Network Expectation	- coverageAreaPolygonContext - coverageTACContext - pLMNContext - dlFrequencyContext - ulFrequencyContext - rATContext	- weakRSRPRatioTarget - lowSINRRatioTarget - aveULRANUEThptTarget - aveDLRANUEthptTarget	
Intent containing an expectation for delivering a service at the edge (clause 5.1.3)	Edge Service Support Expectation	- edgeIdentificationIdContext - edgeIdentificationLocContext - coverageAreaTACContext	- dlThptPerUETarget - ulThptPerUETarget - dLLatencyTarget - uLLatencyTarget - maxNumberofUEsTarget - activityFactorTarget - uESpeedTarget	
Intent containing an expectation on coverage performance to be assured (clause 5.1.4)	Radio Network Expectation	- coverageAreaPolygonContext - dlFrequencyContext - ulFrequencyContext - rATContext	- weakRSRPRatioTarget - lowSINRRatioTarget	
Intent containing an expectation on RAN UE throughput performance to be assured (clause 5.1.5)	Radio Network Expectation	- coverageAreaPolygonContext - dlFrequencyContext - ulFrequencyContext - rATContext - uEGroupContext	- aveULRANUEThptTarget - aveDLRANUEthptTarget - lowULRANUEThptRatioTarget - lowDLRANUEThptRatioTarget	
Intent containing an expectation for delivering 5GC network (clause 5.1.8)	5GC Network Expectation	- nfTypeContext - nfInstanceLocationContext - pLMNContext- taiContext - servingScopeContext - dnnContext	- maxNumberofPDUsessionsTarget - maxNumberofRegisteredsubscribersTarget - incomingDataTarget - outgogingDataTarget	
Intent containing an expectation on RAN capacity performance to be assured (clause 5.1.5)	Radio Network Expectation	- coverageAreaPolygonContext - dlFrequencyContext - ulFrequencyContext - rATContext	- highUlPrbLoadRatioTarget - highDlPrbLoadRatioTarget - aveUlPrbLoadTarget - aveDlPrbLoadTarget	
Intent containing an expectation on RAN energy saving (clause 5.1.7)	Radio Network Expectation	- coverageAreaPolygonContext - pLMNContext - dlFrequencyContext - ulFrequencyContext - rATContext	- rANEnergyConsumptionTarget - rANEnergyEfficiencyTarget - aveULRANUEThptTarget - aveDLRANUEthptTarget	
Intent containing an expectation for delivering radio service (clause 5.1.2)	Radio Service Expectation	- coverageAreaPolygonContext - serviceTypeContext -plMNInfoContext	- dLLatencyTarget - uLLatencyTarget - dLThptPerUETarget - uLThptPerUETarget - numberofUEsTarget	schedulingTimeContext
Intent containing an expectation on radio network traffic assurance (clause 5.1.5)	Radio Network Expectation	- cellContext - uEGroupContext	- weakRSRPRatioTarget - aveULRANUEThptTarget - aveDLRANUEThptTarget - activeUEsNumTarget	schedulingTimeContext
Intent containing an expectation for network maintenance (clause 5.1.9)	Network Maintenance Expectation	-maintenanceTimeContext -maintenanceVersionContext -maintenanceOrderContext	- maintenanceVersionTarget	Intent containing an expectation for network maintenance (clause 5.1.9)

Table 1: 3GPP standardized scenario specific intent expectations

Way Forward

Intent driven management is a key enabler in increasing the autonomy and efficiency of mobile networks, not only for the networks themselves but for those interacting with them. As networks with automation & intelligence become increasingly self-sufficient and able to manage their own resources efficiently, the ways in which we interact with networks must change.. Network operators, and their customers, must increasingly shift their focus to 'what' they wish to achieve from their networks and services. The 3GPP defined Intent Driven Management Service is aligned with, and can be integrated with, similar mechanisms being defined across the industry to provide a comprehensive and interoperable solution. 3GPP SA5 will continuously develop standards for intent driven management solutions for 5G Advanced networks and future networks and stands ready for new requirements for intent driven management from the industry.

Specification References:

Common specifications for 5G management services are also used for the intent driven management, including the SBMA and corresponding generic management services.

- TS 28.533: " Management and orchestration; Architecture framework".
- TS 28.532: " Management and orchestration; Generic management services ".

Specific intent driven management specifications for release 17, release 18 and release 19 are the following:

- TS 28.312: "Management and orchestration; Intent driven management services for mobile networks".(Current latest versions: V 19.1.0)

> As networks with automation & intelligence become increasingly self-sufficient and able to manage their own resources efficiently, the ways in which we interact with networks must change

The importance of standards in the effective management of massive MCvideo

By Sanne Stijve, Global Business Development Director, Ericsson, and co-leader of TCCA's Massive Mission Critical Video Task Force

Broadband Public Protection and Disaster Relief (PPDR) services are becoming more prevalent, and video is one of the most promising and versatile technologies for enhancing operational efficiency and effectiveness.

Video is now widely considered as a significant capability to improve safety, coordination, collaboration, and quality decision-making, particularly during high stakes, first responder operational scenarios.

There are many considerations to be taken into account by public safety agencies and critical communications network operators, especially where the scale of its usage is considered 'massive' – in situations where the amount of video could potentially saturate network resources, if not appropriately managed.

For public safety, there could be multiple sources of mission critical video streams active at an incident, including Mission Critical Services (MCX) clients complying with 3GPP MCVideo specifications, on handheld devices (e.g. smartphones), body-worn cameras, vehicle and aircraft-mounted cameras, fixed wireless cameras mounted on buildings and other infrastructure, Unmanned Aerial Vehicles (UAVs) and robots.

Each of these sources are capable of streaming real-time video to a control room to enhance situational awareness in case of an incident. However, if uncontrolled, these video streams can very quickly overload the mobile broadband network resources and block critical communications.

With the increasing use of video at critical incidents, TCCA has looked at the issue and challenges of deployment and management, with the aim of providing best-practice advice.

The work of TCCA is carried out largely within its many Working Groups, within which task forces are created to address specific topics. TCCA's Massive Mission Critical Video Task Force comprises of representatives from the telecom sector, video application providers, government agencies and specialised operators – all dealing with communication for public safety, all members of TCCA's Critical Communications Broadband Group and Broadband Industry Group.

The task force has created a detailed white paper 'Guidance for the successful usage of Massive Mission Critical Video', with the overall objective of helping to ensure that first responders and public safety agencies (and by implication other critical communication sectors) can use video effectively for operational benefit.

Massive mission critical video is a vast subject that can be approached in many ways, so it was important to identify the key challenges and questions posed by the massive usage of video that the task force wanted to address. This was achieved through a ranking poll among the members of the task force. The identified key challenges are classified in the white paper under the categories: Operational, Network and Video Applications aspects.

Key video use cases representing different categories of operations are documented, i.e. day-to-day (routine) operations, pre-planned events, and major incidents.

Evolution of 3GPP requirements applicable to MCVideo from Release 14 to 17

The 3GPP MCVideo requirements have evolved significantly from Release 14 to Release 17, with new features and improvements introduced to enhance mission-critical communication systems' performance, reliability, and security. Here are some key video related changes in each release:

- Release 14: Initial requirements - MCVideo call scenario support included emergency group calls, imminent peril group calls, emergency alerts, and private call (off-network). The focus was on ensuring interoperability between different devices and networks and providing a basic quality of service for video transmission.
- Release 15: The requirements for MCVideo call scenario support were expanded to include group call enhancements, video push, video pull, private call (on-network), broadcast group call, and ambient viewing call. This release also added support for higher-quality video, such as 4K video, and better support for low-latency video transmission.
- Release 16: Support for MCVideo over 5G networks was introduced, providing higher bandwidth and lower latency for mission-critical communication systems. The requirements for MCVideo were expanded to include support for URLLC (ultra-reliable low-latency communication) and mMTC (massive machine-type communication). This involved adding new features such as support for network slicing, enhanced QoS (Quality of Service) mechanisms, and support for edge computing.
- Release 17: Support for MCVideo over 5G networks was expanded, and the requirements for MCVideo were focused on further improving the quality of video transmission and adding new features, such as support for artificial intelligence and machine learning.

When analysing these use cases, identifying video producers and consumers is fundamental to understanding the overall problem domain, and those identified include a range of stakeholders in the delivery of critical communications services, including first responders, officers, dispatchers, operators, and government agencies.

The incidents were classified in the following categories: Minor, Major, and Critical, and the typical phases of the incident were identified as follows:

1. Warning phase: the indication of the incident from the public (112/999/911 calls, field organisation, sensors etc), when the initial situational picture of the incident is built, and the necessary response is alerted.
2. Initial phase: the phase when the response is arriving on the scene and activating the measures for incident resolution and necessary additional response is summoned.
3. Search & Rescue phase: the phase where the focus is on evacuation of casualties and stabilising the situation.

Each phase has its own requirements and potential challenges for authority communications.

Taking into consideration the use cases analysed as well as the capacity of a typical dedicated radio network (or network layer), of rapidly deployable network solutions, and of a typical commercial mobile network operator (MNO), the conclusions in the white paper are as follows:

- How the warning phase is likely to be supported depends on the criticality of the incidents. A single dedicated radio network offers enough capacity for minor incidents; for major incidents a single commercial network is sufficient, whereas a combination of a dedicated radio network and a commercial network for critical incidents in rural areas.
- The initial and Search & Rescue phases for major and critical incidents are unlikely to be supported by a single dedicated network or commercial network, especially not in rural areas, without applying video compression and prioritisation of video feeds, or by providing additional capacity via a rapidly deployable network or leveraging enhanced coverage installations.
- For urban areas, a single commercial network has the potential to cover the massive mission critical video demands placed upon it, without having to resort to greater video compression or prioritisation techniques.
- Critical incidents are often characterised by very high traffic levels, not only from first responders but also consumers that are using commercial networks, which if not managed could generate congestion impacting all. Implementing QPP including access and application priority mechanisms and optimising the radio network will serve to manage these high load situations.
- Most situations would benefit from implementing greater video compression techniques and prioritisation of video streams wherever possible.
- Ingestion of multiple video feeds into a control room will be greatly simplified if a single, standardised protocol – 3GPP MC Video – is used by all video devices/applications.

Integrating public safety agency CCTV, body-worn cameras, on-vehicle video, and drones with 3GPP systems can provide seamless access to video data from each source, enhanced situational awareness, and improved incident response times. These application integrations require careful consideration of each system's technical and operational requirements. For example, it may involve configuring network settings, encoding video in a compatible format, associating metadata with the video stream, optimising video delivery based on the type and source of feed, developing a unified user interface, implementing a unified storage and retrieval system, and ensuring strong authentication and authorisation mechanisms are in place.

Agencies benefit from a 3GPP-compliant system's interoperability, high reliability, security and ability to prioritise quality of service - based on established standards. This ensures that agency personnel have access to reliable, secure, and high-quality video data in mission critical situations, which can help to save lives and to protect property.

Application providers benefit from 3GPP MCVideo specifications that ensuring high-quality, interoperable, and future-proofed products and services to their customers in the public safety sector.

As Market Representation Partner for critical communications in 3GPP, TCCA, our members and partners work with 3GPP to encourage the widest adoption of standards to help ensure critical communications services such as massive mission critical video are as valuable as possible to our first responders.

TCCA https://tcca.info/

A 6G ecosystem for the Verticals: Considerations for e-Health and Robotics

One6G are the newest Market Representation Partner in 3GPP, having joined the project in November 2024. In this article, Professor Shikh-Bahaei looks at how important it is for 6G standards to meet the needs of the e-Health and Robotics verticals.

By: Mohammad R. Shikh-Bahaei, Professor of Telecommunications
King's college London

The one6G Association is an international non-profit organization dedicated to evolving, testing, and promoting next-generation cellular and wireless communication solutions. one6G seeks to accelerate the adoption and market penetration of advanced technologies that meet societal and industry-driven demands for enhanced connected mobility. Founded in March 2021, one6G brings together experts from academia, industry, and public institutions looking forward to a 6G ecosystem with the capabilities to improve the quality, reduce costs and expand reach of healthcare services.

For robotic systems, one6G envisages that 6G has the potential to increase the reliability, capability and operational efficiency of mobile robots at lower complexity.

Potential impact of 6G on E-Health domain:

Healthcare systems require continuous optimization in order to reduce costs and improve quality of services. So far, medical treatment decisions are based on treatment results of a large number of similar patients. This typically leads to generalized and costly treatments that do not account for the needs of each individual patient.

The 6G communication ecosystem is anticipated to facilitate precise modeling of individual treatments, enhance the interconnection between different medical data sources and models of all stakeholders (e.g., patients, doctors, devices and robots), as well as strengthen the capabilities of mobile robotic systems in the entire treatment process with improved connectivity, sensing, and intelligence services. To enable this vision, one6G has identified the following four usage scenarios in e-Health domain, and is working toward detailed analysis of these.

Medical Robotics Applications: The increasing demand of healthcare services and pressing shortage of healthcare personnel call the need for more capable medical robotic systems for caregiving tasks. These entail robotic systems that, among other capabilities, guarantee safety in close proximity to humans, and context-awareness of the health situation of patients to perform context-sensitive actions (e.g., actions sensitive to distress or disease of a patient).

Vital Sign Wireless Sensing: Vital signs are conventionally measured with fixed instruments such as electrocardiographs (ECG) which are wired to the patient, limiting patients' mobility. Wireless sensing can be used to reliably derive health information of patients to improve quality of patients' lives by not limiting mobility and facilitating proactive actions when healthcare personnel is overloaded.

Medical Data & Model Sharing: The amount of sensitive data generated by healthcare systems is rapidly increasing, and developments in AI/ML can securely exploit these data. There is a need to securely and in a timely manner exchange information between health sensors/models and high-performance computing stations located in-premises, in-network or at trusted/secure third-party providers.

Immersive & Ubiquitous Treatment: Currently, there is a massive burden on global healthcare systems due to mental health diseases. The proliferation of new consumer devices such as extended reality devices and wearables together with AI/ML technologies enables new immersive experiences for remote treatments (e.g., psychotherapeutic) as well as expanding reach of patient monitoring. These 6G technologies can also enable a range of interventional procedures for patients in remote locations.

Potential impact of 6G on Robotics:

It is expected that humanoid robots, as well as robots of other embodiments, will play a huge role in society in the coming years and decades. However, robots face numerous challenges when operating in real world scenarios – such as efficient communication of multi-modal sensor data, interoperability between robot platforms, limitations due to battery life, and more. These challenges must be solved before the future vision of robots as workers, caregivers and human assistants can be realized.

The 6G ecosystem can act as an enabling technology for robotics systems, through enhancements to communications protocols, offering communication-based services to connected robotic devices, enabling computational offloading for reduced energy usage, and by leveraging wireless sensing capabilities. To illustrate the potential of 6G technology applied to robotics, one6G identified a number of use cases in the intersection of 6G and robotics, including the following three highlighted use-cases.

Wireless Sensing for Robotic Search and Rescue: In disaster scenarios such as earthquakes, it can be beneficial to augment the efforts of human search and rescue crews with robots such as mobile robots, quadrupeds and in the future potentially humanoids. However, robots benefit from a "map" of the environment for efficient navigation, which in the event of infrastructure damage to roads and buildings may be out of date. Wireless sensing, which can be effective at longer range than traditional robotic sensors, can be integrated with robotic navigation systems to provide an initial map of the environment, improving the efficiency of search and rescue efforts.

Communication-Aware Robotic Navigation & Motion Planning: A key benefit of robots is the ability to operate in environments which are remote, dangerous or otherwise difficult for human workers – for example, a quadruped robot deployed on an offshore platform for remote inspection. In such scenarios, communication infrastructure is typically limited, and therefore robots may be limited in their ability to transfer high volumes of data, such as RGB image streams. Integration between 6G and robotic motion planning system can enable robots to consider radio coverage conditions in their planning algorithms, thus navigating in a "communication-aware" way to ensure successful data transfer.

Wireless Sensing for Enhanced Physical Interaction: Physical interaction is a hugely important (and challenging) problem that is required to be solved to enable robots to operate safely in real-world conditions.

Robots typically can support diverse range of on-board sensing capabilities to deal with physical interaction tasks, including cameras, force/torque sensors, and touch or haptic based sensing. However, wireless sensing can provide a key benefit to the existing robot sensor suite by leveraging close-range high frequency ISAC to determine the material properties of objects without requiring physical interaction. This could be especially relevant for robots which are tasked with handling irregular objects in real-world scenarios, such as humanoid robots.

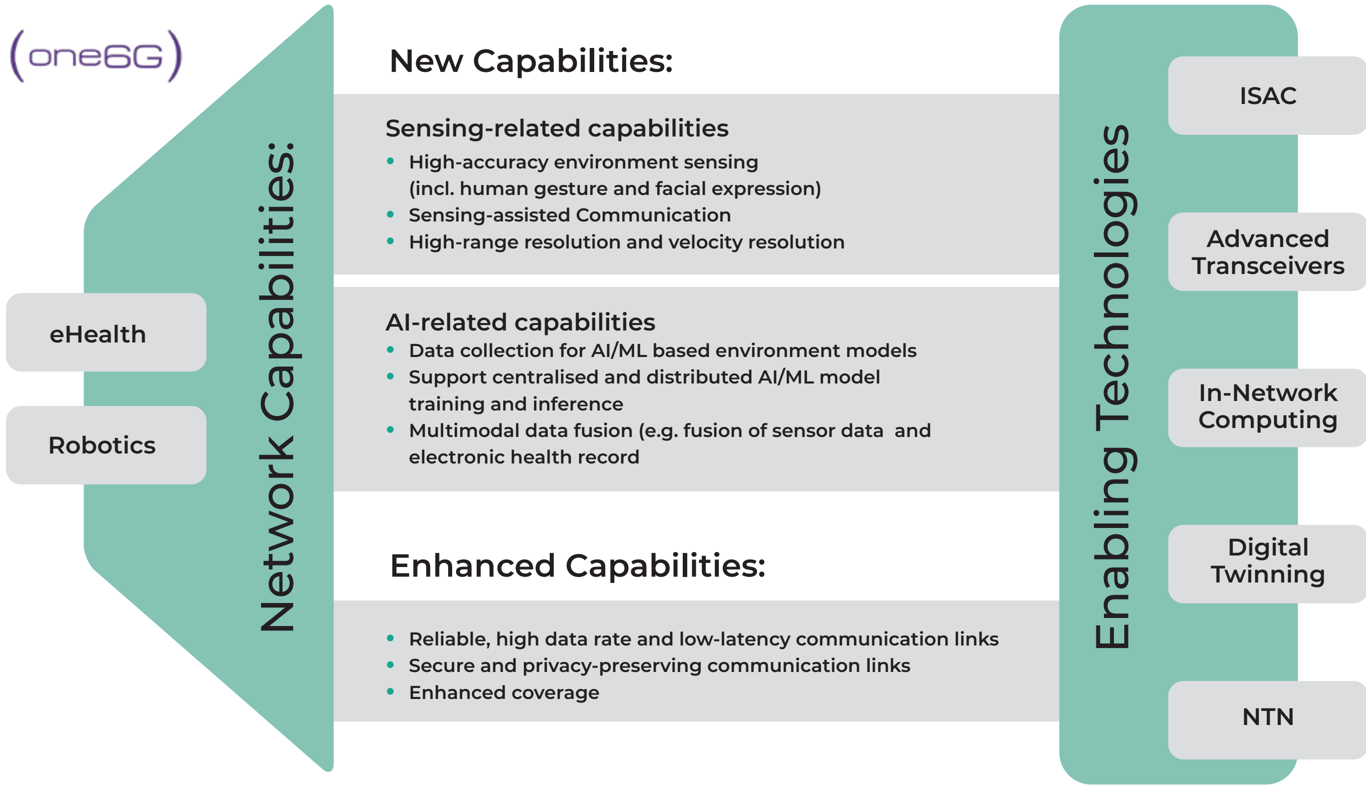


Figure 1: Capabilities and enabling technologies for the support of e-Health and Robotics applications

Identified Capabilities and Enabling Technologies for e-Health and Robotics domains:

The sensing-related and AI-related new capabilities, as well as the enhanced capabilities and the enabling technologies for e-Health and Robotics are highlighted in Figure 1.

Other requirements (functional and operational) for 6G to cater use cases in the e-Health and Robotics domain include:

- Dependability: Healthcare, industrial and consumer environments require reliable and high availability of communication and sensing across outdoor and indoor environments.
- Safety: Collaborative tasks between mobile robots and humans should be safe from the outset. The 6G system shall trigger/perform counter measures against potential risks and hazards to guarantee safety. One example is to trigger protective stop with 3GPP sensing for unintended robot motions as per ISO standards.
- Resilience: Communication and sensing infrastructure should be robust to jamming, eavesdropping and natural events.
- Simplified Operations: Professionals in healthcare and industrial environments shall be able to interact with 6G system with ease.

Although the network capabilities broadly overlap to enable uses cases of different vertical domains, detailed analysis of the use cases reveal some unique and specific network requirements. Given that standardization efforts towards 6G is slowly gaining momentum, early consideration of requirements from e-Health and Robotics verticals for 6G development is vital to contribute towards a unified 6G from the outset. A unified 6G is key towards establishing a fully digital ecosystem that can enable the realization of the use cases to its full potential as envisioned. This is crucial not only from a business perspective, but also in alleviating stress on some of the essential pillars of a well-functioning society.

one6G https://one6g.org/

IRIS^2 - 5G-NR NTN Multi-Orbit Satellite Communications System

As the satellite work in 3GPP matures, we hear from a major regional project that will make use of 3GPP 5G-NR NTN for its system of around 300 satellites deployed to provide a variety of applications. This is a guest article coordinated by the ESA. We would welcome articles from other regional projects in the future, but we hope that you will enjoy this early perspective on how 3GPP 5G will take to the skies.

By, Stefano Cioni – European Space Agency, Jaime Ferragut – European Commission, Daniele Finocchiaro – Eutelsat Group, José Luis Alcolea – Hispasat, Joel Grotz – SES

Connectivity has become an essential pillar of modern societies; however, many regions of the world are not yet adequately covered by terrestrial networks. Reliable connectivity enables education, healthcare, commerce and digital infrastructure – and satellite communications can provide much needed connectivity in regions not yet covered. In parallel to this, the increase of hybrid and cyber threats in recent years calls for additional security and resilience in digital communications. With this backdrop, a qualitative and quantitative improvement of satellite communications is required, moving towards robust security solutions featuring low latency, high data rates, and worldwide availability.

An ambitious plan for the development of IRIS^2: the new EU space-based secure connectivity system is underway. With a total budget of €10.6bn ($12bn), IRIS^2 (Infrastructure for Resilience, Interconnectivity and Security by Satellite) will become a new space pillar for a digital, resilient, and safer Europe; providing secure connectivity services to governmental and commercial users. In December 2024, the European Commission (EC) and the European Space Agency (ESA) signed two parallel contracts for the design, development and exploitation of IRIS^2 with SpaceRISE – an industry consortium led by the three major European satellite operators: SES, Eutelsat Group and Hispasat.

In March 2025, the IRIS^2 system was presented to the 3GPP TSG RAN#107 plenary meeting by industry members in 3GPP, showcasing the first fully fledged 5G-NR NTN multi-orbit satellite constellation enabling broadband services in Ku and Ka bands. Built upon disruptive technologies –such as 100 Gbps optical inter-satellite links (OISL) and the adoption of 5G protocols in the space, ground and user segments– this multi-orbit system will ensure long-term availability of reliable, secure, resilient, and cost-effective satellite connectivity services at a global scale. The adoption of the 3GPP 5G-NR NTN specifications will enable interoperability with terrestrial mobile networks, multi-vendor devices, and future-proof evolution of the IRIS^2 system. IRIS^2 aims to achieve Full Operational Capability in 2030, following the deployment of all its space and ground assets and the activation of all its communication features.

IRIS^2 is a system of systems, comprising circa 300 satellites deployed across low-LEO (<750 km), high-LEO (1200 km) and MEO (8000 km) orbits. IRIS^2 will provide a suite of connectivity services to end users with heterogeneous needs, including governmental and commercial applications. The commercial exploitation of IRIS^2 –along with the synergies between the governmental and commercial infrastructures– is a key element of the first-ever public-private EU partnership in space. The IRIS^2 service portfolio features a variety of communications services, spanning from high-throughput/low-latency broadband services to low-throughput narrowband services. In addition, the low-LEO layer of IRIS^2 has been conceived as an initial demonstration layer to showcase IoT services and direct-to-device (D2D) applications, amongst other. The initial deployment of the low-LEO layer targets 10 satellites of different payload size (small, medium, large) in FR1 spectrum. The multi-layered architecture of IRIS^2 will ensure broad worldwide coverage whilst minimising end-to-end latency thanks to the high-LEO layer. High-speed 100 Gbps optical inter-satellite links built upon the ESA-led ESTOL specification will interconnect IRIS^2 satellites to enable secure, low-latency and effective routing in space. This standards-based approach will also ensure the compatibility with other optical technologies, as well as backwards-compatible solutions. In addition, IRIS^2 will provide optical space data relay services to third-party satellites and aerial platforms, leveraging its optical inter-satellite link network.

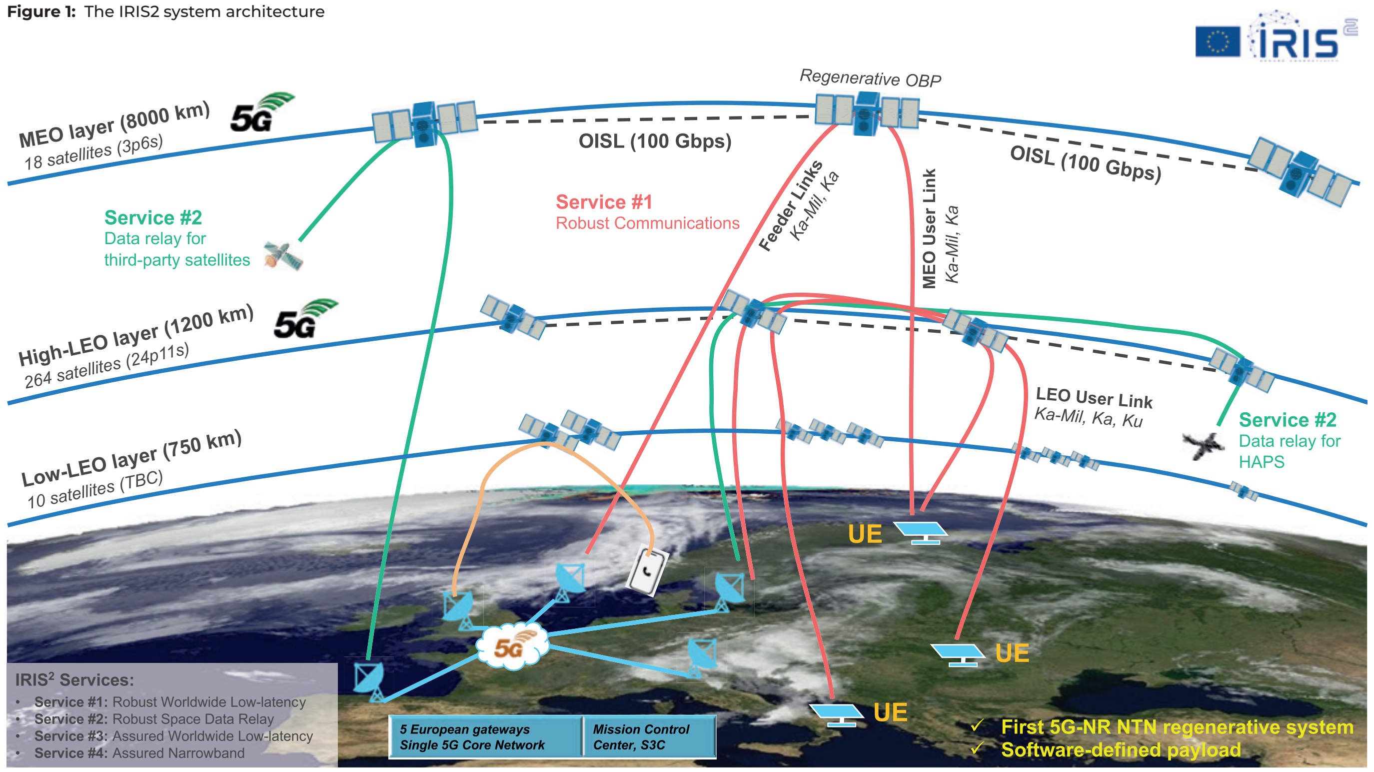
The IRIS^2 system is designed to meet several key requirements, including security, coverage, capacity, service availability and reliability, resource flexibility, mesh connectivity (i.e., UE-SAT-UE connectivity scenario), support of various target user terminals and latency constraints. The multi-orbit architecture of IRIS^2 is a crucial aspect of its design, as it enables optimal satellite visibility whilst increasing cost-efficiency by minimising the number of satellites required. By combining low-LEO, high-LEO and MEO satellites, IRIS^2 offers a robust and resilient communication infrastructure, aiming at the provision of redundant RF links and ensuring high communication resilience and continuous availability.

A high-level description of the IRIS^2 system architecture is shown in Figure 1, along with its main characteristics and features.

The adoption of 3GPP 5G-NR NTN technologies in the space, ground, and user segments will allow IRIS^2 to benefit from a robust and dynamic technology ecosystem, enable interoperability amongst user terminals, and improve its overall cost effectiveness. The use of 3GPP standards will also help realise the IRIS^2 vision of seamless integration of terrestrial and non-terrestrial networks in a single infrastructure and service continuum.

In the space segment, IRIS^2 will feature regenerative payloads enabling 5G radio access nodes in space. Spacecrafts will deploy Direct Radiating Array (DRA) antennas and Digital Beamforming Network (DBFN) for maximising the system capacity and achieving flexible resource allocation. The adoption of regenerative satellite payloads is an essential characteristic to enable the implementation of the UE-SAT-UE connectivity use case, where user-plane traffic does not transit through a ground gateway. In addition to regenerative mode, IRIS^2 will also support a transparent payload operational mode to enable specific applications.

Figure 1: The IRIS2 system architecture



The essential functions of the IRIS^2 ground segment are the Mission Control Centre (orchestrating and allocating resources of the network), the Satellite Constellation Control Centre (ensuring a correct control of the spacecraft platforms), the GOVSATCOM Hub (delivering SatCom services to governmental end users), the high-speed communications links (interconnecting all ground segment sites) and the 5G Core Network (routing and processing 5G user- and control-plane traffic). The choice of a fully-fledged 5G Core Network also enables a seamless integration with mobile terrestrial networks by implementing standardised interoperability functions, thus simplifying both commercial and governmental network interconnection. The IRIS^2 5G Core Network will support different slices that can be exploited by key verticals, such as automotive, railway, mission-critical communications, agriculture, etc.

In the user segment, 5G-NR NTN-based user equipment is an essential and strategic aspect to stimulate competition and reduce terminal costs by leveraging economies of scale. IRIS^2 aims to foster innovative non-geostationary satellite terminals (both in Ku and Ka bands) based on flat panel antenna technology, and adapting as much as possible the technologies available for terrestrial networks. The IRIS^2 user segment will be multi-vendor compatible, enabling an ecosystem of manufacturers to address the needs of the different use case verticals. The broad scope of IRIS^2 use cases comprises a variety of operational conditions – from fixed services to aeronautical, maritime, or automotive, amongst other. This heterogeneity calls for a broad range of user terminals with specific requirements.

Table 1 provides a high-level summary of the key benefits of adopting 5G-NR NTN standards in IRIS^2 in terms of technological and commercial benefits. A stable, complete, and secure set of NTN features and capabilities is fundamental to unlock the ambitious IRIS^2 mission requirements. To achieve this, IRIS^2 will work hand in hand with the 3GPP ecosystem to ensure that mission requirements are well understood, and that appropriate technical solutions are developed within the standards.

Table 1: Technological and commercial benefits of adopting 5G-NR NTN standards in IRIS^2

Technological Benefits	Commercial Benefits
✓ Integrated Quality-of-Service (QoS) architecture	✓ Mature and open standards ecosystem with a clear evolution path
✓ Flexible resource management and scalable network size	✓ 3GPP-enabled vendor interoperability and economies of scale
✓ Built-in 3GPP security and authentication mechanisms	✓ Lower entry barriers for new SatCom actors
✓ Interworking with other 3GPP-based networks	✓ Synergies with other key verticals to extend use cases and scenarios

IRIS^2 will provide secure communications with global coverage, connecting commercial and governmental users worldwide. Its 3GPP-based architecture will enable economies of scale and integration with other terrestrial and satellite networks, with a particular focus on security and resilience for governmental applications. As the first fully-fledged 5G-NR NTN system, IRIS^2 stands as a tangible and timely opportunity for the 3GPP ecosystem to demonstrate its leadership in Non-Terrestrial Networks and to turn global ambitions into reality.

More about the Infrastructure for Resilience, Interconnectivity and Security by Satellite (IRIS^2) Public-Private Partnership project is available at: **https://defence-industry-space.ec.europa.eu/**

5G RedCap: Unlocking Scalable IoT and FWA Innovation with Reduced Capability 5G

By Joe Barrett, President of Global mobile Suppliers Association (GSA)

5G Reduced Capability (RedCap), introduced in 3GPP Release 17 and refined in Release 18 with enhanced RedCap (eRedCap), marks a pivotal step in the evolution of 5G for mid-tier applications. Positioned between the extremes of massive machine-type communications (mMTC) and enhanced mobile broadband (eMBB), RedCap addresses a previously underserved segment – namely, devices requiring modest data throughput, reduced latency and extended battery life, but without the cost and complexity of full 5G NR

Originally referred to as "NR-Light," Release 17 RedCap simplifies the 5G device transceiver by limiting bandwidth (up to 20 MHz), removing support for carrier aggregation and dual connectivity, and supporting single-antenna configurations. These design choices significantly reduce device complexity, size and power consumption while maintaining a peak data rate of up to 226 Mbps in downlink and up to 120 Mbps in uplink.

In Release 18, eRedCap takes this further, targeting applications with even more modest data rate requirements by capping the peak data rate to 10 Mbps in both downlink and uplink, contributing to further reduce the device cost compared to RedCap.

In addition, Release 17 introduces some features for lowering the device power consumption that can be implemented by RedCap devices, eRedCap devices, and other 5G NR devices.

The introduction in Release 13 of extended discontinuous reception (eDRX) cycles for battery endurance stretching into years for industrial sensors and wearables is further improved in Release 18 to provide even better battery life by enabling even longer cycles.

Crucially, RedCap is based on the 5G Standalone (SA) architecture, unlocking features such as network slicing, URLLC, API-based network services and cloud-native orchestration. This provides mobile network operators with the flexibility to serve a broader spectrum of IoT use cases without relying on legacy LTE infrastructure.

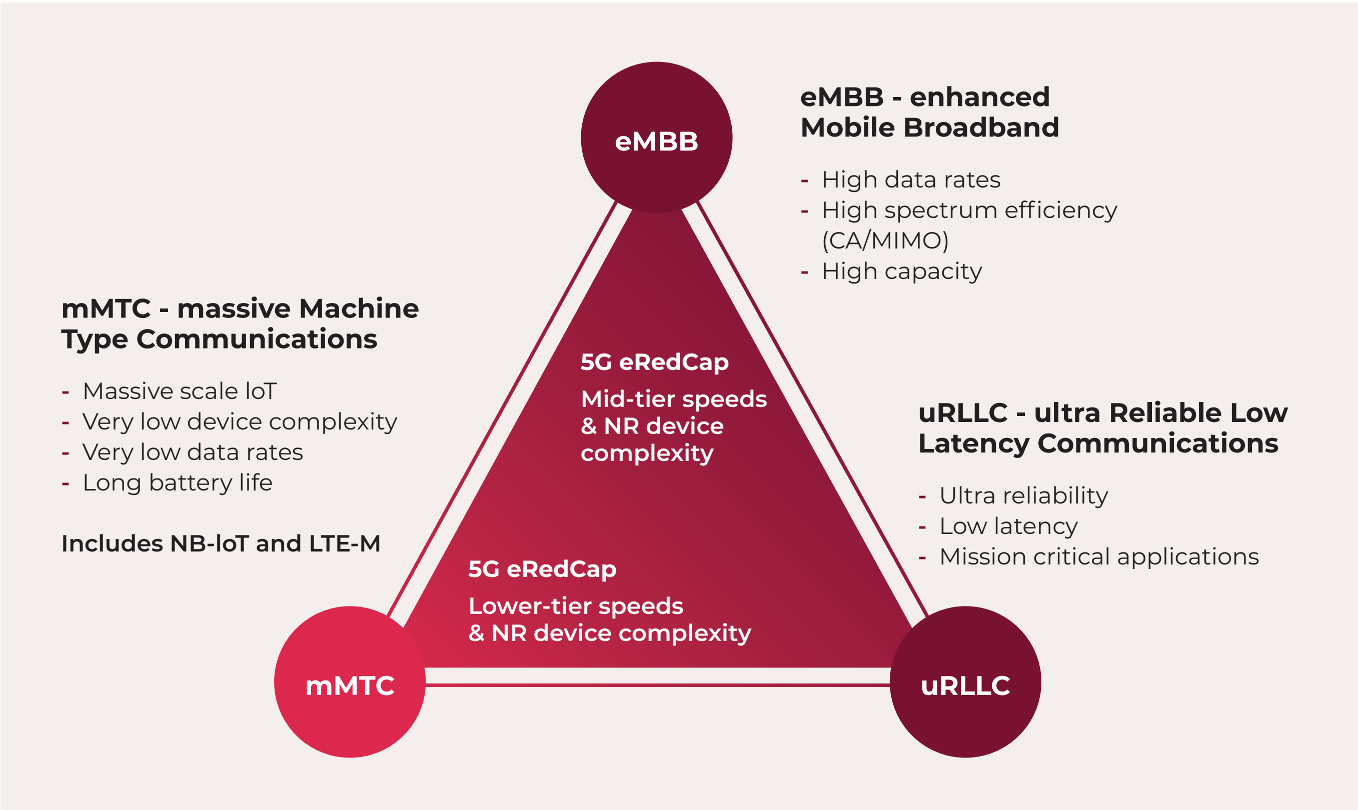


Figure 1: RedCap/eRedCap positioning against 5G use case groups defined in IMT-2020, Source: GSMA - RedCap/eRedCap for IoT (February 2025)

> Commercial tests and pilot deployments are underway globally, spanning the Americas, Europe, the Middle East and Asia-Pacific

Early RedCap ecosystem momentum

As of April 2025, GSA has identified 30 operators across 21 countries investing in RedCap, including commercial launches by China Mobile, China Telecom, China Unicom, Dito (Philippines), STC (Kuwait) and T-Mobile US. Commercial tests and pilot deployments are underway globally, spanning the Americas, Europe, the Middle East and Asia-Pacific.

This early operator deployment momentum is being mirrored in the device ecosystem where leading chipset vendors such as Qualcomm, MediaTek, ASR and Sequans are providing RedCap-ready platforms. Module makers including Fibocom, Quectel, Telit Cinterion, Smawave and MeiG Smart have introduced RedCap-enabled products targeting gateways, wearables and CPEs. GCF-certified RedCap modules and devices are now emerging, with further growth expected throughout 2025 and 2026.

RedCap's relevance spans both IoT and Fixed Wireless Access (FWA) domains and both consumer and industrial products. In IoT, RedCap enables scalable deployments across verticals such as industrial automation, smart energy and logistics, in retail with Point of Sales devices, and through consumer wearables such as smart watches and connected health devices. For instance, wireless industrial sensors can now benefit from enhanced uplink performance and energy efficiency, while wearables can offer voice over NR (VoNR) support without sacrificing form factor or battery life. Smart grid applications, such as substation telemetry and distribution automation, stand to benefit from RedCap's latency and throughput profile, particularly in uplink-dominant traffic scenarios.

In parallel, RedCap is emerging as a viable alternative for FWA in markets transitioning away from LTE. GSA data shows that, as of late 2024, 494 operators in 176 countries had launched LTE or 5G FWA services. With 5G SA networks expanding and spectrum refarming on the agenda, RedCap-capable FWA CPEs present a compelling opportunity to deliver broadband to underserved regions, while freeing up LTE assets and simplifying operators' RAN portfolios.

RedCap future

However, while RedCap is an abbreviation of Reduced Capability, the name can be misleading. New RedCap-based AI-enhanced devices are now being brought to market by vendors, combining local compute with smart networking. Supporting intelligent features such as adaptive roaming and power optimization modes using embedded AI models, RedCap devices can extend beyond connectivity to become an intelligent platform for service delivery.

Nevertheless, deployment is not without challenges. RedCap requires a functioning 5G SA core and while momentum is building, with GSA data reporting 154 operators investing in SA as of Q1 2025, coverage remains uneven. Roaming support is similarly nascent, requiring dedicated inter-PLMN agreements and the introduction of RedCap RAT types in core policy frameworks. Furthermore, network policies must be carefully managed to prevent low-complexity RedCap devices from adversely affecting cell-level resource efficiency, particularly in high-density scenarios.

For mobile ecosystem vendors, encompassing chipset suppliers, module manufacturers, device OEMs and infrastructure providers, RedCap represents both a commercial opportunity and a strategic lever for the deployment of new 5G use cases. By enabling cost-effective, future-proof connectivity across a diverse device landscape, RedCap supports the industry's transition to scalable 5G SA infrastructure, while preparing the ground for future 6G use cases.

As RedCap matures, it will place a central role in the mid-tier device segment, replacing LTE Cat-3 / Cat-4 in IoT, and supporting mass-market 5G FWA deployments in parallel. Looking forward to the replacement of LTE Cat-1/Cat-1bis, eRedCap will further extend this value proposition into constrained device categories starting in 2026 and beyond.

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3GPP Excellence Awards for 2024

The annual Excellence awards for outstanding delegates in 3GPP have been presented by the Working Group Chairs during the May 2025 WG meetings. The 2024 awardees are:

CT3 - Abdessamad El Moatamid

Major contributor in WG CT3, holding number of technical Rapporteur-ships. His major areas include: Network Capability Exposure frameworks and APIs (i.e., SCEF/NEF Northbound APIs and Application Enabler Layer APIs), 5G Core Network Signalling, Policy and Charging Control (PCC) frameworks and Multicast/Broadcast services and the definition of service-based Open APIs.

CT4 - Ulrich Wiehe

Active in WG CT4 work on: NRF API enhancements to avoid signalling and storing of redundant data (NRFe), SBI Protocol enhancements (SBIProtoc18/19) and Reducing Information Exposure over SBI (RedInfExp_SBI), 5G Timing Resiliency and TSC&URLLC enhancements (TRS_URLLC), CT aspects of Edge Computing Phase 2 (EDGE_Ph2) and CT aspects of Generic group management, exposure and communication enhancements (GMEC).

RAN4 - Ruixin Wang

Held a number of Rapporteur-ships on OTA projects, including: FR2 OTA SI, MIMO OTA SI/WI, and TRP TRS WIs. Editor of OTA specs, including TS 38.151 (MIMO OTA performance requirements), TS 38.161 (TRP TRS requirements), and TR 38.827(MIMO OTA test methods) and TR 38.870 (SISO OTA test methods), showing great leadership on Rel-18 TRP/TRS projects.

SA3 - Rajavelsamy Rajadurai

Responsible for multiple WIDS/SIDs - Security aspects of NR mobility enhancement Phase 4 (Rel-19), Security aspect of Subsequent Conditional PSCell Addition or Change (SCPAC) (Rel-18), Service Enabler Architecture Layer (SEAL) (Rel-16, Rel-17 & Rel-18), Integrated Access and Backhaul (IAB) (Rel-17), Security Assurance Specification (SCAS); User Plane Function (UPF) (Rel-16), Common API Framework (CAPIF) (Rel-15 & Rel-16), Machine-Type Communications (MTC) (Rel-12 & Rel-13).

Elections at TSG and WG level

The March 2025 TSGs#107 meetings featured elections for the Plenary level leadership for the next two years. Peter Schmitt (CT) and Puneet Jain (SA) were elected for their second terms and Younsun Kim was elected to the TSG RAN Chair.

There are Working Group elections in May 2025 for CT6, RAN1, RAN3 and SA1,2,3,4.

At the time of writing (May 15), the current TSG and WG Chairs are:

CT	Plenary	Peter	Schmitt	Huawei
CT	1	Lena	Chaponniere	Qualcomm
CT	3	Yali	Yan	Huawei
CT	4	Yue	Song	China Mobile
CT	6	Heiko	Kruse	IDEMIA
RAN	Plenary	Younsun	Kim	Samsung
RAN	1	Younsun	Kim	Samsung
RAN	2	Diana	Pani	InterDigital
RAN	3	Yin	Gao	ZTE
RAN	4	Yang	Tang	Apple
RAN	5	Jacob	John	Motorola Mobility
SA	Plenary	Puneet	Jain	Intel
SA	1	Jose Luis	Almodovar Chico	TNO
SA	2	Andy	Bennett	Samsung
SA	3	Suresh	Nair	Nokia
SA	4	Frederic	Gabin	Dolby
SA	5	Lan	Zou	Huawei
SA	6	Atle	Monrad	InterDigital

The results of the 3GPP Group elections are posted on the website at Delegates Corner/Elections.

Working alongside the O-RAN Alliance

A two-day workshop, held in Sophia Antipolis, from April 24 provided an opportunity for 3GPP and O-RAN Alliance experts to share ideas on how to best deliver RAN specifications for the next generation of systems.

Around 110 delegates attended in person to hear about the respective work plans and to study how best to approach future cooperation – avoiding any potential for standards duplication or fragmentation in 6G.

Following the final session of the workshop, a summary of the discussions over the two days was presented (3ORW-250035). Although the workshop summary is non-binding, both bodies agreed that the discussions were positive, contributing to a better mutual understanding between 3GPP and O-RAN Alliance experts.

Run for fun in Malta

During the recent RAN WG meetings a fun-run was held, at the Pembroke Natura 2000 park, near St. Julian's bay, Malta on behalf of HospiceMalta. Delegates bought T-shirts, walked and ran after the close of the meetings on Wednesday, May 21 to raise money for a fantastic local charity. https://hospicemalta.org/

RAN 3 (left) and RAN 2 basketballers

Hoops in Wuhan

A basketball game between the RAN3 and RAN2 delegates on April 7 – during the May RAN WGs meeting week – has been described as both 'friendly' and 'intense', with a thrilling end-to-end match resulting in a narrow win for RAN2 by a scoreline of 24–21.

The game organiser Chen Jiajun thanked participants and member sponsors ZTE Corp., OPPO, Nokia, TTA, Huawei, Lenovo, CATT and CAICT for their generous support.

CALENDAR OF MEETINGS

Here is a snapshot of upcoming TSG (bold) and WG meetings.

The full calendar is online at: https://portal.3gpp.org

Meeting	Start date	City
TSGs#108	**09-Jun-25**	**Prague**
SA4#133-e	21-Jul-25	Online
CT1#156	25-Aug-25	Goteborg
CT3#142	25-Aug-25	Goteborg
CT4#130	25-Aug-25	Goteborg
RAN1#122	25-Aug-25	Bengaluru
RAN2#131	25-Aug-25	India
RAN3#129	25-Aug-25	India
RAN4#116	25-Aug-25	India
RAN5#108	25-Aug-25	Bengaluru
SA1#111	25-Aug-25	Goteborg
SA2#170	25-Aug-25	Goteborg
SA3#123	25-Aug-25	Goteborg
SA5#162	25-Aug-25	Goteborg
SA6#68	25-Aug-25	Goteborg
CT6#123	26-Aug-25	Goteborg
TSGs#109	**15-Sep-25**	**Beijing**
CT1#157	13-Oct-25	Sophia-Antipolis
CT3#143	13-Oct-25	Sophia-Antipolis
CT4#131	13-Oct-25	Sophia-Antipolis
RAN1#122-bis	13-Oct-25	Prague
RAN2#131-bis	13-Oct-25	Prague
RAN3#129-bis	13-Oct-25	Prague
RAN4#116-bis	13-Oct-25	Prague
SA2#171	13-Oct-25	Wuhan
SA3#124	13-Oct-25	Wuhan
SA5#163	13-Oct-25	Wuhan
SA6#69	13-Oct-25	Wuhan
CT1#158	17-Nov-25	Dallas
CT3#144	17-Nov-25	Dallas
CT4#132	17-Nov-25	Dallas
RAN1#123	17-Nov-25	Dallas
RAN2#132	17-Nov-25	Dallas
RAN3#130	17-Nov-25	Dallas
RAN4#117	17-Nov-25	Dallas
RAN5#109	17-Nov-25	Dallas
SA1#112	17-Nov-25	Dallas
SA2#172	17-Nov-25	Dallas
SA3#125	17-Nov-25	Dallas
SA4#134	17-Nov-25	Dallas
SA5#164	17-Nov-25	Dallas
SA6#70	17-Nov-25	Dallas
CT6#124	18-Nov-25	Dallas
TSGs#110	**08-Dec-25**	**Baltimore**

- 852 Member Companies or Organizations
- 41 Countries
- 20,323 Meeting Delegate Registrations in 2024
- 124 Meetings in 2024
- 4,310 3GPP Specifications

3GPP Technical Specifications are transposed by our seven Organizational Partners into their appropriate National and Regional deliverables (Specifications/Standards).

A full listing of 3GPP Members is online at: www.3gpp.org/about-us/membership