3GPP A GLOBAL INITIATIVE

3GPP Highlights

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the 3GPP Newsletter

Technical News

We look at Secure Roaming and why the end-to-end security introduced in 5G represents a fundamental change in how roaming security is approached.

Our TSG SA and TSG RAN Chairs look forward to the workshop season, and at how Rel-19 work and Rel-20 planning are progressing.

3GPP TSG CT have stepped up again, providing three articles on Capability Exposure APIs, Edge computing protocols and the group's work on Network Automation Enablers.

There is also a case study on how Indirect Network Sharing (INS) is helping 5G cross-network roaming for participating operators in China.

We also have articles on Rel-18 management & orchestration features and on the status of WG SA1's study on 6G requirements.

Partner Focus

We hear from TCCA on how they are bringing user requirements for next generation critical broadband services into 3GPP.

The Alliance for private networks look at 3GPP UE groups of features that are being used in 5G NPN deployments.

The GSA consider the Global impact of pandemics and Geopolitical uncertainties on the resilience of supply chains for the mobile industry.

Our end piece by the 5G-ACIA explains how the ICT and Operating Technologies (OT) industries have adopted 5G and asks what lessons have been learned as we look towards 6G?

FORE - WORD

This issue of Highlights again attempts to reflect a diversity of material and a broad range of interests from the 3GPP groups and from our partners.

Our Technical Highlights this time include some insights from the leadership – on the status of the latest release and the evolving plan for Release 20. As Rel-19 continues its progress and remains the main focus of specification work, until its completion in late 2025, the early stage workshops around Rel-20 already show that it is shaping up as a major bridge from 5G Advanced to 6G studies – and onwards towards its normative phase from Release 21 onwards.

The detailed technical articles in this issue range from Security for 5G roaming, Management support of new network features and services, an operator perspective on Network Sharing Evolution, news on 3GPP Capability Exposure APIs, Edge computing in CT protocols, and an article on the latest protocol descriptions and interface design to support network automation.

There is also a first look at the WG SA1 approach to their Study Item Description and the schedule for the first draft of the resulting Technical Report (TR 22.870 - Study on 6G Use Cases and Service Requirements).

Four of the official Market Representation Partners (MRPs) have also penned their latest thinking on how 3GPP can help their members towards a better and bigger 6G world.

TCCA raise the need for both 5G Advanced and future 6G to continue to help societies to a greater position of trust in the network. The Alliance for private networks tell us about how Uni5G™ technology blueprints are simplifying private network deployment for industry verticals. The GSA bring us their expertise on the effect of the pandemic and resulting global developments on the maintenance of an effective supply chain for goods and services.

Finally, General Chairs of 5G-ACIA have looked at the status & progress of Industrial 5G to date and the lessons learnt for the journey towards Industrial 6G.

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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NEWS IN BRIEF

one6G becomes a 3GPP Market Partner

Founded in 2021, one6G provides an innovation hub for partners from the vertical domains. The major areas of work for the Association include the collection and study of 6G use cases with a view to shaping technology & architecture aspects and ultimately helping the work progress through testing and 6G pilots.

The areas where one6G is operational include; the green transition, the energy sector, transportation, industrial and smart factories, health, cities & public services, media & entertainment, tourism & culture. By bringing expertise from these areas into 3GPP, one6G is set to be an important supporter and contributor to the project.

3GPP now counts on 27 MRPs for their support and expert guidance. See **www.3gpp.org/about-us/partners** for a full listing.

www.One6G.org

F2F meetings schedules agreed for 2026

At the recent Organizational Partner meeting (OP#52) the 2026 calendar & venues for major meetings were nailed down. A highlight worth waiting for will be the June 2026 Plenaries (TSGs) going to Singapore, for the first time. The other locations are decided at the national and regional level, with details of the cities selected to be confirmed during 2025:

February 2026	RAN WGs	Europe
February 2026	SA and CT WGs	India
March 2026	TSGs	Japan
April 2026	CT1, 3, 4, RAN1, 2, 3, 4 WGs SA2, 3, 5, 6	Europe
May 2026	RAN, SA and CT WGs	China
June 2026	TSGs	Singapore
August 2026	RAN, CT WGs, SA WGs	Europe
September 2026	TSGs	Europe
October 2026	RAN1, 2, 3, 4 WGs	Korea
October 2026	SA2, 3, 5, 6 and CT1, 3, 4 WGs	Europe
November 2026	CT WGs, SA WGs, RAN WGs	North America
December 2026	TSGs	North America

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

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Rel-20 Planning and Progress in TSG SA

5G-Advanced and the First Steps Toward 6G

By Puneet Jain, 3GPP TSG SA Chair

In the fast-evolving world of mobile telecommunications, standards development is an intricate process, with each new release refining, building, and expanding upon its predecessor. 3GPP's latest focus on Release 20 (Rel-20) represents a crucial step toward the next-generation network architecture, balancing the dual objectives of advancing 5G while laying the groundwork for 6G.

This journey is about pushing boundaries, meticulous planning, and fostering collaboration on a timeline that must come together in seamless harmony.

Rel-20 introduces a unique approach, dividing its focus into two key components: Rel-20_5GA for 5G-Advanced and Rel-20_6G for early 6G studies (see figure 1). This dual-track framework allows 3GPP to innovate within 5G-Advanced, supporting near-term network upgrades, while simultaneously initiating the research phase for 6G, which will unfold more fully in Release 21. Each track operates under separate timelines and planning strategies, making Rel-20 adaptable across various TSG and WG groups based on their resource priorities.

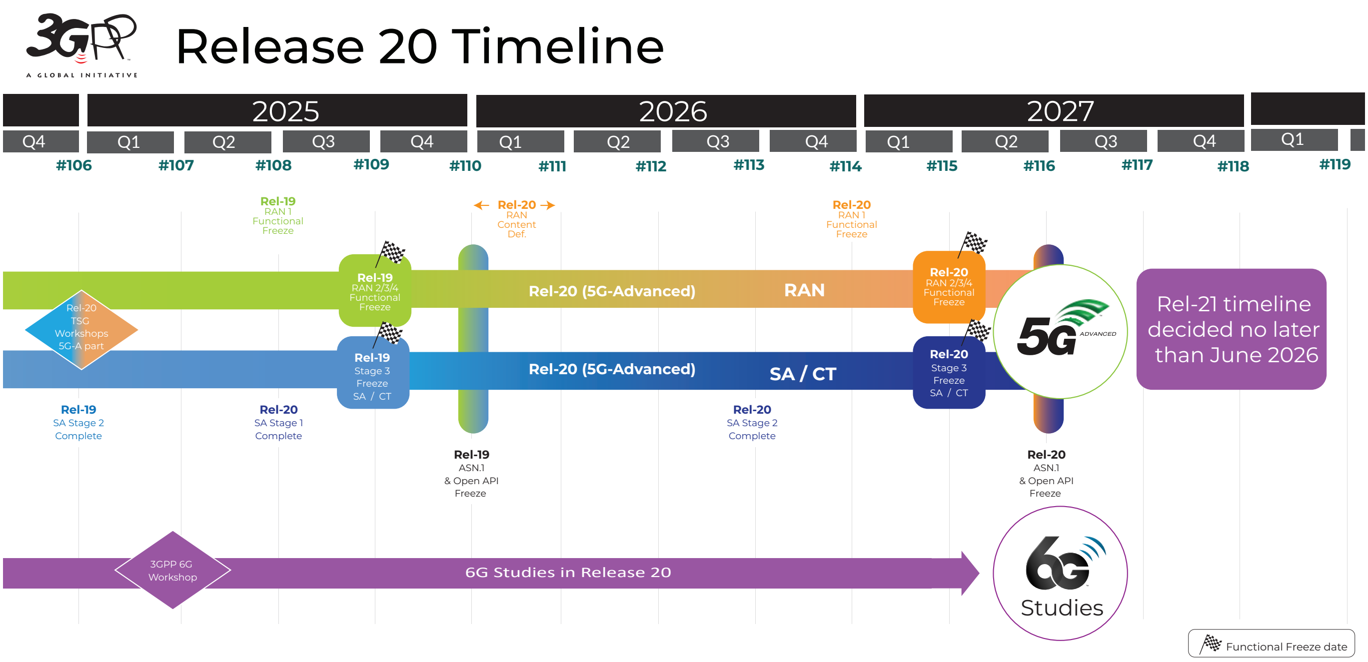


Figure 1: Rel-20 timeline

5G-Advanced in Rel-20: Building on the Foundations of 5G

For Rel-20 5G-Advanced, 3GPP has set an 18-month roadmap focused on enhancing the current capabilities of 5G. The planned schedule ensures a steady progression toward critical upgrades, with progressive freezes as follows:

- Stage-1 (service requirements) is expected to freeze in June 2025.
- Stage-2 (system architecture aspects) has a two-tier timeline, with 80% completion anticipated by June 2026, leading to a final freeze in September 2026.
- Stage-3 (protocol details) is targeted for March 2027, followed by the final ASN.1/OpenAPI freeze in June 2027.

In SA1, which is dedicated to service requirements and use cases, three Rel-20 5G-Advanced studies are advancing steadily: Satellite Access - Phase 4 (FS_5GSAT_Ph4), Future Railway Mobile Communication System - Phase 6 (FS_FRMCS_Ph6), and Energy Efficiency as Service Criteria Phase 2 (FS_EnergyServ_Ph2). Six new Mini-WIDs (Work Item Descriptions) have also been agreed upon, furthering Rel-20's innovative focus.

For the other SA working groups, the primary focus remains on preparation for the Rel-20 5G-Advanced Workshop scheduled for December 2024. This workshop, a key component of SA#106, will bring together each working group's insights to identify high-level themes that deserve focused attention in Rel-20. The gathering will mark a pivotal point, where initial concepts begin to take shape and crystallize into a roadmap for the future. Key decisions on the prioritization process—whether a single-step or two-step prioritization will be applied—are expected to follow the workshop.

6G Studies in Rel-20: Laying the Groundwork for the Next Generation

For Rel-20 6G studies, the journey ahead involves deep exploratory work. This track of Rel-20 is solely dedicated to 6G studies, with the normative work for 6G slated for the next release, Release 21. These studies will form the foundation for 6G's service requirements, use cases, and system architecture.

There is a detailed article in this issue (see page 18) for WG SA1 aspects, covering the 3GPP workshop on IMT2030 use cases (May 2024), the start of SA1 work on 6G use cases and service requirements (FS_6G_REQ), and the progress of TR 22.870, which is to serve as their on-going study as the release progresses.

Other working groups, such as SA2, aim for SI approvals by June 2025 (TSG#108), while timelines for SA3/4/5/6 are still under consideration. The completion of 6G studies will be coordinated across TSG SA Working Groups, with final milestones projected for as late as 2027. This gradual approach will enable 3GPP to iterate, refine, and build consensus, setting the stage for Release 21, which will officially initiate normative work for 6G.

To streamline 6G's development, 3GPP's TSG-wide 6G workshop will be held in Mar 2025 alongside TSG#107, bringing together stakeholders from RAN, SA, and CT.

This workshop will include both parallel and joint RAN/SA/CT sessions, focusing on 6G topics such as radio aspects, system architecture, and core network requirements. The agenda includes a range of 6G-focused contributions from companies, providing a forum for industry leaders to help shape the technical studies for 6G within the working groups.

Towards IMT-2030: Rel-21 and Beyond

The journey from Rel-20 to Rel-21 represents a critical phase, particularly for 6G. Release 21 marks the official start of normative 6G work and is expected to produce the first formal 6G technical specifications, aligning with IMT-2030 submission requirements. The Release 21 timeline, expected to be finalized no later than June 2026, ensures that 3GPP's specifications for 6G will be ready ahead of the IMT-2030 submission window, with ASN.1/OpenAPI freezes projected by March 2029.

Rel-21 will be a landmark, showcasing the initial wave of 6G technologies through a single, comprehensive release. For stakeholders across the industry, it will be the true inflection point, revealing 3GPP's vision for 6G, poised to influence global standards for years to come.

A Shared Vision for the Future

Rel-20 is more than just an incremental upgrade—it is the bridge between today's networks and the transformative potential of tomorrow. With each TSG and WG tasked with balancing efforts between the near-term advancements of 5G-Advanced and the exploratory groundwork for 6G, 3GPP's work in Rel-20 will shape the telecommunications landscape for years to follow.

As we anticipate the outcomes of the December workshop and the subsequent finalization of Rel-20's themes, it's evident that each milestone brings us closer to a transformative era where 5G-Advanced and 6G redefine connectivity for consumers, enterprises, and society as a whole. Through Rel-20, 3GPP is not just setting a course—it's building a future that is faster, more resilient, and profoundly intelligent. A future where the promise of 6G becomes not only a goal but a realized vision.

TSG SA#105 in session, Melbourne (September 2024)

5G Roaming Security

By Yousif Targali (Verizon), Anja Jerichow (Nokia),
Andreas Pashalidis (German Federal Office for Information Security)

The 5G-Standalone (5G SA) roaming security, as specified by SA3, marks a substantial enhancement over the roaming mechanisms of previous generations. This is because it aims to address the root cause of a wide range of attacks that have taken and continue to take place over the roaming infrastructure in the past decades: the lack of attribution

More precisely, 5G SA roaming aims to increase the transparency how the signalling infrastructure is interconnected by enabling a form of trace back of each signalling message to its originator, without the need for complex procedures that require the collaboration of players, typically spanning multiple jurisdictions.

This is possible because 5G SA roaming requires that:

(a) Operators and roaming intermediaries be equipped with cryptographic credentials, bound to their unique identity, and that they use these credentials to digitally sign the messages they generate.

(b) Security associations be established end-to-end between the Secure Edge Protection Proxies (SEPPs) of the two roaming partners, i.e. without terminating at roaming intermediaries such as IPX service (hub) or roaming hubs providers.

This article summarises the work done within the SA3 WG since Release 15 to provide end-to-end security for the different 5G Roaming deployment models and to address the gaps that existed in the legacy networks.

5G Roaming security architecture

The 5G roaming security architecture, as defined by SA3 WG, introduces the SEPP as an architectural element and defines N32 as the interconnect interface, to allow end-to-end secured communication between service-consuming and service-producing NFs in the different PLMNs. The SEPPs are located at the perimeter of each operator network and communicate via the N32 interface. This interface is split into two constituent sub-protocols: N32-c and N32-f.

The purpose of N32-c is to verify that the SEPPs of the roaming partners are configured in a compatible manner, and the purpose of N32-f is to exchange the signalling messages.

Initially, the SEPPs authenticate themselves mutually via N32-c and negotiate the security mechanism for N32-f end-to-end protection matching the needs for the deployment scenario. This can be either the Transport Layer Security (TLS) protocol for bilateral/direct roaming solutions between operators or the Protocol for N32 Interconnect application layer Security (PRINS) for mediated roaming solutions.

N32-c is also used for control signalling, such as for error reporting and closing of N32-f. When the PRINS mode is selected for N32-f, N32-c is further used to negotiate protection policies ensuring integrity and confidentiality protection for certain information elements, and modification policies, that define which elements are allowed to be modified by the Roaming Intermediaries between the two operators. The functionality of the SEPP includes message filtering and policing the Inter-PLMN control plane interface as well as topology hiding by limiting the internal topology information visibility to entities external to operator network.

The different roaming models and their security are described below.

Direct roaming model

The direct roaming model refers to a direct bilateral roaming deployment model between two operators PLMN-A and PLMN-B, depicted in Figure 1. The interconnection between PLMN-A and PLMN-B could be direct or through Roaming Intermediaries (RIs) which only offer IP routing service.

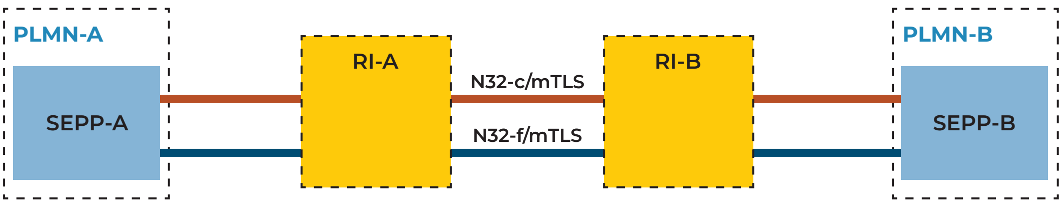


Figure 1: Security for the direct roaming model

TLS with mutual authentication is used in the direct roaming model. N32-c is used to negotiate TLS as the security method for N32-f. The termination points for the N32-f and N32-c are the SEPPs located at the border of each operator network.

Assuming a globally trusted PKI for the management of the TLS certificates, this architecture ensures the security of the HTTP/2 roaming signalling messages over the N32-f interface, through mutual authentication, encryption, integrity, and replay-protection.

Mediated roaming model

While some roaming relations are direct bilateral, others are mediated. In the latter case Roaming Intermediaries, i.e. IPX service (hub) providers and/or roaming hub providers are involved in the establishment of the relation and the routing of the signalling traffic with an interest in having access to the HTTP/2 roaming signalling messages to offer more than just IP routing.

Figure 2 illustrates the mediated roaming model. The maximum of two Roaming Intermediaries (RI), each of them in a contractual relationship with one SEPP's PLMN, is allowed if the RI is not only for IP routing.

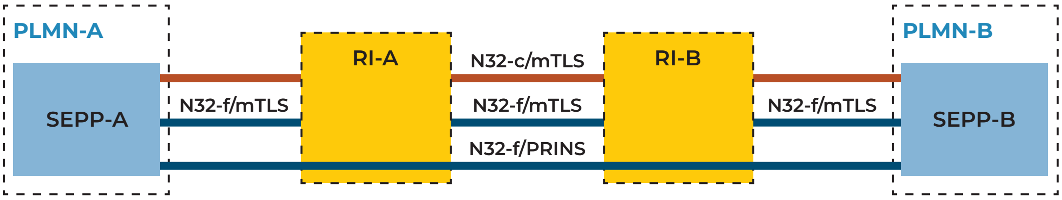


Figure 2: Security for mediated roaming model

The logical security associations of the constituents of the N32 interface in this hubbing context are as follows: N32-c/TLS, which terminates at the SEPPs is used, among other things, to exchange keying material for PRINS, and N32-f/PRINS, which is used to exchange the actual signalling while enabling intermediaries (RIs) to offer services.

In more detail, N32-c is used to negotiate PRINS as the security method for N32-f, and to exchange the information necessary to proceed with exchanging N32-f signalling securely. In mediated roaming, a cascade of TLS connections is setup between SEPPs and RIs providing transport layer security of the links between each hop, as shown in the figure, and PRINS is used as the application layer security protocol over this cascade allowing the RI to read those HTTP/2 message elements that are unencrypted per operator policy and selectively modify if allowed.

Support for additional features

The support of additional features for Roaming Hubs by SEPPs was introduced in Release 18 and back ported to Releases 16 and 17. Applicability from Release 16 onwards is recommended and technically possible.

These features enable Roaming Hubs to originate error messages to either PLMN SEPPs or adjacent Roaming Hubs, in an identifiable/traceable way, and Roaming Intermediaries to determine the intention of using PRINS as the security method for the N32-f protocol.

The mechanism used by the SEPP for setting up N32-c over TLS via a chain of Roaming Intermediaries makes use of the HTTP CONNECT method and contains sufficient information such that the target PLMN and the Roaming Intermediaries can determine the identities of the initiating PLMN and the target PLMN. .

In addition, Release 18 defines that a Roaming Hubs can generate application layer control plane messages to trigger a Network Function to reject registration attempts and/or deregister the UE.

In this case, such messages are transparent to the SEPP and the SEPP acts on them as any other message on the N32-f interface not making use of Roaming Intermediaries. How the SEPP authorises such messages is left to implementation.

Support for RVAS

In its simplest form, a Roaming Value Added Service (RVAS) merely needs to observe certain fields in order to generate statistics or reports. Such an RVAS can be implemented in a straight-forward manner since all that is required is to ensure that suitable PRINS protection policies are used at the SEPPs (e.g. by avoiding to encrypt the required data). Other RVAS require an on-the-fly modification of the values in certain fields in the signalling. Such RVAS are supported since PRINS enables intermediaries to modify signalling messages in a traceable manner; again, a suitable protection policy at the SEPPs is required.

More complex RVAS require intermediaries to generate signalling triggered by their own application logic. Such support has been included since R18. It should be noted that PRINS is not the only way in which an RVAS may be implemented in 5G: instead of being placed on the route between the two roaming partners, an RVAS provider may choose to integrate its service directly in the 5G core or to connect it via the Network Exposure Function. Several RVAS services are specified in TS.22.261.

Outlook

Despite the flexibility and options provided by the 5G roaming protocols, it must be said that the end-to-end security approach introduced in 5G represents a fundamental change in how roaming security is approached. The roaming ecosystem, with its diverse set of players and stakeholders, still needs to fully embrace this approach at the time of writing.

While the migration of some existing RVAS into the 5GSA roaming framework is straight-forward, other RVAS are likely to require substantial development and perhaps further standardisation. 3GPP SA3 firmly believes that these efforts are a valuable investment for the industry as a whole.

3GPP SA3 and CT4 specifications on 5GSA roaming (TS 33.501 and TS 29.573) have evolved significantly over the last two years. One of the driving forces behind this is the collaboration between 3GPP and GSMA. While the information exchanged via Liaison Statements has been valuable and has led to the identification and closure of a series of gaps, direct participation in 3GPP by players that so far are active only in GSMA would be desirable, for example to avoid market fragmentation that may occur if GSMA and 3GPP specifications are not fully aligned. The effort required to make 5G SA roaming a reality is a collective and an orchestrated one.

For more on WG SA3: www.3gpp.org/3gpp-groups

3GPP Capability Exposure Frameworks and APIs

By Narendranath Durga Tangudu (CT3 Vice-Chair), Dongwook Kim (CT3 MCC), Yali Yan (CT3 Chair), Susana Fernandez (CT3 Vice-chair), Abdessamad El Moatamid (CT3, Rapporteur)

Mobile communication is at an important juncture - leaping from 5G to 6G. This is a good time to take-a-peek at the 3GPP capabilities enabled for 3rd party entities and for developers to leverage their industry use cases on mobile networks.

From 3GPP Rel-12 (LTE) to Rel-18 and 5G Advanced, 3GPP TSG CT Working Group 3 (CT3) has specified a series of exposure of network capabilities via 3GPP Capability Exposure frameworks.

This article summarizes the work done on protocol and interface aspects for the 3GPP Capability Exposure interfaces, bridging 3rd party entities and mobile networks, enabling collaboration for the benefit of the verticals and the mobile ecosystem.

Unlocking the potential of Capability Exposure APIs

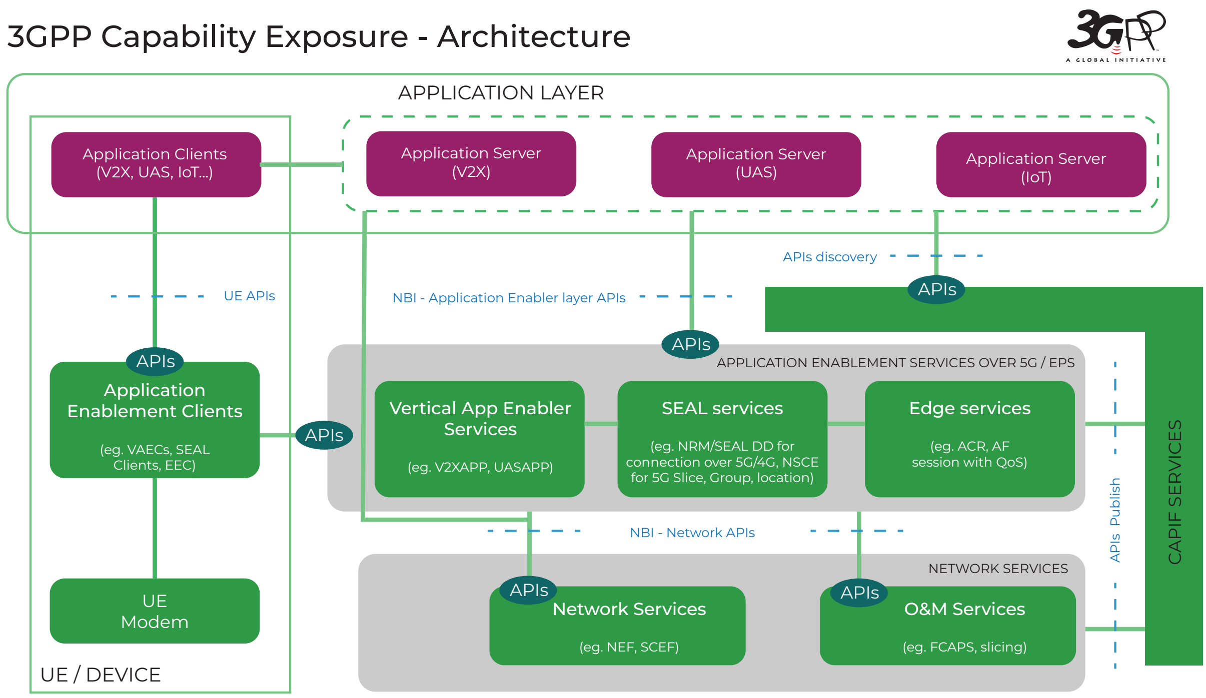
Whereas in the past users had to adapt to the capabilities given by the mobile network, 3GPP Capability Exposure APIs allow users and applications the flexibility to leverage and influence the capabilities of the network and enable the telecom service providers the potential to monetize their network capabilities, by allowing external applications.

The potential revenue enabled by network APIs in the next 5-7 years is forecasted to be up to $300billion [1]. To unlock this potential, harmonized and standardized approaches are required to provide further reach and economies of scale.

A High-level architecture

The 3GPP defined capability exposure frameworks can be categorized as follows:

- Network Northbound APIs, expose in a secure way the 3GPP (i.e., 4G or 5G) core network capabilities (e.g., Network Events exposure, QoS and network traffic influence, etc.) to external applications via either the Service Capability Exposure Function (SCEF) for 4G or the Network Exposure Function (NEF) for 5G.
- Application Enabler Layer APIs (e.g., Service Enabler Architecture Layer for Verticals (SEAL), Enabling Edge Applications (EDGEAPP), Vehicle to Everything Applications (V2XAPP), etc.) are enabler abstraction layers for specific vertical applications or common to various vertical applications. They offer the enablement and common core services catering to various industry vertical applications and provide an abstraction layer in parallel or on top of the abstraction functionalities already provided by the Network Northbound APIs. The network and application enabler layer APIs are discoverable via the Common API Framework (CAPIF).



ACR - Application Context Relocation, **CAPIF** - Common API Framework, **DD** - Data Delivery, **EEC** - Edge Enabler Client, **FCAPS** - Fault, configuration, accounting, performance, security, **NEF** – Network Exposure Function, **NRM** - Network Resource Management, **NSCE** - Network Slice Capability Enablement, **QoS** – Quality of Service, **SCEF** – Service Capability Exposure Function, **SEAL** - Service Enabler Architecture Layer, **VAEC** - Vertical Application Enabler Client

3GPP Capability Exposure Frameworks and APIs

As of Rel-18, the capability exposure frameworks and APIs can be categorized as Network Northbound APIs and Application Enabler Layer interfaces and APIs (also referred to as NBIs). All the APIs are mainly designed based on REST (Representational State Transfer) design principles.

3GPP Network Northbound APIs

The 3GPP Northbound Network Exposure Framework allows the external applications to leverage or influence the mobile core network via the SCEF/NEF exposed APIs, which acts as a single entry point to the mobile core network.

Fundamentally, these APIs allow several types of applications to make use of the mobile network to carry out specific services such as Network Events (e.g., UE location, UE roaming status) exposure, QoS and application traffic influence within the network, Network Analytics exposure and management, application/service related parameters provisioning, etc.

3GPP Application Enabler Layer APIs

The 3GPP Application Enabler Layer APIs are enabler abstraction layers for specific applications (e.g., Edge, UAS, V2X, etc.) or common for multiple vertical application (e.g., SEAL), which allow the exposure of common core and application enabler services to external applications.

These APIs provide an abstraction layer that can make use of the APIs exposed by the SCEF/NEF and any other network APIs (e.g., network management APIs) to fulfill the received requests from applications. For example, the EDGEAPP APIs support, expose and manage edge computing services (e.g., discovery of application servers deployed on edge, application context relocation, adaptation of application parameters to enable mobility, etc.). With EDGEAPP APIs, in Rel-17, 3GPP has enabled for the first time the exposure of services on the network side, as Open APIs to the entities on UE.

The 3GPP Application Enabler Layer APIs designed to be common for multiple vertical applications also enable its secure and efficient use for vertical applications over 3GPP networks. This is achieved via the Service Enabler Architecture Layer for Verticals (SEAL).

The consumers of these APIs are VAL Servers, on which the vertical applications are deployed and Vertical Application Enabler entities specified by 3GPP for specific verticals (e.g., V2XAPP). The services offered include for example location management, network resources management, data delivery management, etc.

Common API Framework (CAPIF)

CAPIF is defined to establish a single and harmonized platform for exposure of all the 3GPP capability exposure APIs (network northbound APIs and application enabler layer APIs), and also for any non-3GPP defined APIs (i.e., APIs defined by other SDO or consortiums such as ETSI ISG MEC, TM Forum, CAMARA, etc.). CAPIF offers the common functionalities (e.g., API publication, API discovery, API exposing function (e.g., NEF) management, API invoker (e.g., Application Function) onboarding management, Security (e.g., NBI API access control), Routing management, auditing and charging) applicable to any set of network or service APIs. Among its security, authentication and authorization functionalities, CAPIF also enables the collection and management of user consent for applications that require the consent of the end users.

CAPIF avoids duplication, brings in a consistent approach to common supporting capabilities, eases the development and rapid deployment of applications (AFs) invoking APIs (e.g., 3GPP network and service APIs).

Playing with Capability Exposure APIs

The Capability Exposure APIs are defined following the same principles as the 5GC SBI APIs, complying with the OpenAPI specifications. Each API is described in an "OpenAPI description" that is part of the Annex of the 3GPP Technical Specification that defines the corresponding interface. Informative copies of the OpenAPI description files defined in those Annexes are stored in a Git-based repository hosted in the 3GPP Forge.

All the files for both 5GC and Network Capability Exposure APIs corresponding to a common Release and date are stored in the same directory. The 3GPP Forge is the platform that contains the software produced by 3GPP, providing the tools to check the syntax of the OpenAPI "yaml" files separately and allows for the cross-checking of the references for all the data types defined in the different APIs.

Both 5GC APIs and Northbound APIs are commonly tested, using forge provided tools for parsing, linting, data type finder, OpenAPI version identification, ABNF checker for HTTP headers, etc.

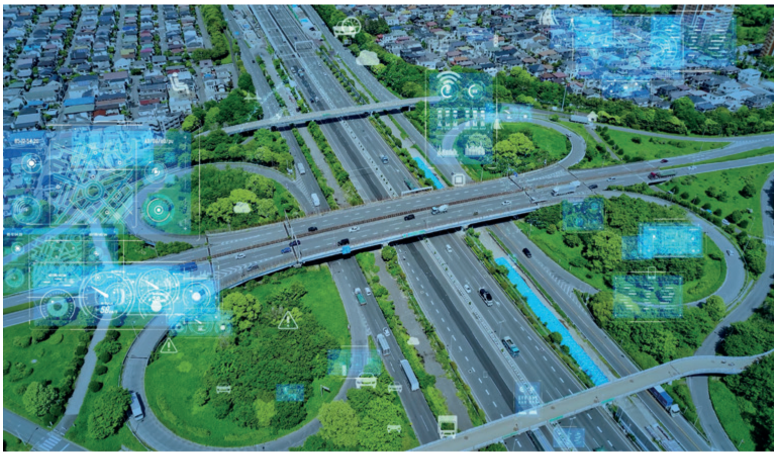
Conclusion

In summary, the 3GPP Capability Exposure APIs offer varied and easily extensible and evolutive capabilities for enabling the consumption of 4G/5G operators' networks via 3GPP Network Northbound APIs and/or Application Enabler Layer APIs. These capabilities comprehensively offer services hierarchically, opening the door for enabling various sets of use cases for 3rd party applications enabled on mobile networks.

These APIs have evolved and matured over four 3GPP releases. By adopting the industry popular Open APIs, RESTful-design style principles and 3GPP Forge GitHub repository, the 3GPP TSG CT3-defined Capability Exposure APIs are now closer and more relevant to the developer community. As mobile networks embrace new verticals and network capabilities in future, the 3GPP Capability Exposure APIs are expected to evolve with new features and more robust framework aspects.

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

[1] https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/what-it-will-take-for-telcos-to-unlock-value-from-network-apis



Network Sharing Evolution

By Qun Wei (Rapporteur, China Unicom), Tianqi Xing (Rapporteur, China Unicom), Zelin Wang (Director of China Unicom Research Institute), Chenyi Li (Project Manager of China Unicom Research Institute)

3GPP has just selected Indirect Network Sharing (INS) as the next evolutionary step for 5G-Advanced Rel-20, at the recent Melbourne TSG SA plenary (TSGs#105). This follows a big year for the technology in 2024, where INS was commercially deployed - as a Rel-19 technology.

Indirect Network Sharing is specified in 3GPP TS 22.261, TS 23.501 and TS 23.502, allowing the communication between the shared RAN and the core network of the participating operator to be routed through the core network of the sharing parties, as one of the key pragmatic measures of 5G Network Co-Construction and Sharing.

Examples of INS scenarios include; wide-range coverage of rural areas, long-distance road coverage, compatibility with existing networks, service consistency and cooperation with diverse networks.

With INS, the communication between the Shared NG-RAN and the participating parties' core network happens via a number of inter-network interfaces that are independent of the actual number of base stations at the shared NG-RAN.

Motivation

INS is designed to support the capability for users to access another operator's 5G networks when outside their own operator 5G coverage, enabling the continuous use of 5G services. It can significantly improve 5G network resource utilization, 5G network coverage in remote areas, 5G services user experience, and promote the high-quality development of the communication infrastructure.

Operators have deployed 5G access networks and core networks with a Multiple Operator Core Network (MOCN).

The challenge for the network operators is the maintenance generated by the interconnection (e.g., number of N2 and N3 interfaces) between the shared RAN and two or more participating operators' core networks, especially for a large number of shared base stations.

For these reasons, it is valuable to introduce a newly supported network sharing scenario.

By agreeing to build a shared network together - to cover the entire country - multiple operators can share one NG-RAN while their 5GCs are independently operated, without mandatory direct connectivity of the shared NG-RAN to the core networks of the other participating operators (as per Figure 2).

For users, the network services can still be transparent. UEs access their subscribed PLMN services and/or subscribed services, including Hosted Services, provided by their participating operators, when entering the Shared NG-RAN.

Figure 1: RAN Sharing (Pre Rel-19)

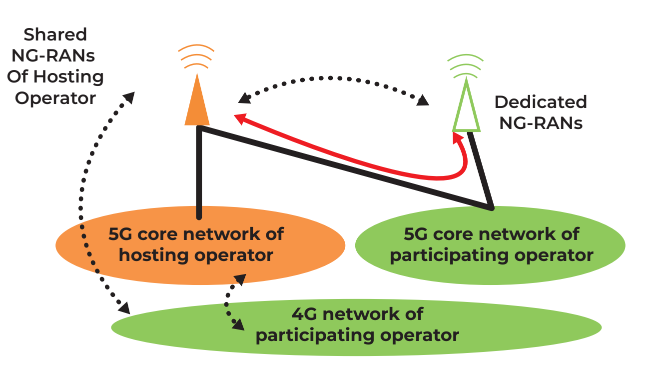
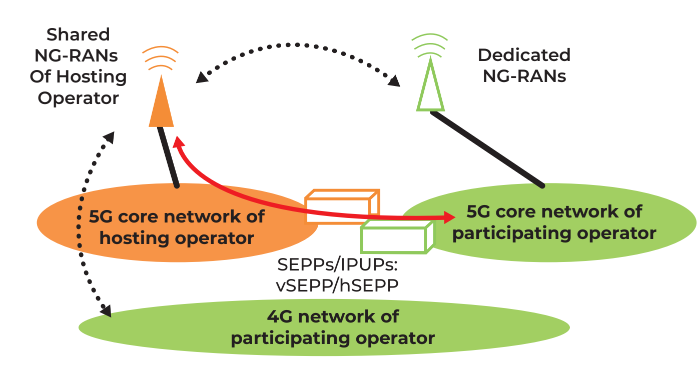


Figure 2: Indirect Network Sharing (Pre Rel-19)



User's movement
Communication between the shared NG-RAN and the core network of th participating operator

Network architecture and functionality

3GPP TS 23.501 specifies a network sharing architecture to allow multiple participating operators to share resources of a single shared network according to agreed allocation schemes. The 5G System may support Indirect Network Sharing deployment between the hosting operator (i.e. shared network operator) and participating operator, in which the RAN is shared.

The communication between the shared RAN and the core network of the participating operator is routed through the core network of the hosting operator that connects to the shared RAN. The architecture is illustrated in figure 3:

NOTE: The architecture of Indirect Network Sharing is based on the basic principle of home routed roaming architecture as specified in clause 4.2.4 of TS 23.501. Not all interfaces between the hosting operator and the participating operator are depicted in the Figure for simplicity.

Enhancements for the Indirect Network Sharing aspect:

- New definition and architecture of Indirect Network Sharing in 3GPP TS 22.261 and TS 23.501 accompanied by signaling/ procedures updates in 3GPP TS 23.502, and
- NF discovery in the inter PLMN case considering the UE location information, and
- Network slice handling considering the different PLMN IDs broadcast by shared RAN.

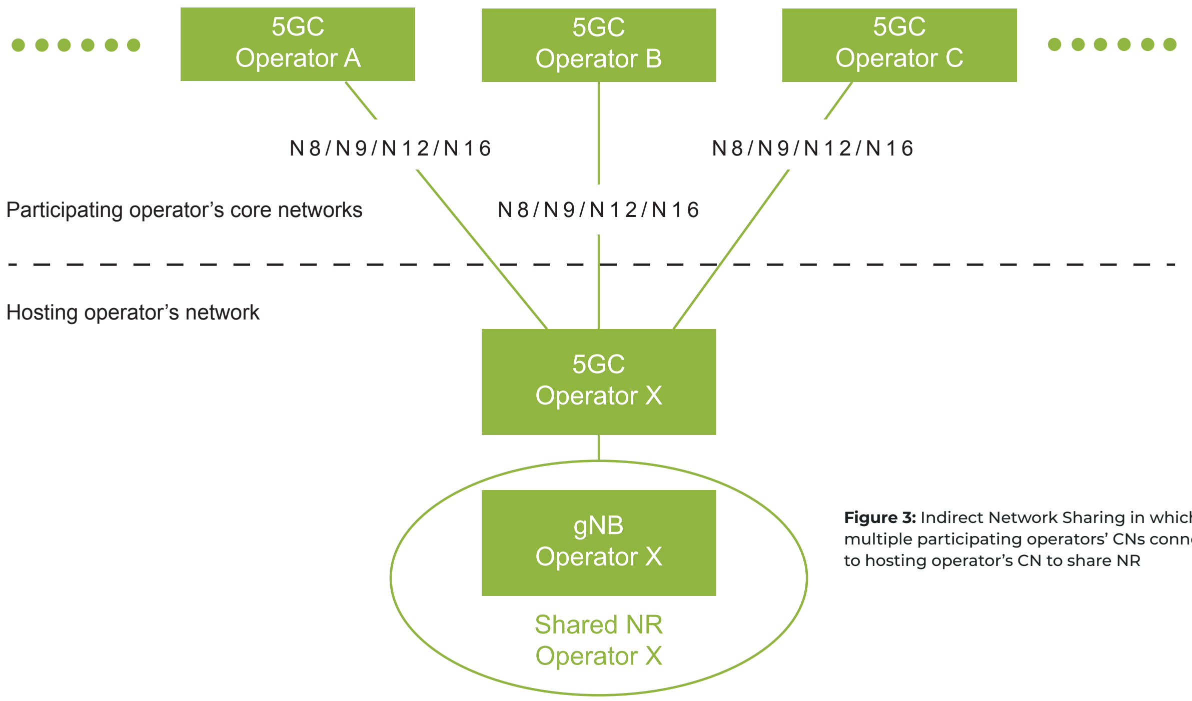


Figure 3: Indirect Network Sharing in which multiple participating operators' CNs connect to hosting operator's CN to share NR

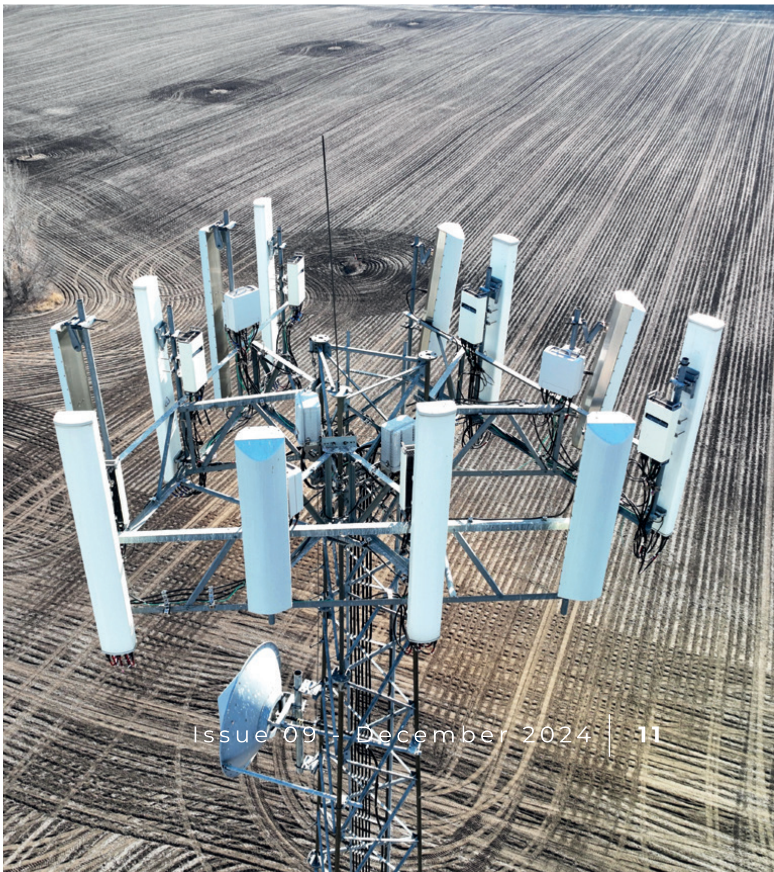
Deployment Progress

On May 17th 2024, the World Telecommunication and Information Society Day, China Unicom, China Telecom, China Mobile, and China Radio and Television jointly announced commercial deployment of 5G cross-network roaming technology, as the successful implementation of Indirect Network Sharing as per the 5G-Advanced 3GPP specifications, validating the commercial feasibility of 5G-Advanced network sharing and its compatibility with traditional terminals.

Indirect Network Sharing on Satellite Access Network

Based on Indirect Network Sharing, specified in Rel-19 NetShare items, including; the aspects for the definition, mobility management, network access control and charging... more scenarios and cases can be implemented using INS technology, including satellite use.

One of the challenges for satellite sharing is related with the compatibility and maintenance generated by the interconnection between the network element of sharing parties, e.g., shared satellite access network and two or more core networks of terrestrial participating operators via MOCN.



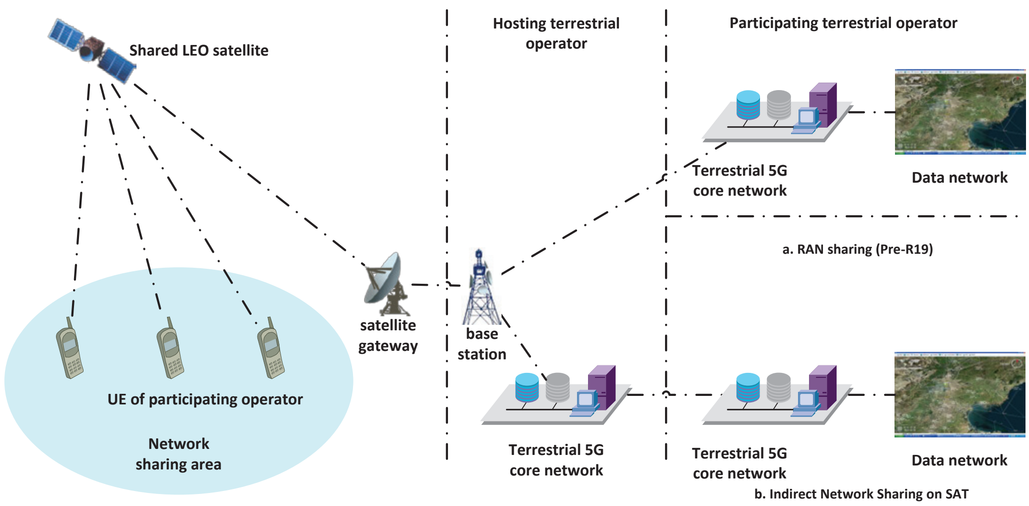


Figure 4: Indirect Network Sharing on SAT

With Indirect Network Sharing, the satellite access network can be shared by the participating terrestrial network operator without direct interface between the shared satellite access network and participating terrestrial operator's core network (see figure 4).

As LEO satellites are not stationary - with respect to the ground, the limited potential impact in terms of network access control involving both terrestrial and non-terrestrial network needs to be considered.

Indirect Network Sharing on Disaster Condition

Network sharing may also be applicable in a disaster situation, based on the Rel-19 INS, which requires the pre-configuration of the network. Meanwhile, there is an existing use case in TS 22.261 (clause 6.31) that discusses minimising service interruption associated with roaming during a disaster scenario. However, this method of disaster roaming may not be applicable in some cases due to the potential impact on the UE.

When disaster conditions arise in the specific area, the participating operator's network (access network, core network, both) may be inoperative. In that case the UE of the participating operator can use the subscribed services via the shared network using Indirect Network Sharing (see figure 5).

At that time, issues need to be considered, for example when and how to trigger the NG-RAN of hosting operator to provide the participating operator's information, and how to select the core network of the participating operator if its core network has failed in the disaster affected area.

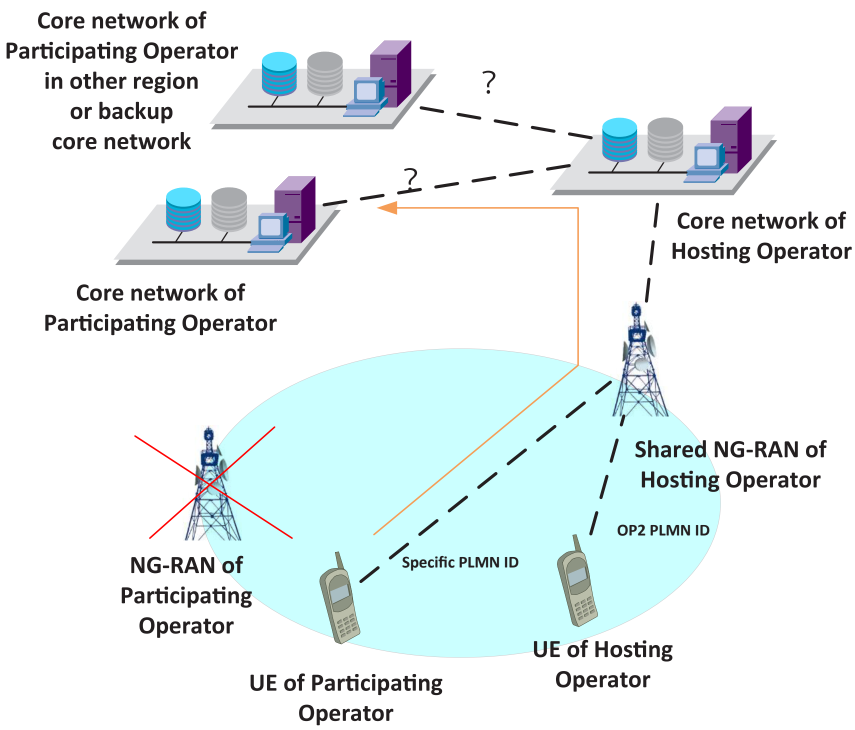


Figure 5: Indirect Network Sharing on Disaster Condition

> Through 5G Network Sharing, operators make annual savings and are reducing greenhouse gas emissions by millions of tons per year.

Summary

INS defines a new sharing method, with improvements in network access control, registration management, and session management, while the reuse of existing technologies also ensures minimal impact on pre Rel-19 UE, making INS applicable to a wider range of terminals on the market and a variety of business models.

Operators are increasing 5G Network Co-Construction and Sharing and continuously expanding the breadth and depth of 5G coverage.

Through 5G Network Sharing, operators make annual savings and are reducing greenhouse gas emissions by millions of tons per year.

Network sharing is also providing users with ubiquitous connectivity and high-quality services.

Rel-18 management, orchestration and charging features in SA5

By Lan Zou (WG SA5 Chair)

3GPP initiated discussions on 5G in Rel-15. Since then, while more and more network features have been introduced in to the specifications, more management features have also been specified. 3GPP officially published Release 18 (Rel-18) in March 2024. Rel-18 new management features can be classified according to the following four aspects:

- Management support of new network features
- Autonomous network management
- Management support to new services
- Charging management

Management support of new network features:

The management support to new network features in multi-vendor scenario includes network configuration and data collection from the network.

Data collection from the network includes specifying new network measurements and KPI, UE level measurements, QoE data, trace data and corresponding mechanisms for data collection.

The following new measurements for monitoring network performance and KPI are standardized:

RAN related measurements & KPI:

- RSRP measurements: SRS-RSRP measurement support monitoring of remote interference
- UE throughput measurements: Average DL UE buffered Throughput per DRB UE throughput of Dedicated BWP
- Delay related measurement: downlink delay to support NTN, one way packet delay between PSA UPF and UE supports satellite backhaul, Distribution of DL GTP packet delay between PSA UPF and NG-RAN, Distribution of UL delay between NG-RAN and UE, Mean interruption time interval for 5QI, air interface UL/DL average efficiency, Average air-interface efficiency achievable per UE
- Packet loss measurements: DL Packet Loss rate on Uu
- Paging measurements: Positive Paging Rate, NG-RAN Initiated paging records
- Mobility management: Conditional PSCell Change
- Connection related measurements: Idle-state RRC release, multi-access PDU Connectivity, Handover per beam-cell pair for inter-system mobility, numbers of DRB setup for Dual Connectivity
- EES related measurements: EEC Registration, EAS discovery failure
- Reliability related measurements: Packet transmission reliability KPI in UL/DL on F1-U
- Radio resource measurements: Distribution of PDCCH CCE PRB Usage, proportion of time domain resources, Network and Service Operations for Energy Utilities, NgU data volume, connected mode power saving Wake-Up Signal functionality, peak PRB usage per PLMN, PRB Usage per SSB, Distribution of Scheduled PUSCH/PDSCH PRBs, MIMO Layers Coverage Map per UE and PRB
- Time advance measurement: Timing Advance per SS-RSRP and AOA ranges
- GTP capacity measurements: Average DL GTP packet delay between PSA UPF and NG-RAN, Distribution of DL GTP packet delay between PSA UPF and NG-RAN

5GC related measurements & KPI:

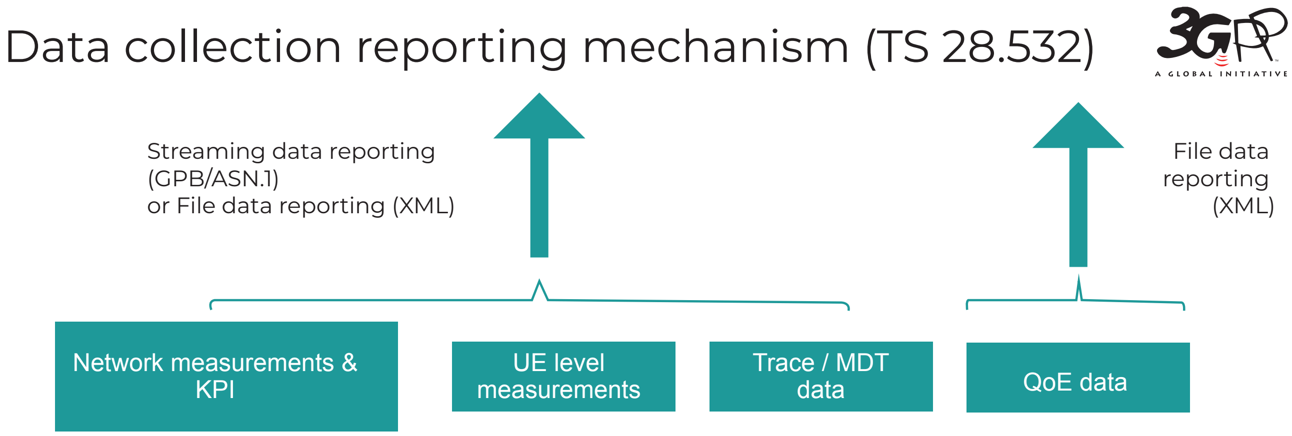
- **5G LAN measurements:** The performance measurements and KPIs for SMF session management, SMF N4 interface measurements, UPF N3 interface measurements, UPF QoS flow measurements and UPF N19 interface measurements are enhanced to include subcounters for 5G VN group communication.
- **NWDAF related measurements:** NWDAF analytics service statistics, NWDAF service failure statistics, Measurements related to the coordination between multiple NWDAFs, NWDAF service provisioning statistics, NWDAF Data Collection measurements, NWDAF ML model provision service and NWDAF ML model training service measurements, measurements on coordination between multiple NWDAFs.

UE level measurements: Average DL packet delay between PSA UPF and UE for a QoS flow, Average UL/DL packet delay between PSA UPF and NG-RAN for a QoS flow, Average delay DL air-interface, Average delay DL in gNB-DU, Average delay DL on F1-U, Average delay DL in CU-UP, UL PDCP packet average delay, Average delay UL on over-the-air interface, Average RLC packet delay in the UL, Average PDCP re-ordering delay in the UL, DL Packet Loss Rate on Uu, Packet loss for split gNB deployment scenario, UE throughput, UE Data Volume.

The following enhancement on data collection reporting mechanisms are supported:

MDT data collection mechanism enhancement: Based on the existing MDT data collection mechanism, operators could further select MDT measurement names that are subject to user consent to be activated/deactivated.

Enhancement of QoE Measurement Collection: The QoE Measurement Collection enables collection of application layer measurements from the UE for specified end user service type. The supported service types are Streaming services, MTSI services and VR services with corresponding new measurements. Based on the existing QoE data collection mechanism, operator could further configure RAN visible QoE Metrics. Mechanism to support signaling based QoE activation in NG-RAN is introduced.



Network configuration capability includes specifying the corresponding network resource models and enhancement of management operations. CRUD operations as generic management operations are normally used to manage the lifecycle of network resource model since Rel-15. In order to support interoperability in a multi-vendor scenario, the following configurations are standardized:

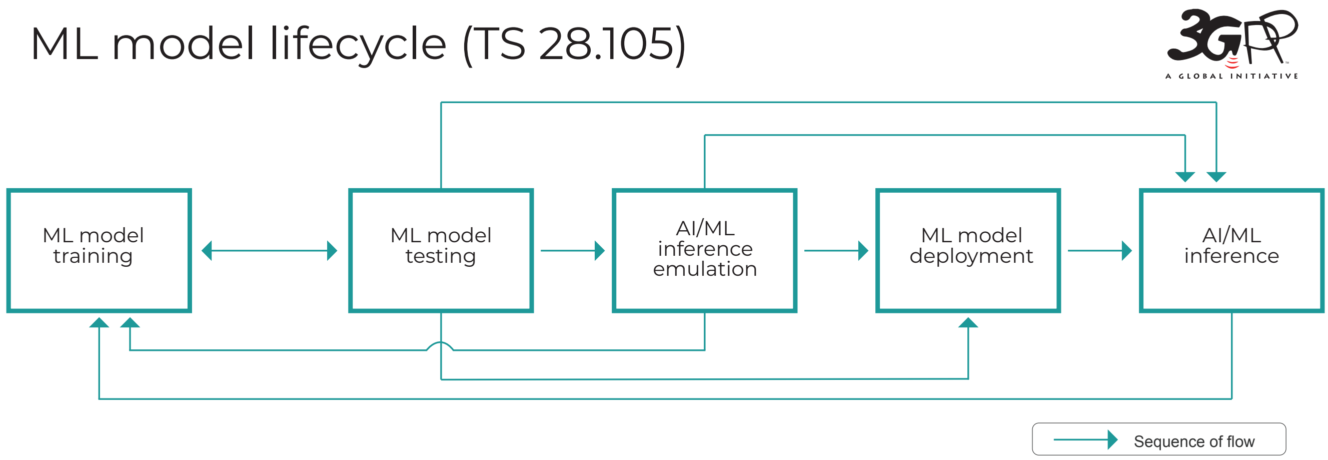
Core network configuration: 5G Core managed NFs Profile, UDR Function, UDM Function, PCF Function, NSSF Function, UPF Function, NSSAAF Function, EASDF Function, AF Function, LMF Function, SMSF Function, UDSF Function, SEPP Function, SCP Function, NWDAF Function, NSACF Function, NEF Function, AUSF Function, DCC Function, MFAF Function, CHF Function, GMLC Function, TSCTSF Function, AANF Function, BSF Function, MBSMF Function, MBUPF Function, NRF Function, MNPF Function, enhanced data model for AmfInfo, SmfInfo to support satellite backhaul and 5G LAN.

RAN configuration: radio network sharing modeling, NTN Function, BWPset configuration, NG-RAN 5QI configuration.

Network slicing and other configuration: network slicing isolation Profile, transport entry point model, scheduled slice availability, asynchronous lifecycle management operations for network slicing.

Autonomous network management

AI/ML management specifies AI/ML management related terminology and definitions, a general management framework for ML model lifecycle (i.e., model training and testing, emulation, deployment, and inference), various management deployment scenarios, AI/ML lifecycle management capabilities including OpenAPIs for ML training, AI/ML emulation, ML model deployment and AI/ML inference. With regard to AI/ML functionalities in the RAN, the management of NG-RAN AI/ML-based distributed Network Energy Saving, NG-RAN AI/ML-based distributed Mobility Optimization, NG-RAN AI/ML-based distributed Load Balancing have been specified in Rel-18.



Intent driven Management Service for Mobile Network specifies intent driven management capabilities for managing radio network and core network in coordinated manner. In the RAN energy saving scenario, operator can provide energy consumption targets and RAN UE throughput targets for selected geographical area, enforce the context for execution, evaluate and adjust targets when needed. The automated system continuously monitors the network performance and energy consumption information, adjusts accordingly to achieve the optimal balance between energy saving effect and service experience by utilizing intelligent mechanisms. With intent driven radio capacity performance assurance, operators can express expected network throughput capacity as target.

The operator can also express expected 5GC network capacity targets in a standard way for delivering new 5GC network and system will try its best to achieve the best performance according to the desired intent. Query capability is also provided through which the operator can obtain the supported targets for each intent handling functions and select the proper intent handling function to execute the intent handling process. 3GPP defined intent driven management framework is flexible and easy to be extended for new features.

To facilitate the end-to-end intent driven solution, the two Intent-driven deployment scenarios are shown in TS 28.312, as potential examples utilizing 3GPP defined intent solution to support requests from the communication service customers.

Management Data Analytics (MDA) specifies analytics capabilities to support prediction statistics, NF resource utilization and 5GC congestion analysis.

The MDA is a management functionality that utilizes the collection of current and historical management and network data including e.g., communication service, slicing, management and/or network functions data to perform analytics that could enable intelligent and automated network operations and service assurance. MDA capability allows consumer to request and obtain analytics outcome related to a specific use case (MDA type).

The new use cases and corresponding solutions specified in Rel-18 includes Prediction and statistics of Mobility management performance related predictions, Coverage related predictions, SLS prediction, Critical maintenance management related predictions and Energy saving predictions, physical and virtualized NF resource utilization analysis, and 5GC Control plane congestion analysis. Analytic coordination across multiple domains are also supported.

Self-Configuration of RAN Network Entities (NE) specifies the operators controlled self-configuration process of RAN NEs. With operator provided policy and planned data, RAN NE can be taken to a state ready to carry traffic using self-configuration process in an automated manner. Self-configuration process includes four major steps: generate RAN NE configuration data based on operators' inputs, download and activate software, download and activate configuration data, self-test. Self-configuration process also provides the capability for operators to more the progress and intervene the automated process execution when needed with standardized solution.

Support to new services

- **Enhancements of EE for 5G** specifies new 5G network EE measurements include energy consumption of Virtualized Network Functions (VNF) and new Energy Consumption KPIs for virtual compute resources.
- **Network and Service Operations for Energy Utilities (NSOEU)** is a feature that exposes management information and capabilities from the 5G system to energy utility operators to achieve higher service availability.
- **Management of non-public networks (NPN)** specifies the requirements and solutions for key aspects of NPN management.
- **Enhancement of Service based management architecture (SBMA)** provides overview of 5G management specifications, management capabilities, and collaboration with other industry groups from management architectural perspective. New advertising NRM properties capability allows operators to obtain supported configurable properties from providers in a multi-vendor environment.
- **Access control for management service** introduces the access control capabilities for Management Services.

Charging management

Charging support of new network features and services:

Charging aspects of 5GSAT specifies the Satellite access and satellite backhaul charging, in which operator can deploy and monetize the new business and charging scenarios about the integration with the Satellite/NTN (Non-Terrestrial Network).

Charging Aspects for Enhanced Support of Non-Public Networks specifies the data connectivity and network access usage charging for Standalone Non-Public Network (SNPN) and Public network integrated NPN (PNI-NPN). Operator can monetize the deployment of dedicated and reliable private networks.

NEF Charging enhancement to support AI/ML in 5GS, specifies charging aspect about exposure of 5GC information to authorized 3rd party for Application AI/ML operations, which benefit and enhance the exposure capabilities of operators.

Charging Aspects of IMS Data Channel, specifies Charging Aspects for Enhanced Support of Non-Public Networks new business model.

Network Slice Charging enhancement, help the operators can provide variety and new 5GA business and charging scenarios based on the multiple dimensions, including:

- **Charging Aspects for NSSAA:** monetize Network Slice(s) assigned to third-party providers based on allowing such third-party to grant authorization or not to individual UEs for accessing a particular network slice via NSSAA.
- **Charging Aspects of Network Slicing Phase 2:** Network Slice level new criteria for charging Network Slices usage, allowing Operators to monetize Network Slice(s) assigned to third-party providers (i.e. Network Slice Tenant) controlling of UE access and the Network Slice Tenant Charging based on the consumer CCS and Business CCS interactions.
- **Network Slice Replacement charging:** Operators can monetize the network slice (instances) replacement scenarios.
- **Charging enhancement for Network Slice based wholesale in roaming:** network slice roaming retails and wholesale charging for Home PLMN and visited PLMN.

Charging Aspects of 5WWC phase 2 specifies 5WWC enhance charging based on the differentiated support for UE(s) behind an RG. The operators could provide more refined and accurate charging for the customers.

Charging Aspects of TSN specifies the time Sensitive Networking charging for supporting the integrated between 5GS and vertical new business and charging scenarios.

Charging Aspects for SMF and MB-SMF to Support 5G Multicast-broadcast Services, specifies the unicast, multicast and broadcast charging for supporting operators to provide new 5G MB services.

Multimedia Messaging Service Charging using service-based interface, specifies the MMS charging for supporting operators to provide new 5G MMS services.

New Charging management capabilities

CHF Distributed Availability describes the Centralized and Local/Edge CHF deployment, which supports the flexible distributed deployment options for operators.

Charging for roaming and additional actor using CHF to CHF interface describes the new LBO roaming charging architecture, which provides optional inter CHF commutations for operators, including the Home MNO, visited MNO and MVNO retails and wholesale charging.

Charging Aspects of B2B describes the common B2B charging architecture and charging principle, which helps the operators can provide the communication service for the customer subscriber and business subscriber more conveniently.

TSG RAN Rel-19 Status and a Look Beyond

By Wanshi Chen, 3GPP TSG RAN Chair

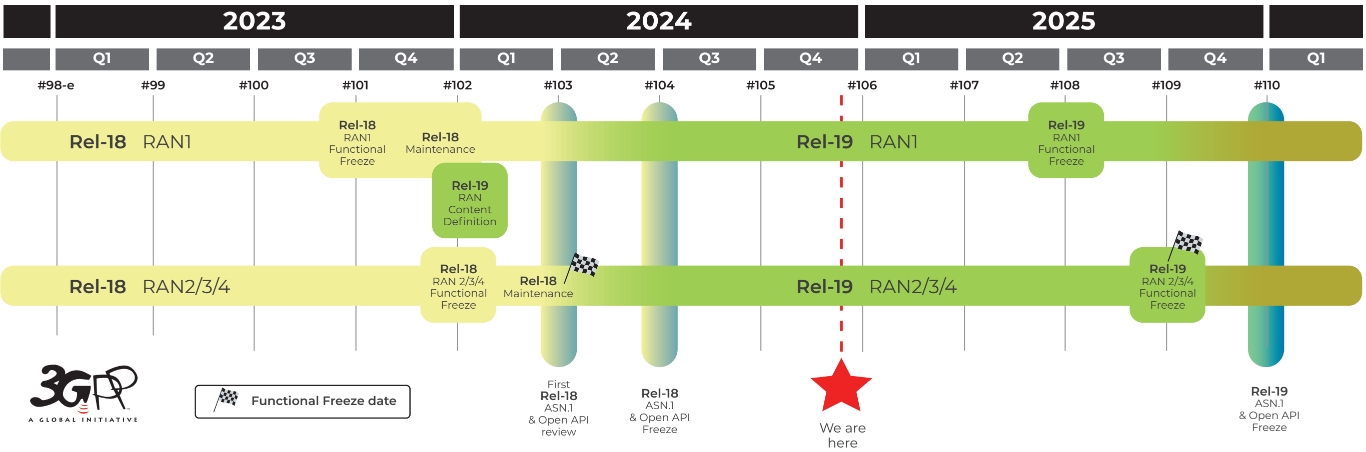
As the year of 2024 is coming close to an end, it is time to take an overall look at where TSG RAN stands and how it is planning for the next releases - particularly related to 6G.

TSG RAN is currently working on Release 19 (Rel-19) projects, the 2nd release of 5G-Advanced and also the last release fully dedicated to 5G.

As illustrated in Figure 1, the start of Rel-19 is in the 1st quarter of 2024 in Working Group (WG) RAN1, with a one-quarter staggered start in WGs RAN2/3/4.

The release is planned for an 18-month duration, with the Rel-19 functional freeze of features due in June 2025 for RAN1, and September 2025 for RAN2/3/4.

Figure 1: Illustration of Release 19 Timeline



As was the case with Rel-18, the aim in Rel-19 is to provide a balanced evolution in terms of:

- Mobile broadband evolution and further vertical expansion, enhancing mobile experiences and extending 5G's reach into new areas
- Addressing immediate and longer-term commercial needs, to drive new value in commercialization efforts and to efficiently enable advanced deployments
- Supporting new and enhanced devices and network evolution, so as to focus on the end-to-end 5G technology progression & new levels of performance

This steady and balanced evolution is of particular importance as 6G will start from Rel-20, putting Rel-19 in place as the foundation stone for the bridge to 6G.

Among the approved Rel-19 projects, we have the "traditional" ones such as enhancing MIMO, mobility, topology, and self-organized networks (SON)/minimization of drive testing (MDT). We also have the continued evolution for non-terrestrial networks (NTN), and eXtended Reality (XR).

A new area worth highlighting is a study called 'Solutions for Ambient IoT in NR', with the possibility of being converted into a work item in TSG RAN#106 (December 2024). Ambient IoT aims for a harmonized design for low-end tags with backscattered (up to ~1μW) and active transmissions (≤ a few hundred μW) in a licensed frequency-division-duplex (FDD) spectrum in frequency range 1 (FR1). Two topologies are considered, one is where a base station (BS) is connected directly to a tag and the other one is where a user equipment (UE) can serve an intermediate node under the network control.

Energy efficiency has always been a focus of 3GPP standardization. Rel-19 takes this a step further, with enhancements introduced to improve network energy savings. Based on the outcome of the study in Rel-18, we will see specifications for the support of low-power wake-up signal/receiver (LP-WUS/WUR) in Rel-19.

Artificial intelligence (AI)/machine learning (ML) is taking the main stage across TSG RAN in Rel-19. WG RAN1 is leading an AI/ML project focusing on specifying use cases for CSI prediction, beam management and positioning, as a continuation of the study in Rel-18. The group (RAN1) also continues to study the use case of CSI compression (started in Rel-18). In parallel, WG RAN2 is leading a study of AI/ML for mobility management, focusing on network triggered layer 3 mobility, while WG RAN3 continues its work on AI/ML for NG (next generation)-RAN and WG RAN4 investigates all the necessary aspects related to performance and the requirements for AI/ML in the RAN.

Another Rel-19 project worth emphasizing is the specification of sub-band full-duplex (SBFD) in a time-division duplex (TDD) system, which enables the conversion of some frequency portion of a downlink slot into an uplink subband, orthogonal to the remaining subbands for downlink. This is a continuation of Rel-18 study, and is expected to bring benefits such as improved uplink coverage and reduced latency for TDD.

Two studies in Rel-19 provide a direct bridge to 6G topics: Channel modeling for integrated sensing and communications (ISAC), and Channel modeling for higher mid-band spectrum (e.g., 7-24 GHz). These two Rel-19 projects are critical in laying the necessary foundation for further technical study and specification work, at a later stage.

6G Planning – Agreement on a Timeline

3GPP is expected to develop technology submission to ITU-R for the IMT-2030 process. To that end, the very first, although brief, 6G timeline discussion occurred in RAN#101 (September 2023), triggered by an incoming liaison from ITU-R WP5D (see RP-231518) titled “On completion of draft new Recommendation ITU-R M.[IMT.FRAMEWORK FOR 2030 AND BEYOND]”.

Subsequently, high-level considerations for 6G timeline were discussed in RAN#102 (December 2023), including a TSG-wide joint session, resulting in the endorsed way forward in RP-233985.

Additional considerations for 6G timeline were discussed in RAN#103 (March 2024), including another TSG-wide joint session, with the endorsed way forward in RP-240823.

6G Planning – Workshop and Studies

RAN#104 (June 2024) also endorsed some additional details for the planned 3GPP TSG-wide 6G workshop, now scheduled for March 10th to 11th, 2025. The workshop will be arranged as follows:

- Parallel TSG RAN and TSG SA sessions starting from Monday afternoon to Tuesday early afternoon
  - Monday: 14:00 – 18:00; Tuesday: 09:00 – 15:30
- Joint TSG RAN/SA/CT sessions
  - Monday morning: 09:00 – 12:30; Tuesday 16:00 – 18:00: Summary of the workshop

More details for the workshop are being developed and will be announced soon. Note also that the regular TSGs#107 plenary meetings are in the same week (March 12th to 14th), also hosted in Incheon, KR.

Studies for 6G in 3GPP will start from Rel-20. The study in TSG RAN will consist of two parts:

- An ITU-R IMT_2030 focused study, and
- A general 6G RAN study.

The ITU focused study is expected to be approved in RAN#106, and continues till June 2025, focusing on IMT-2030 radio requirements defined in ITU-R WP5D. The general 6G RAN study will cover aspects such as radio requirements and KPIs, and is expected to be approved in RAN#107, continuing until June 2026.

6G studies in RAN WGs are scheduled to be approved in RAN#108 (June 2025), with RAN1 starting work from the 3rd quarter of 2025, and RAN2/3/4 starting from the 4th quarter of 2025. The studies in each WG are expected to last for 21 months.

Note also that in parallel to the 6G studies in Rel-20, there will be additional evolutions of 5G-Advanced in Rel-20, in order to further address urgent and real commercial needs. The duration of 5G-Advanced work in Rel-20 will be 18 months.

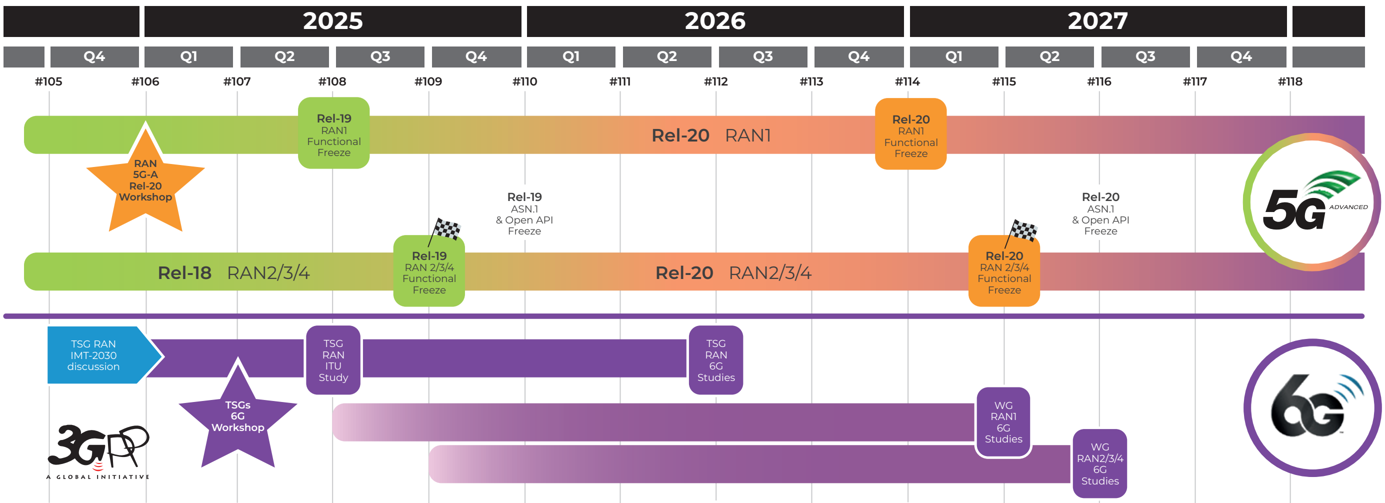
Specifications for IMT-2030

The normative work for 6G in 3GPP is expected to start from Rel-21, producing the 1st set of 3GPP 6G technical specifications.

Rel-21 will be the 3GPP release for our IMT-2030 submission, delivered before 2030, and expected to be delivered with a single drop (i.e., a single code freeze). Although we do not have a concrete Rel-21 timeline yet, we plan to make a decision no later than June 2026 (when the 6G RAN study completes), with the understanding that the ASN.1/OpenAPI freeze date for Rel-21 will be no earlier than March 2029.

Figure 2 illustrates the overall TSG RAN Rel-20 timeline.

Figure 2: Illustration of TSG RAN Rel-20 Timeline



Concluding Remarks

TSG RAN is currently heavily involved in Rel-19 5G-Advanced standardization providing necessary evolutions addressing the ever-increasing commercial deployment needs.

At the same time, TSG RAN is preparing for the start of 6G with the first TSG-wide 6G workshop just a few months away and the subsequent studies set to investigate and bring real 6G values at both the TSG level and the WG level.

Based on the 6G studies and the expected specification work in Rel-21, 3GPP is committed to provide timely inputs to the ITU-R IMT-2030 process.

Edge computing in CT protocols

Caixia QI (WI rapporteur), Christian Herrero-Veron (Huawei)

Though the 5GS supports Edge computing since day one of Release 15, 3GPP provides Edge computing (EC) specific enhancements from Release 17 onwards.

In addition, Release 18 - the first release of 5G-Advanced (5GA) - brings roaming improvements to support access to the edge home environment (EHE) in a visited PLMN. Release 19 will bring further enhancements for Edge Application Server (EAS) discovery and re-discovery and User Plane Function (UPF) selection and re-selection and reduce the impact on central 5GC network function (NF).

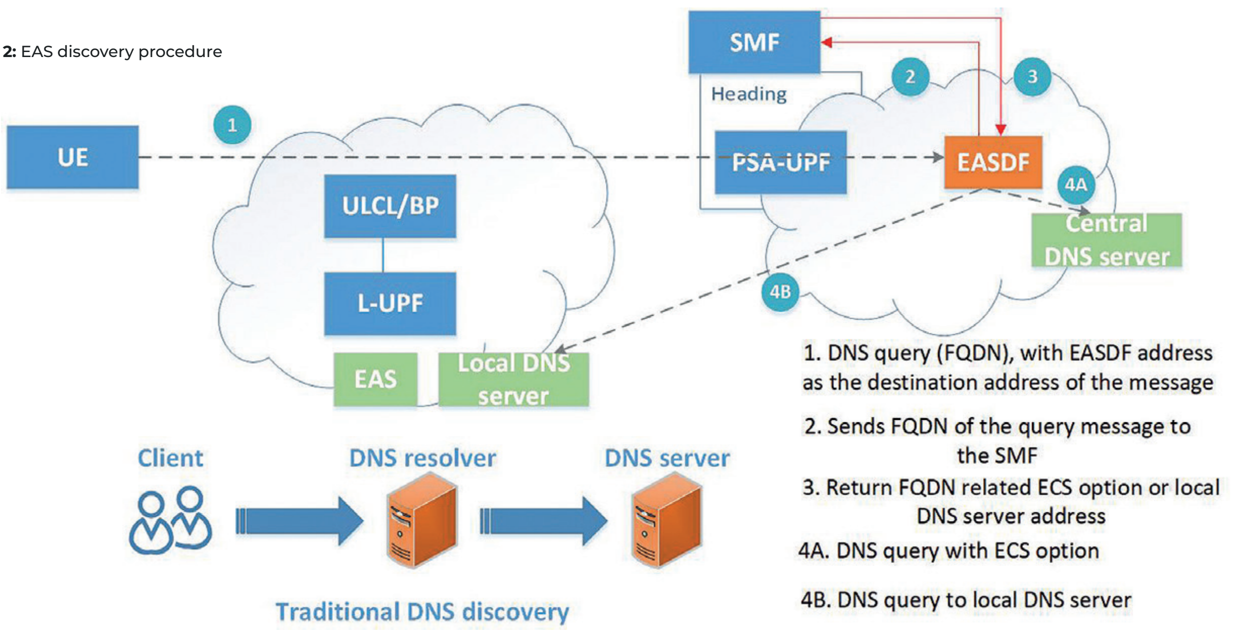
All this is done with the additional focus of providing cutting-edge native use cases and applications, like augmented reality (AR)/extended reality (XR), autonomous vehicles & vehicle-to-everything (V2X) communications and other metaverse or virtual environments.

From the outset, the 5G architecture allows cloud-native applications to support edge compute use cases without any edge infrastructure awareness. However, the 5GS does not provide the possibility for user equipment (UE) to discover edge applications (IP addresses).

This is accomplished at the application layer by using, for example, domain name servers (DNS). Furthermore, though the 5GS offers mechanisms to handle data traffic (user plane UP) and redirect it towards the correct applications (EC applications), there is no particular handling of Edge computing.

In Release 17, the 3GPP Core-network and Terminals (CT) working groups added protocol support for a new network function of the 5G architecture called edge application server discovery function (EASDF). The EASDF supports session breakouts (i.e., forwarding domain name service (DNS) traffic based on FQDNs of DNS Query messages) by providing edge application server (EAS) which is closer to the UE physical location. The EASDF also provides EAS information such as EAS IP addresses or AS FQDNs in the received DNS Response message to the session management function (SMF) to trigger the local PDU session anchor (L-PSA)/UPF insertion for dynamic steering of edge application traffic.

Figure 2: EAS discovery procedure



The 3GPP CT WGs also added the possibility for network operators setting forwarding rules of EC data traffic (user plane UP). The policy and charging function (PCF), which manages the traffic rules, provides the SMF with user-plane latency requirements by using policy and charging control (PCC) rules. Then, the SMF uses these rules to detect data packets and decide where to forward them to meet quality of service (QoS) requirements, the SMF may perform PSA/UPF relocation if the target PSA/UPF cannot satisfy the maximum UP latency.

The PCF also authorizes UP latency requirement so the PCF checks whether the application function (AF) has an authority to make a request on UP latency requirements.

In short, the 5GS offers not only discovery of edge application but also mechanisms to handle data traffic of edge applications (user plane UP) and redirect it towards the correct applications ensuring secure authentication and consistent QoS.

The UE sees the EASDF as a DNS resolver for edge application servers (EAS) so that the UE discovers the IP address of an edge application. The procedures supported from the UE side are EAS (re)discovery and edge configuration server (ECS) address configuration information provisioning.

All starts at protocol data unit (PDU) session establishment procedure where the UE sends a request which indicates to the SMF the support of EC enhanced features; EAS (re) discovery support, edge DNS client (EDC) support, and ECS configuration information provisioning support. The SMF is the entity in the PLMN which performs EAS discovery. The SMF selects the EASDF and provides its IP address to the UE as the DNS server to be used for the requested PDU session. Also, the SMF can provide the IP address of the local DNS server (to resolve application server FQDNs) to the UE as the DNS server to be used for the PDU session. The SMF may select an uplink classifier branching point (ULCL/BP) (based on PCC rules from the PCF pushed by, e.g., the AF) and a L-PSA/UPF for the PDU session.

The SMF can decide to select a new EASDF, for example, if the UE changes its location or network resources are not sufficient. In order to trigger EAS rediscovery (i.e., to provide updated DNS server address(es) due to the newly selected local DNS server or the newly selected EASDF), the SMF uses the network-requested PDU session modification procedure so that the UE obtains new EAS rediscovery information.

In addition to enhance the 5G architecture, the 3GPP CT WGs have developed the interactions towards the application layer architecture for EC defined by SA6 and compatible with the multi-access edge computing (MEC) architecture developed by ETSI (ETSI MEC Framework Specification).

The edge configuration server (ECS) may be in the PLMN or in the edge computing service provider (ECSP; mobile network operator (MNO) or 3rd party service provider) and provides functions for the edge-enabled client (EEC) residing in the UE to connect with an edge enabler server (EES).

3GPP CT WGs have therefore added the provisioning of ECS configuration information from the SMF to UEs. This configuration information may contain ECS addresses corresponding to different ECSPs and spatial validity conditions; geographical service area, a list of TA(s) or a list of countries (list of MCCs).

In Release 18, further enhancements are added to support access to EHE when roaming (in a VPLMN) including improved network exposure of UE traffic related information to common EAS via local PSA/UPF. Also, support for offload policies to match more granular sets of UEs without exposing operator-internal configurations to ECSP AFs, solutions to influence PSA/UPF and EAS (re)location for collection of UEs are added. There are also solutions to avoid the UE to switch the EC traffic away from the EC PDU session and the 5GS altogether (due to conflicting connectivity preferences in the device). Finally, the ECS provisioning information has also been enhanced by optionally provide ECS authentication methods to the UE.

For more on CT groups: www.3gpp.org/3gpp-groups

You will need to dig deeper. Start here:

CP-212021	CT aspects of support for Edge Computing in 5G Core network (eEDGE_5GC)
CP-241027	CT aspects of Edge Computing phase 2 (EDGE_Ph2)
CP-242026	New WID on CT aspects of enhancement of support for Edge Computing in 5G Core network - Phase 3 (eEDGE_5GC_Ph3)
TS 29.514	5G System; Policy Authorization Service; Stage 3
TS 22.261	Service requirements for the 5G system
TS 23.501	System architecture for the 5G System (5GS)
TS 23.502	Procedures for the 5G System (5GS)
TS 23.503	Policy and charging control framework for the 5G System (5GS); Stage 2
TS 23.548	5G System Enhancements for Edge Computing; Stage 2
TS 23.558	Architecture for enabling Edge Applications
TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3
TS 24.501	Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3
TS 29.502	5G System; Session Management Services; Stage 3
TS 29.503	5G System; Unified Data Management Services; Stage 3
TS 29.508	5G System; Session Management Event Exposure Service; Stage 3
TS 29.510	5G System; Network function repository services; Stage 3
TS 29.512	5G System; Session Management Policy Control Service; Stage 3
TS 29.513	5G System; Policy and Charging Control signalling flows and QoS parameter mapping; Stage 3
TS 29.522	5G System; Network Exposure Function Northbound APIs; Stage 3
TS 29.556	Edge Application Server Discovery Services; Stage 3

Network Automation Enablers in 5GS

By Yali Yan (CT3 Chair), Zhenning Huang (China Mobile, WID Rapporteur), Xuefei Zhang (Huawei, WID Rapporteur)

As 5G network supports more and more telecommunication scenarios and considerably higher data exchange and processing, it is becoming increasingly urgent to optimize the service experience, as well as improve the network efficiency in an automated, real-time and flexible manner.

3GPP has specified a network automation architecture to leverage 5G information exposure and network data analytics. It enhances network performance, operational assurance and resource utilization and enables self-optimization and automated management, as shown in Figure 1.

The Network Data Analytics Function (NWDAF) specified from the 5G's initial Release (Rel-15), is designed to control the management of sophisticated network data, as specified in 3GPP TS 29.520 [1].

Upon reception of the analytics request from the consumer, the NWDAF collects network data, service data, management data and/or UE performance data from dedicated data sources, then processes and generates the reliable analytics information to assist the consumer to improve the user experience and optimize the network performance.

A consumer (e.g., the PCF or NSSF) may subscribe to the network slice load level analytics information to assist in deriving the policy/Quality of Service (QoS) decisions and/or performing the network slice selection process. The analytics information offered by the NWDAF can be either statistical events that happened in the past, or predictive information of the future.

In Release 16, 3GPP extended the data sources so that the NWDAF can collect different kinds of data from more sources, such as the 5GC Network Functions (NF), Application Functions (AF) and/or Operation Administration and Maintenance (OAM), then process the collected data to perform analytics to support more scenarios, for example, the Abnormal UE behavior analytics scenario which is used to detect ping-pong handovers and prohibit the communication of the hijacked UE in a timely manner.

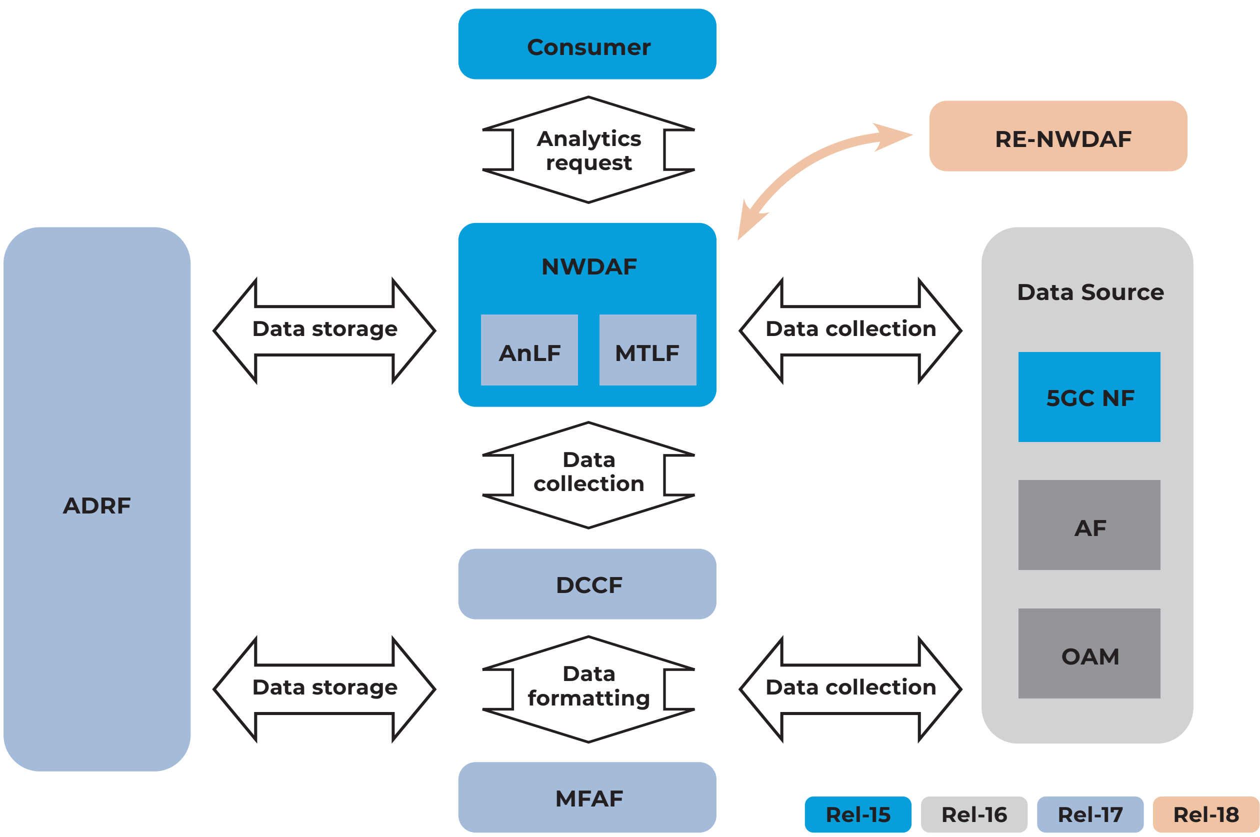


Figure 1: Architecture of 3GPP-defined Network Automation Enablers

In Release 17, the NWDAF was decomposed into two functionalities, i.e., the Model Training Logical Function (MTLF) and the Analytics Logical Function (AnLF). The MTLF trains Machine Learning models and exposes new training services, and the AnLF performs inference, derives analytics information and provides analytics services. The Data Collection Coordination Function (DCCF) as defined in 3GPP TS 29.574 [2], the Messaging Framework Adaptor Function (MFAF) as defined in 3GPP TS 29.576 [4], and the Analytics Data Repository Function (ADRF) as defined in 3GPP TS 29.575 [3] were specified as new functions into the network automation architecture to improve the efficiency of data collection, analytics exposure and data storage.

Release 18 covers additional functionality, e.g., the Packet Flow Description (PFD) Determination performs data analytics on existing PFD information and User-Plane traffic, and provides analytics in the form of new or updated PFDs to the analytics consumer.

Meanwhile, in order to ensure more accurate calculation, prediction, and decision, the NWDAF supports computing the accuracy of the ML models and analytics, Federated Learning, i.e., training a ML Model across multiple decentralized NWDAF instances without exchanging and sharing the local data set in each NWDAF, and the analytics and data exchange in the roaming scenario, etc.

The standardization timeline of the network automation architecture evolution and typical use cases definition from Release 15 all the way to Release 19 are illustrated in figure 2 with some use cases described in further detail below.

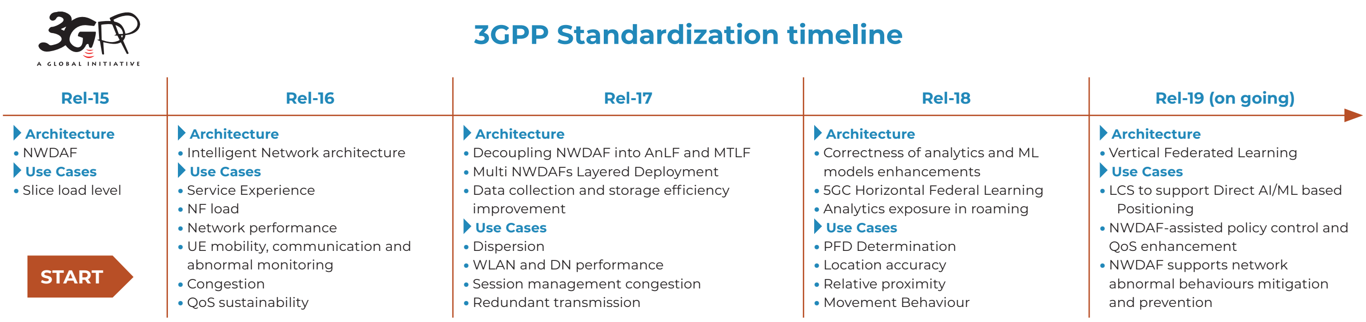


Figure 2: Network Automation architecture evolution and typical use cases definition

Use Case 1: Service Experience

The Service Experience case takes the Mean Opinion Score (MOS) for services, like the audiovisual streaming or the non-audiovisual service (e.g. the V2X and Web Browsing service). The NWDAF collects the the Quality of Experience (QoE) metrics and performance data, e.g., the average packet delay, average packet loss rate and throughput from the AF. Other input data includes the QoS flow level network data from the 5GC NFs and the radio-related data, e.g., RAN throughput for uplink and downlink from the OAM.

With the collected data, the NWDAF can offer diverse, multi-level analytical capabilities that support fine granularity experience prediction and analysis. For instance, the NWDAF can provide analytics for an individual UE or a group of UEs, different access types, multiple applications, as well as different network slices. The operator takes the analytics into account to measure the actual user's service experience and to identify the opportunities for network optimization.

Use Case 2: NF load analytics

The NF Load analytics refers to analyzing the load status of 5G NFs to assist the consumer in optimizing the NF selection process. Once the target NFs are indicated by the consumer, the NWDAF will interact with the NRF to collect the targeted NF's load status and the resource usage related data, e.g., the usage of virtual CPU, memory, and disk from the OAM. Further, the NWDAF can also retrieve the traffic usage reports from the UPF and the UE movement information from the AF. With this data, the NWDAF produces the NF load analytics result including the NF type, NF instance ID, NF status, NF resource usage, NF load, and NF peak load.

The NF load analytics is very helpful for an operator for, e.g., capacity planning. Some NFs can use it to select less-loaded NFs, e.g., SMF selection by the AMF or UPF selection by the SMF to improve the network efficiency.

In summary, since the introduction of 5G, 3GPP has already specified various intelligent network and Network Automation use cases, mainly focusing on optimizing network resources utilization and improving user experience. Meanwhile, the service-oriented architecture design ensures highly efficient and fully secure interactions between the Network Functions within the mobile core network.

3GPP is actively and continuously enhancing 5G network intelligence in Release 19. In particular, TSG CT (mainly driven by the CT3 working group) continues to build elaborated protocol descriptions and efficient interface design to support more functionalities and use cases, such as AI-assisted positioning enhancement, vertical federated learning, QoS policy recommendation and network abnormal behavior mitigation and prevention.

For more on CT groups: **www.3gpp.org/3gpp-groups**

References

[1] 3GPP TS 29.520: "5G System; Network Data Analytics Services; Stage 3".

[2] 3GPP TS 29.574: "5G System; Data Collection Coordination Services; Stage 3".

[3] 3GPP TS 29.575: "5G System; Analytics Data Repository Services; Stage 3".

[4] 3GPP TS 29.576: "5G System; Messaging Framework Adaptor Services; Stage 3".

SA1 road to 6G

By José Luis Almodóvar Chico (3GPP SA1 Chair)
and Alain Sultan (3GPP SA1 Secretary)

As for previous generations, ITU defines the 6G calendar and 3GPP develops the standardized technology that will be the project's candidate to the ITU international mobile telecommunications (IMT) process

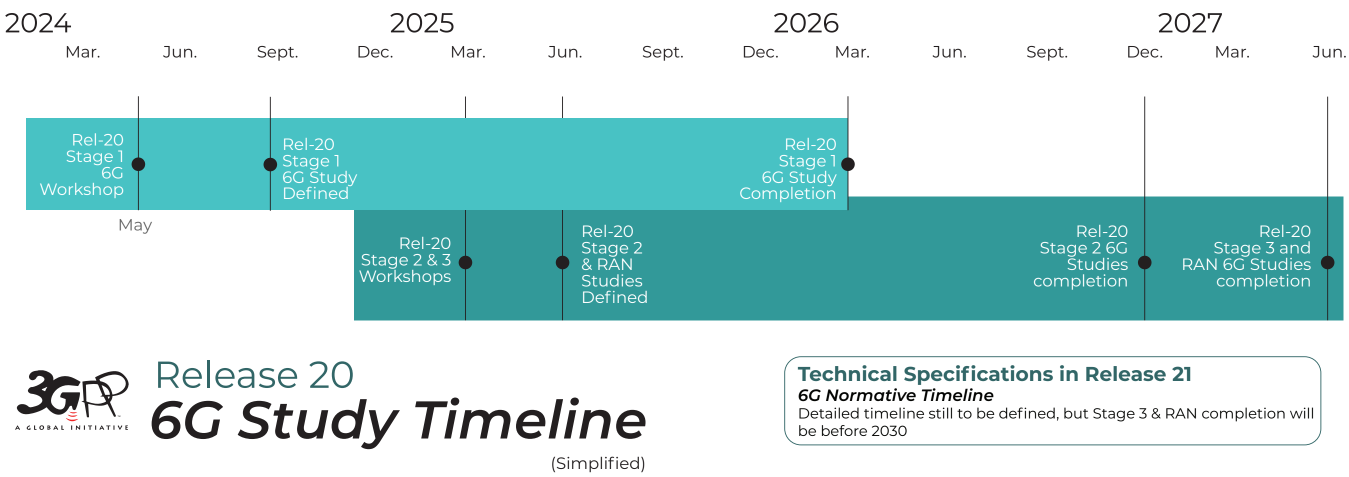
On this occasion, the target date for "Technology proposals for IMT-2030" has been defined by ITU to be early 2029, and resulting specifications (i.e. full system definition) are to be submitted by mid-2030 at the latest.

To meet these target dates and to give 3GPP enough time to perform relevant studies, 3GPP has concluded that two 3GPP Releases are needed to specify 6G:

- Release 20 for Studies
- Release 21 for the normative work

Given that it takes nearly two years to complete a Release, this means that the 3GPP 6G work must start…now! In practice, 3GPP has started the planning and preparation for 6G a few months ago. Working Group SA1, defining the Stage 1, is targeting to have its Release 20 study ready by March 2026. In addition, SA1 will be invited to provide status update on the study at the 3GPP-wide 6G workshop scheduled for March 2025.

All the 6G 3GPP timelines for Rel-20 are provided in the figure below. The milestones for Rel-21 have not yet been defined.



Taking the initiative on 6G

A brief reminder of SA1's role in 3GPP may help the reader understand where each new generation enters the 3GPP sphere. Simply put, the role of SA1 is to "…consider and study new and enhanced services, features, and capabilities and identify any corresponding Stage 1 requirements to be met by 3GPP specifications."

In mid-2023, when planning for the 6G work, SA1 organized the '3GPP Stage 1 Workshop on IMT2030 Use Cases' in Rotterdam, May 8-10, 2024. This Workshop was a great success with representatives from operators' associations, from the industry (including the "verticals"), from international research projects, academics and from ITU.

This kick-off event was followed by two regular SA1 meetings - SA1#106 (Jeju, in May) and SA1#107 (Maastricht, in August) where 3GPP companies were invited to share their vision on 6G.

The output from these meetings were quite aligned with the views expressed at the Workshop and were documented in the first 3GPP 6G study item.

The SA1 6G study and TR

To better manage the wide scope of 6G, the SA1 Chair proposed a new approach, which consisted in working concurrently on both the Study Item Description (SID) and the first draft of the Technical Report (TR 22.870), i.e. contributions were asked to be provided on both documents.

Additionally, he appointed a "temporary editor" to manage and synthesize contributions for discussion at the meeting. Mona Mustapha, Apple, was nominated to take on this role, and provided the initial draft versions of the SID and TR, that were discussed and concluded upon at SA1#107. This collaborative approach was widely supported by the SA1 delegates.

The SA1 6G TR will follow the usual SA1 study approach: first identify use cases, and then derive the potential system requirements, which will be later “consolidated”, i.e. sorted, modified and combined. Then the normative phase will start in Release 21, to define the 6G system requirements. These requirements will be taken as a basis for work in other 3GPP groups.

The 6G Study Item Description was agreed in SA1#107 with the support of more than 90 companies. The agreement of the SID opens the doors for companies to contribute to use cases on the next generation of Mobile Networks.

As for the TR 22.870, its draft version resulting from SA1#107 indicates some initial 6G work areas of interest, such as System and Operational Aspects, Integrated Sensing and Communication, Ubiquitous Connectivity, Immersive Communication, etc. This initial list may be updated in future SA1 meetings during the study phase, ending March 2026. Each of these sections corresponds to one of the main areas identified in various 6G visions presented by 3GPP members.

Additionally, the TR includes a section named ‘System and Operational Aspects’ which intends to cover general considerations such as CAPEX/OPEX reduction, improvement of overall 3GPP system performance, and migration from and interworking with 5G aspects.

Finally, TR 22.870 also includes a section on ‘Other Use Cases’, introduced as a temporary place holder for agreed use cases that do not belong to any of the other sections.

Next steps

Two co-Rapporteurs have been appointed for the SA1 6G SID and TR: Xiaonan Shi, China Mobile and Jean Trakinat, T-Mobile USA.

These are key roles in the SA1 6G work, and the two Rapporteurs will manage the planning and the coordination of the work in the coming meetings, until its completion in March 2026. As these lines are written, the Rapporteurs have already taken the initiative to start some early discussions in preparation for the next SA1 meeting (SA1#108, November 2024, Orlando, Fl., USA).

As always, the WG SA1 leadership and colleagues in the group stand ready to offer support and many helping hands at the start for the new generation.

For more on WG SA1: www.3gpp.org/3gpp-groups

The SA1 6G session at SA1#107

6G – Society's lifeline?

By Tero Pesonen, TCCA Critical Communications Broadband Group Chair

Societies are increasingly dependent on mobile communication, with identity authentication, payment transactions and inter-family communications all prime examples of services citizens rely on every day.

The need is set to grow as traditional services are digitised and made increasingly 'mobile-first'. If a hiccup in mobile connectivity feels like a disaster now, how much more serious will this be for our society when 6G is the dominant mobile communication technology?

Dependency calls for trust - This means, above all, availability under all circumstances. Sunny day best effort service is not enough. It calls for integrity and security for users to trust that their information is treated responsibly and only by those entitled to have access.

Societies in the 2040s will demand something the critical communication sector has always advocated in technology development: That a communication service is only good enough when you can trust your life to it. At the Society scale this means trusting the destiny of a nation and all of its citizens to it.

3GPP driving economies of scale

In a world where connectivity is not yet ubiquitous and where development timescales are long, we in TCCA have learned that it is crucial to be in at the beginning if our user requirements for next generation critical broadband services are to be met. Unlike narrowband technologies such as TETRA, specifically designed for critical communications, the broadband world has to date been built to meet a diversity of consumer expectations.

So, while 6G may seem a long way away, TCCA has gathered views from its sector on its 6G position, with support from other interested stakeholders, and is involved already in the early stages of the 3GPP studies and pre-specification work.

TCCA is the global Market Representation Partner (MRP) for critical communications in 3GPP, representing users working in public safety (police, fire & rescue, ambulance services); border control & military; the transport sector (railways, buses, highways, airports, ports); in critical infrastructure (electricity, water); in resource industries (oil & gas, mining); manufacturing and at major events. Critical communications are everywhere communications are critical.

The main role of TCCA in 6G is to identify the long-term needs of these sectors and give them a voice in the 3GPP standardisation process, to help consolidate what the specifications should deliver. A joint effort involving the mission critical industry and other interested partners will help 3GPP bring their needs in with the necessary broad support, ultimately bringing economies of scale for manufacturers supporting consolidated features.

When submitting our 6G use cases, TCCA posed the question 'What will it take for societies to be able to depend on 6G?' It is fair to say that we do not know exactly what society will look like in the 2040s, but what is certain is that the core critical communications requirements will remain unchanged. Those requirements are coverage, availability, resilience, performance and scalability – All available 24/7 with instant connectivity. The connection is the lifeline – in critical communications as well as in society at large.

3GPP has addressed many of the critical communications functional requirements Release by Release starting from Release 12 (LTE 4G), continuing to add capabilities with 5G Advanced features like Non-Terrestrial-Networks (NTN) and Device-to-Device communication multi-hop over 5G sidelink in Release 19 - currently being worked on.

Trust as the design principle

For our input into 3GPP, we set out four trust-based principles for 6G to serve critical communications sectors as well as the future societies.

Guaranteed service

- End-to-end service guarantees
- Efficient ways to track and observe service performance
    - Are services reachable? Communications to control room / field command available? Smart routing decisions on service level also between other technologies?
- Predictable service performance evolution allowing corrective automatic actions by operators
- Enhanced handling and differentiation of Mission Critical traffic (e.g. using AI/ML tools)
    - Use case-based priorities for multi-service communication

Resilience and robustness

- Standards support for reducing, mitigating, and recovering from failures
    - Automatic error detection and recovery to support continuous communications
- Architecture and deployment options for efficient redundancy
    - Full support for architecture interworking expected

> Dependency calls for trust - This means, above all, availability under all circumstances. Sunny day best effort service is not enough

- Standards ready for leveraging secure cloud-native tools for improved resilience
  - Cloud native tools enabling more distributed architectures and as a consequence better preparedness
- Increased robustness against GNSS service degradation
  - Non-Terrestrial-Networks based positioning and timing
  - Further development of terrestrial mobile network positioning (XYZ -axis accuracy)

Deployment and coverage

Efficient solutions for providing coverage everywhere

- Ultra-rural areas
  - Native satellite integration to mobile networks
  - 3D / multidimensional networks
- Challenging propagation scenarios
  - Cities, indoors, ultra rural solutions ranging from Device-to-Device to satellites needed
  - Communication capabilities on the move moving first responders especially but not limited to ultra-rural areas

Simplified deployment and operation

- Roaming between different MNO networks
- Seamless interoperability between macro and private networks (NPN)
- Cloud native for e.g. network scalability in rapidly expanding scenarios

Opportunistic ad-hoc solutions

- Support for autonomous systems and vehicles on land/sea/air
- Increasing amounts of sensors and autonomous systems results in growing capability requirements for massive data handling

Interoperability within and across networks, including mission critical roaming scenarios

Security

Detection and protection against electromagnetic threats

- Means to hide the critical traffic to other traffic
- Radio interface capabilities and enhancements to sustain interference and electronic organised crime

Standards and solutions ready for quantum safe communications

- On time with sufficient cybersecurity standards
- Future proof algorithms and key lengths
- Capability to utilise own crypto

Above all, 6G should enhance the level of trust users have in the system, for mission and safety-critical operations. It is the first standard where trust could be the design principle to answer the needs of the connected world.

It is the standard to enable new fully connectivity-dependent business models, where price differentiation based on the service assurance is normal. This enables MNOs to truly differentiate to serve different market sectors. 'Price leader' level of service might offer the user best effort service, perhaps funded by advertising. A 'Quality leader' QoS could ensure bitrates capable of delivering telemedicine, immersive gaming or perhaps critical communications services, at a price.

This is one of the areas about to be tested, how far the critical communications sector is ready to pay for guaranteed quality – and at what price?

These are (as always) exciting times. Join us in TCCA, alongside other critical communications stakeholders, as we work to build trust in 6G as society's lifeline.

TCCA

https://tcca.info/

Uni5G technology blueprints

Simplifying private network deployment for industry verticals

By Asimakis Kokkos, Technical Specification Group Chair of the Alliance for private networks and Head of Industry Environment Strategy at Nokia

The Alliance for private networks is championing the global industry adoption of private networks by educating the ecosystem and providing publicly available tools that ease the deployment process.

As part of our ongoing effort, the Alliance developed the Uni5G™ technology blueprints, a document based on 3GPP specifications and designed to be used as a tool for enterprises to efficiently deploy their own optimized, reliable, and secure 5G private network - in any available spectrum.

We partnered with Beecham Research to interview industry verticals operating around the world to better understand their connectivity requirements. Based on the responses received, we identified four primary feature groups beyond baseline enhanced Mobile Broadband (eMBB) that were required: coverage, reliability, connection density, and latency.

Additionally, we were able to identify 10 feature categories based upon the 3GPP Release 15 specification that map to the key attributes required by industry verticals.

In this article, we are pleased to provide a preview of the second generation of the Uni5G technology blueprints. Building on the first generation of blueprints, we have classified selected 3GPP Release 15 User Equipment (UE) feature groups for 5G private network deployments. The functionalities are mapped to four feature groups and defined to align with the most relevant attribute(s) for 5G private network deployments.

Table 1: Criteria to Map Features to Attributes

Attribute	Criteria
Coverage	Feature groups that can support MCL larger than baseline eMBB
Reliability	Feature groups that can be used to achieve improved reliability than baseline eMBB
Connection Density	Feature groups that relieve control channels from being the performance bottleneck and that optimize UE performance for scenarios where pre-emption need to be utilized.
Latency	Feature groups that can be used to achieve lower latency than baseline eMBB

Additionally, the categorized feature groups are further organized into categories based upon provided functionalities. The following tables were created to explain in user-friendly terms the 3GPP features and how they can add value to the various industry use cases.

Better Alphabet Coverage Reliability	**Smaller Mini-Slots** Coverage Reliability	**Flexible Scheduling** Latency Connection Density	**UL Steady Flow** Latency Connection Density	**DL Steady Flow** Connection Density
• **Ultra-reliable MCS** • Rel 15 specified additional MCS (modulation and coding scheme) tables to achieve lower error rates together with lower latency • Shipping ports cover large indoor and outdoor environments, using moving machinery, containers and more. Reliable coverage is necessary to provide real-time video surveillance, remote control of crane operations, container trucks and other heavy machinery, drone inspection of port operations, and more	• **Mini-slot** • Rel 15 defines slot size of 1 ms corresponding to 14 symbols (under 15kHz subcarrier spacing) • Support of mini-slots of 2, 4 and 7 symbol duration meets strict latency requirements • An example of mini-slot scheduling could be found within the manufacturing vertical which can experience low latency and boosted scheduling efficiency, enabling highly automated manufacturing environments, including connected manufacturing robots, autonomous guided vehicles, and more. Low latency and efficient scheduling is essential to enable reliability operation of advanced manufacturing equipment.	• **PDCCH processing** • Physical Downlink Control Channel carries the scheduling information • NR uses some subcarriers of OFDM symbol to enhance scheduling flexibility time spans of 3 OFDM symbols • Rel 16 time spans to 2 OFDM symbols • In complex industrial scenarios with many UEs and bustling traffic, enhanced PDCCH monitoring provides reduced blocking probability of critical control channels by increasing the networks scheduling flexibility. For instance, in a manufacturing scenario, PDCCH processing will enhance scheduling protocols and boost overall process efficiency for automated devices on the network; vital during critical and high-demand periods.	• **UL configured grant** • Resources are assigned periodically, and the UE transmits on these pre-assigned resources without the need for scheduling request • Multiple UL configured grants would improve the efficiency according to the required QoS • Control loops with feedback or critical sensors such as IMUs and video cameras are omnipresent in industrial scenarios. For instance, modern video cameras support various coding rates and modes which may have to be switched quickly and often require efficient and periodic signalling in the network. Configuring the UE attached to the sensors/cameras with uplink-configured grants would be a very efficient way of transporting this critical data for industrial users.	• **DL semi persistent scheduling** • Similar to UL configured grant but for downlink • Steady flow of data at periodic intervals • Reduces the control signaling overload • Benefits of Semi persistent signalling (SPS) usage in an industrial setting include process control and AGV control. According to 5G-ACIA, process control can a have period of 20 ms and a small payload of 64 bytes – significantly increasing efficiency and response times. Another compelling use case involves a human-machine interface (HMI) emergency button. A watchdog supervision message of 64 bytes is sent every 5 ms to the device hosting the emergency button with the controller expecting an acknowledgement, increasing safety.

Repeating Coverage Reliability	**Acknowledge** Latency	**Faster Processing** Latency	**Diversity** Reliability	**Priorities** Connection Density
• **Repetition** • Sending the same transport block multiple times to increases the chances of successful reception. It improves the reliability in a proactive way • Reduces over-the-air (OTA) latency by not relying on feedback indication of data corruption. • For example, in agricultural industries network reliability is essential to maximize food production while minimizing land and water usage through smart farming. The challenging radio environment and increase capacity in repetition can cause data or communication drops and interruptions – potentially causing delay in operations. Through repetition, the network can ensure that transport blocks are received, even during high-activity periods, and avoid interruptions in tough radio conditions.	• **HARQ-ACK** • Direct impact on round-trip time and thus on latency. • Short PUCCH is allocated at the end of every slot, time multiplexed with PUSCH allocations. • HARQ-ACK is a viable option for providing low latency in manufacturing facilities in rural environments. In highly automated manufacturing environments, a single millisecond latency will likely be needed to maintain ultra-reliability, up to 99.999% for advanced manufacturing. Keeping uptimes high is crucial in any manufacturing process. Connected manufacturing robots, autonomous guided vehicles, remote diagnostics and inspection require low latency to enable factory automation.	• **UE processing capability 2** • UEs supporting the related UE capabilities support shorter processing time, hence resulting in faster turn-around for the corresponding HARQ processes • UE capability 1 – 360 us • UE capability 2 – 161 us • Latency reduction and quick turnaround are essential in smart factory operations to enable deterministic transfer of data in industrial use cases in a cable-free environment. Even during periods of heavy network traffic, manufacturers expect processing to continue to maintain uptimes and support the factory's automated devices.	• **PDCP duplication** • Transmits a single PDCP packet to two or more independent radio link entities, so that the PDCP packet can exploit diversity via being transmitted over different radio channels to achieve higher reliability and to reduce the time delay by eliminating need for retransmission. • A warehouse utilizing automated flow management could employ video surveillance cameras to ensure secure facility access, confirm appropriate material handling, and manage available inventory. Autonomous guided vehicles transport goods from the unloading dock to the warehouse for inventory control and management and then move deliveries from packaging to outbound shipping. By using PDCP duplication we ensure higher reliability with less link interruptions.	• **Pre-emption indication** • Allows for gNB to schedule a mini-slot with URLLC-type of traffic that overwrites an ongoing eMBB-type of transmission of lower priority in the same slot. • High priority control or other information can securely and timely be delivered by implementing this feature as they will be prioritised against other less critical messages.

Moreover, this newest release of the Uni5G technology blueprints maps the association of these features and attributes to industry verticals by providing use case examples for each category.

Our goal is to take the guess work out of the deployment process. By combing through hundreds of 3GPP features, we were able to develop our recommended 3GPP feature list, optimizing enterprise and industrial applications. Our quarterly Private Networks Report is available to the public and will provide access when the second generation Uni5G technology blueprints are released.

We hope you will subscribe! For more information, visit **www.mfa-tech.org.**

Our goal is to take the guess work out of the deployment process. By combing through hundreds of 3GPP features, we were able to develop our recommended 3GPP feature list, optimizing enterprise and industrial applications.

Maintaining an effective supply chain for the Mobile Industry

By Joe Barrett, GSA President

During the pandemic, the supply chains of all industries were thrown into disarray. Of course some industries faired better than others but the disruption was witnessed on a global scale. The ICT industry in particular was faced with unprecedented challenges.

On the one hand there was an enormous rise in consumer demand. We were all forced into "work from home" mode and this required investment in ICT as the "office" became the "home office". Citizens relied heavily on mobile devices to remain in contact with family and friends and in many cases that device also served as the most effective means to access the internet. "Shopping" became an online experience by default.

One positive outcome from this period in that there was a rapid acceleration of digital connectivity and a corresponding growth in ICT demand.

On the other hand, this surge in demand placed great strain on the semiconductor industry. Fabrication plants were temporarily closed due to raw material shortages and the forced unavailability of staff , resulting in a worldwide shortage of chips that lasted for several years. Our dependence on ICT products in general, and mobile phone networks in particular, led to a call for greater resilience in the supply chain and prompted regulatory change.

It was widely expected that, in a post-pandemic era, those problems would be behind us and normality would be restored. In many cases however, this does not appear to be the case. By way of example, recent press articles have reported airlines cancelling hundreds of flights because they cannot obtain the parts needed to service their aircraft. The economic impact of such supply chain disruption is obvious. It is interesting then to consider the challenges faced by the mobile industry today and the steps being taken by our industry to maintain an effective and resilient supply chain.

The mobile landscape is constantly evolving, influenced by market dynamics and economic forces. GSA Members understand the need to provide long term stability and predictability in order to safeguard the investments made by those deploying mobile systems. Key to this are the standards being developed within 3GPP which provide sufficient commonality to support mass deployment but which also provide sufficient flexibility to support product diversity and innovation by GSA members.

This has always been a difficult balance with both the breadth and depth of standards needing to be carefully considered at every stage of the process. The end result by design, is a portfolio an interoperable products available from multiple vendors.

Other external events have also impacted mobile supply chain resilience in recent years. Geopolitical tensions have surfaced and placed great strain on existing relationships. Fortunately, 3GPP has managed to reduce any external geopolitical impact to a minimum which has allowed GSA members to continue to work collaboratively to prepare the standards on which our industry thrives. It is a testimony to the 3GPP leadership that this has been achieved and long may it continue.

The security standards produced by 3GPP and other SDOs are playing an increasing role in achieving this objective. But it is not just a matter of the manufacturer being satisfied that the software used within mobile products is secure. Customers also place demands on their suppliers to demonstrate transparency in the origin of software components used within their products.

Looking to the future, and especially in the context of 6G, it is highly likely that 3GPP will be called on to produce more software based standards than the text based standards produced today. Such a change will need to be carefully considered in the context of improving supply chain resilience.

> "The mobile landscape is constantly evolving, influenced by market dynamics and economic forces.

But external to 3GPP, the geopolitical tensions are affecting the supply chain. The availability of rare earth metals and gases for example are disrupted by world events as well as more direct trade restrictions by Governments.

Extreme weather episodes have also impacted our industry's supply chains with fires and flooding being just two examples that have led to product shortages and caused large scale disruption. This has emphasized the need to have diversity within the supply chain and not to be dependent on single sources for materials or components.

Historically, the mobile industry has been largely hardware based and global standards have proven to be effective in maintaining choice for customers, be they operators of mobile networks or users of mobile devices. Today, mobile systems are heavily dependent on software and this raises the level of complexity in the supply chain. Manufacturers of mobile systems may develop their own software, may select open source software from third parties, or may decide to use a combination of both. For the future, software may even be AI generated. This results in a complex software bill of materials which manufacturers need to maintain in order to ensure product security.

The security of mobile systems is paramount and the increasing dependency on software within those systems provides an opportunity for rogue actors to exploit. The mobile industry therefore devotes considerable resources to ensure the origin of software and that it remains inherently secure.

Perhaps of less interest to engineers, but of equal importance to manufacturers, is the need to demonstrate sustainability and environmental compliance within the supply chain. Here, standardization within ISO helps greatly for example in ensuring compliance of product packaging. Once again, it is not just the manufacturer that is required to meet these standards but suppliers of components used by manufactures in the assembly of their products. And as is the case with software transparency, there is equally a call for transparency for product packaging as customers also need to demonstrate that they are achieving their sustainability targets.

More recently, the impact of ICT supply chain subversion has emerged in the press which adds another angle to this multi-faceted subject and illustrates the importance of maintaining the integrity of the supply chain. Not surprisingly, the whole process of supply chain management has become incredibly complex in recent times. Fortunately, international standards are available which assist industry in understanding that complexity and guiding them on how best to demonstrate compliance.

Maintaining an effective supply chain for the mobile industry is of course a matter that goes far beyond 3GPP or even standardization. Nevertheless, the value that 3GPP provides should not be underestimated as the standards produced form the centrepiece of an effective mobile industry supply chain.

The Journey Towards Industrial 6G

Key Requirements & Lessons Learned from 5G

by the General Chairs of 5G-ACIA: Andreas Mueller (Bosch) and Afif Osseiran (Ericsson)

The industrial sector has been among the most promising verticals for 5G since its early days, holding the potential to accelerate Industry 4.0 developments and enable new levels of efficiency, productivity, flexibility and ease-of-use.

For the mobile industry, the industrial domain represents a promising business opportunity with the perspective to generate significant additional revenue beyond the classical consumer business. This was also underscored in many presentations at the IMT-2030 workshop organized by 3GPP SA1 in Rotterdam in May 2024.

However, despite the initial enthusiasm, Industrial 5G adoption is lagging initial expectations. This doesn't indicate a lack of progress but instead shows that achieving the full vision requires more time than originally anticipated. To set Industrial 6G on a strong footing, it's critical to reflect on the lessons learned from 5G from the very beginning. Below, the General Chairs of 5G-ACIA share their views on the past, present and future of Industrial 5G and 6G.

Reflections on Industrial 5G: Achievements and Challenges

The 5G Alliance for Connected Industries and Automation (5G-ACIA) was established in 2018 to create a global forum for stakeholders in the ICT and Operating Technologies (OT) industries to drive and shape Industrial 5G developments. Representing the voice of the manufacturing sector in 3GPP as a market representation partner, 5G-ACIA has identified and analyzed numerous industrial use cases and requirements, many of which were discussed in 3GPP SA1. Industrial applications are characterized by multi-dimensional requirements, such as high performance (e.g., low latency and high reliability), specialized functions (e.g., non-public networks and time synchronization), and specific operational needs (e.g., ease of use).

Starting with Release-16, 3GPP introduced features critical to industrial use cases, including ultra-reliable low-latency communication (URLLC), support for time-sensitive networking (TSN), high-accuracy positioning, and 5G NR RedCap for reduced capability devices. Many companies have tested Industrial 5G through dedicated testbeds, including those facilitated by the 5G-ACIA testbed program.

Despite these advancements, adoption in manufacturing is still below initial expectations. This gap can be attributed to several factors:

- **Standards vs. Implementation Gap:** In early 5G stages, consumer-focused features took priority. However, fortunately, industry-specific features are gaining more and more traction nowadays.
- **Different Life Cycles:** The OT industry has substantially longer equipment life cycles than the ICT industry. While consumers upgrade devices every few years, industrial equipment often lasts 20 years or even longer.
- **Device Ecosystem Challenges:** Building a rich ecosystem of compatible devices takes time, and there is a "chicken-and-egg" dilemma between device availability and network deployment.
- **Holistic Solution Complexity:** 5G is typically only one part of an industrial solution, requiring careful integration with existing systems. This is only possible with the right know-how and mindset, which also takes time to be established.

These challenges are gradually being addressed, and the good news is that finally more and more manufacturers are beginning to incorporate 5G into their production systems.

Key Lessons Learned from 5G for 6G Developments

One of the most important lessons from 5G is the need for realistic expectation management. For the OT industry, it's not just about achieving the best-case performance with a theoretical standard but delivering reliable, real-world performance with commercially available products. The solution must also be cost-competitive, providing a positive return-on-investment (RoI) within a reasonable time and an attractive offering compared to other (non-3GPP) alternatives. While public networks rely on 3GPP standards, enterprise applications (like manufacturing) clearly have other options.

To ensure 6G meets industrial needs, the early involvement of the OT industry in its development is crucial. By collaborating from the start, ICT and OT industries can build a shared understanding of the challenges and solutions needed for Industrial 6G. Organizations like 5G-ACIA are essential in this process, especially as many OT companies lack the resources to engage directly with 3GPP.

Moreover, rather than overloading 6G with numerous features and implementation options, it would be prudent to prioritize those with the highest likelihood of being implemented and adding clear value. This focus would help streamline the standards, reduce complexity, and ultimately bring down costs.

First Perspectives on Industrial 6G

For many industrial players, a critical requirement for 6G is that it builds upon 5G's foundations, ensuring compatibility with current and planned investments, given the long life cycles of industrial equipment and facilities. Aligning with the OT industry's operational timelines, 6G should continue to support the use cases already identified for Industrial 5G.

Key requirements for 6G include:

- **High Dependability and Resilience:** Industrial environments require precise time synchronization, end-to-end latencies of ~1 ms, and robust reliability, which is not yet fully supported in practice.
- **Simplified Operations:** Operational complexity must be further reduced, and non-public network integration with enterprise IT should be further simplified, such as through advanced capability exposure.
- **Flexible and Modular Design:** Manufacturing facilities are becoming more versatile, so future networks should be equally adaptable, supporting modularity and flexibility.
- **Seamless Interworking with Non-3GPP Systems:** 6G must integrate seamlessly with other industrial networks, such as wired TSN or Industrial Ethernet. Cost-effectiveness, rather than just the best technical performance, should be prioritized to achieve a favorable cost-benefit ratio.

New Capabilities for 6G: Emerging Technologies and Their Industrial Potential

Several advanced capabilities are central to current 6G discussions and could unlock new opportunities for industry. These include:

- **Integrated Sensing and Communication (ISAC):** Industrial settings already rely on extensive sensing capabilities today, but these are typically separate from the communication infrastructure. By integrating sensing into the network, complexity and costs could be reduced, enabling applications such as real-time monitoring, digital twin enrichment, and predictive maintenance.
- **AI and Machine Learning (AI/ML):** AI could be deeply embedded in 6G for tasks such as data management, aggregation, and model distribution. In industrial networks, AI/ML could simplify network management, enhance flexibility, and support predictive maintenance. Already vital to the industrial sector, AI unlocks significant optimization potential, and its integration into 6G could further enhance automation and efficiency.
- **Real-Time Digital Twins:** Digital twins are becoming essential in manufacturing, enabling virtual replicas of physical assets for monitoring and optimization. In 6G, digital twins will demand features like higher uplink capabilities and precise space-time synchronization. Furthermore, digital twins of the network itself could interact with digital twins of production facilities, improving overall operation and management, for example.

Clearly, these are only some very initial perspectives on Industrial 6G, and organizations like 5G-ACIA are continuously working to identify and assess the full potential that 6G may bring to the manufacturing industry.

Conclusion

As the 3GPP and research communities turn their focus toward 6G, it's important not to overlook the ongoing work needed to fully realize the Industrial 5G vision. Initial expectations for 5G adoption in industry were ambitious, especially regarding the timeline. However, 5G is gradually transitioning from theory to practice in manufacturing. Lessons learned from 5G should be considered in the development of 6G from the outset.

A collaborative approach between the ICT and OT industries, grounded in realistic expectations and a clear focus on RoI, will be essential. By prioritizing these elements, 6G can deliver new capabilities, such as advanced sensing, AI-driven automation, and sustainable connectivity solutions that will elevate industrial operations even further than Industrial 5G, paving the way for a more connected, efficient, and intelligent future.

5GACIA
5G Alliance for Connected Industries and Automation

www.5g-acia.org

A LOOK INSIDE

CALENDAR OF MEETINGS

Here is a snapshot of upcoming TSG (bold) and WG meetings. Only Working Group meetings for the first quarter of 2025 are listed:

Meetings	Start Date	City
TSGs#106	**09-Dec-24**	**Madrid**
CT1#153	17-Feb-25	Athens
CT3#139	17-Feb-25	Athens
CT4#127	17-Feb-25	Athens
RAN1#120	17-Feb-25	Athens
RAN2#129	17-Feb-25	Athens
RAN3#127	17-Feb-25	Athens
RAN4#114	17-Feb-25	Athens
RAN5#106	17-Feb-25	Athens
SA1#109	17-Feb-25	Athens
SA2#167	17-Feb-25	Athens
SA3#120	17-Feb-25	Athens
SA4#131	17-Feb-25	Geneva
SA5#159	17-Feb-25	Sophia-Antipolis
SA6#65	17-Feb-25	Athens
CT6#121	18-Feb-25	Athens
TSGs#107	**12-Mar-25**	**Incheon**
TSGs#108	**09-Jun-25**	**Prague**
TSGs#109	**15-Sep-25**	**China**
TSGs#110	**08-Dec-25**	**Baltimore**

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

3GPP'S GLOBAL MEMBERSHIP

- 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

MCC TF160 ready for testing 5G-Advanced UE

Task Force 160 (TF160), the dedicated project within the 3GPP Mobile Competence Centre (MCC), developing and maintaining a reference software implementation of the RAN5 protocol conformance test cases. It is used by certification organisations, such as GCF and CTIA/PTCRB, to certify UE compliance to 3GPP standards.

Following the Rel-18 ASN.1 freeze, TF160 has performed a full upgrade of their test suites software to incorporate the new & updated protocol messages from Rel-18 specifications. It provides the baseline upon which Rel-18 conformance test cases can be implemented. Several Rel-18 eRedCap tests have already been implemented and delivered by TF160, and are available to the industry. Many more Rel-18 tests will be made available in the coming months.

www.3gpp.org/about-us/mobile-competence-centre/mcc-task-forces

2025 Elections at TSG level

The Technical Specification Groups (TSGs CT, RAN and SA) leadership elections will take place during the March 2025 plenaries (TSGs#107), with each group electing a Chair and a maximum of three Vice Chairs.

This process takes place every two years, with officials elected by their group from amongst the Individual Member representatives. Any candidate for election to a TSG Chair or Vice Chair position is nominated by a letter of support from the Individual Member that they represent.

Chairs and Vice Chairs may offer themselves for election for a second consecutive term, but may not stand for a third, if another candidate is announced prior the meeting deadline.

Keep an eye on the 3GPP website (**www.3gpp.org/delegates-corner/elections-technical-votes**) for details of the nominations received prior to the March TSGs#107 meetings, Incheon, KR.

(Detail inspired by Article 22 of the 3GPP Working procedures)