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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

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- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

Introduction

The present document provides a summary of each and every 3GPP Release 15 Feature, and more generally of all Work Items for which a summary has been agreed to be provided.

These summaries are based on the inputs issued by the Work Item Rapporteurs, slightly rewritten by the TR Rapporteur to ensure overall consistency. The original Work Item Rapporteur inputs can be retrieved as temporary document (tdoc), as stated in the first sentence of each clause.

1 Scope

The present document provides a summary of each Release 15 Feature or, whenever needed, of each significant Work Item.

The information provided in the present document is limited to an overview of each Feature, explaining briefly its purpose and the main lines of the system's behaviour to execute the Feature.

More information is available by consulting the 3GPP Ultimate web site, as explained in "Annex C: Process to get further information".

The present document presents the "initial state" of the Features introduced in Release 15, i.e. as they are by the time of publication of the present document. Each Feature is subject to be later modified or enhanced, over several years, by the means of Change Requests (CRs). It is therefore recommended to retrieve all the CRs which relate to the given Feature, as explained in Annex C, to further outline a feature at a given time.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] TR 21.905: "Vocabulary for 3GPP Specifications".

NOTE: Due to the specificity of the present document, consisting in a collection of independent summaries, the references are given at the end of each clause rather than in this clause.

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1]. Abbreviations specific to a given clause are provided in the clause they appear.

KPI Key Performance Indicator
Rel 3GPP Release

4 Rel-15 Executive Summary

3GPP main area of work in Release 15 is the definition of the initial phase of 5G, the Fifth Generation of Mobile Communications, also referred to as "5GS" ("the 5G System").

5G is to be defined in at least 2 phases, the phase 1 being specified in Release 15, as summarised in the present document. Subsequent phase(s) will be specified in future Release(s).

Beside 5G Phase 1, Release 15 also specifies, among other Features: further enhancements on Critical Communications (including Ultra Reliable Low Latency Communication and Highly Reliable Low Latency Communication), Machine-Type of Communications (MTC) and Internet of Things (IoT), Vehicle-related Communications (V2X), Mission Critical (MC), and features related to WLAN and unlicensed spectrum.

The continuation of the present document provides an exhaustive view of all the items specified in Release 15 by 3GPP.

5 The 5G System (5GS) - Phase 1

5.1 Work organisation for 5GS

The 5G System is the main topic of 3GPP Release 15. Release 15 defines the 5G system Phase 1, while the 5G system Phase 2 is to be defined in Release 16.

The specification of Phase 1 has involved all the 3GPP Working Groups and TSG, defining all the (many) necessary aspects.

The table in Annex A provides the overall view of all the 5G-related work items in Rel-15, including their hierarchical structure.

Next clauses provide a summary of 5G System service aspects, its architecture, the protocols, the radio aspects and several specific aspects such as security, charging, etc.

5.2 The 5GS service aspects

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
720005	**(Stage 1 of 5G) New Services and Markets Technology Enablers**	SMARTER	S1	SP-160364	Vodafone , Li, Alice

Summary based on the input provided by Vodafone in SP-180883.

The 5G requirements have been defined in terms of new services and markets by SA1, under the "SMARTER" work item. These are defined mostly in TS 22.261 [1], which describes different types of requirements for different 5G usage:

- **Enhanced Mobile Broadband (eMBB):** the new requirements -higher than for 4G- are specified for data-rates, traffic/connection density, user mobility, etc. Various deployment and coverage scenarios are considered, addressing different service areas (e.g., indoor/outdoor, urban and rural areas, office and home, local and wide areas connectivity), and special deployments (e.g., massive gatherings, broadcast, residential, and high-speed vehicles). The scenarios and their performance requirements can be found in table 7.1-1 of TS 22.261 [1]. For instance, for the downlink, data rate of up to 50 Mbps are expected when outdoor and 1 Gbps when indoor (5GLAN), and half of these values for the uplink. For services to an airplane, a bitrate of 1,2 Gbps is expected per plane.

- **Critical Communications (CC) and Ultra Reliable and Low Latency Communications (URLLC)**: Several scenarios require the support of very low latency and very high communications service availability. These are driven by the new services such as industrial automation. The overall service latency depends on the delay on the radio interface, transmission within the 5G system, transmission to a server which may be outside the 5G system, and data processing. Some of these factors depend directly on the 5G system itself, whereas for others the impact can be reduced by suitable interconnections between the 5G system and services or servers outside of the 5G system, for example, to allow local hosting of the services. The scenarios and their performance requirements can be found in table 7.2.2-1 of TS 22.261 [1]. For instance, in the context of remote control for process automation, a reliability of 99,9999% is expected, with a user experienced data rate up to 100 Mbps and an end-to-end latency of 50 ms. This is provided in particular through the Edge Computing capability described below.

- **Massive Internet of Things (mIoT)**. Several scenarios require the 5G system to support very high traffic densities of devices. The Massive Internet of Things requirements include the operational aspects that apply to the wide range of IoT devices and services anticipated in the 5G timeframe.

- **Flexible network operations**. These are a set of specificities offered by the 5G system, as detailed in the following sections. It covers aspects such as network slicing, network capability exposure, scalability, and diverse mobility, security, efficient content delivery, and migration and interworking.

This diversity of requirements, associated to the different categories of usage described above, enables the use of the 5GS by different sectors of the industry, referred to as "verticals". Some of these verticals are mentioned in the annexes of TS 22.261 [1]:

- Automotive and other transport (trains, maritime communications),
- Transport, logistics, IoT,
- Discrete automation,
- Electricity distribution,
- Public Safety,
- Health and wellness,
- Smart cities,
- Media and entertainment.

Some of these aspects are further described in corresponding clauses of this document: e.g. Railways, eV2X and its associated requirements as defined in TS 22.186 [10], etc.

As for the migration path, the 5G system supports, in addition to the new 5G-specific services, all the former EPS (4G) capabilities that were defined in TS 22.278 [2] and in TSs 22.011 [3], 22.101 [4], 22.185 [5], 22.071 [6], 22.115 [7], 22.153 [8], 22.173 [9]. There are some exceptions, i.e. some 4G services are not supported in 5G: they relate to the interworking with legacy systems, as specified in clause 5.1.2.2 of TS 22.261. Finally, mobility between a 5G core network and an EPC (4G) is supported, with minimum impact to the user experience.

NOTE: In this document, EPS and all the other concepts related to LTE, such as "LTE Advanced Pro", will be referred to as "4G", although this is not an official 3GPP terminology.

References

[1] TS 22.261, "Service requirements for the 5G system".
[2] TS 22.278, "Service requirements for the Evolved Packet System (EPS)".
[3] TS 22.011, "Service accessibility".
[4] TS 22.101, "Service aspects; Service principles".
[5] TS 22.185, "Service requirements for V2X services".
[6] TS 22.071, "Location Services (LCS); Service description".
[7] TS 22.115, "Service aspects; Charging and billing".
[8] TS 22.153, "Multimedia priority service".
[9] TS 22.173, "IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services".
[10] TS 22.186, "Service requirements for enhanced V2X scenarios".

5.3 Overview of the 5GS architecture

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
740061	**Stage 2 of 5G System - Phase 1**	5GS_Ph1	S2	SP-160958	China Mobile, Tao Sun

Summary based on the inputs provided by China Mobile, Nokia, Ericsson, Huawei in SP-180595, by Vodafone in SP-180883 and by NTT DOCOMO, INC. in RP-181724.

5.3.1 Introduction

As seen above, 5G is designed to support diverse services with different data traffic profiles (e.g., high throughput, low latency and massive connections) and models (e.g., IP data traffic, non-IP data traffic, short data bursts and high throughput data transmissions). Various PDU session types are supported including IPv4, IPv6, IPv4v6, Ethernet and Unstructured.

The 5G's main characteristic is the introduction of a new radio interface, the New Radio (NR), which offers the flexibility needed to support these very different types of services.

Another key characteristic of 5G is that the 5G Access Network can connect not only to a new 5G Core Network but also to the 4G (LTE) Core Network. This is known as the NSA architecture, while the 5G AN connected to a 5G CN is called the SA architecture.

On the Core Network side, the 5G System offers also a wide array of new characteristics, such as a deeper use of Network Slicing, Mobile Edge Computing or Network Capability Exposure. All these concepts are presented below.

5.3.2 The NSA versus SA architecture

Two deployment options are defined for 5G:

- the "Non-Stand Alone" (NSA) architecture, where the 5G Radio Access Network (AN) and its New Radio (NR) interface is used in conjunction with the existing LTE and EPC infrastructure Core Network (respectively 4G Radio and 4G Core), thus making the NR technology available without network replacement. In this configuration, only the 4G services are supported, but enjoying the capacities offered by the 5G New Radio (lower latency, etc). The NSA is also known as "E-UTRA-NR Dual Connectivity (EN-DC)" or "Architecture Option 3". See also the clause on EDCE5.

- the "Stand-Alone" (SA) architecture, where the NR is connected to the 5G CN. Only in this configuration, the full set of 5G Phase 1 services are supported.

The NSA architecture is illustrated in the following figure.

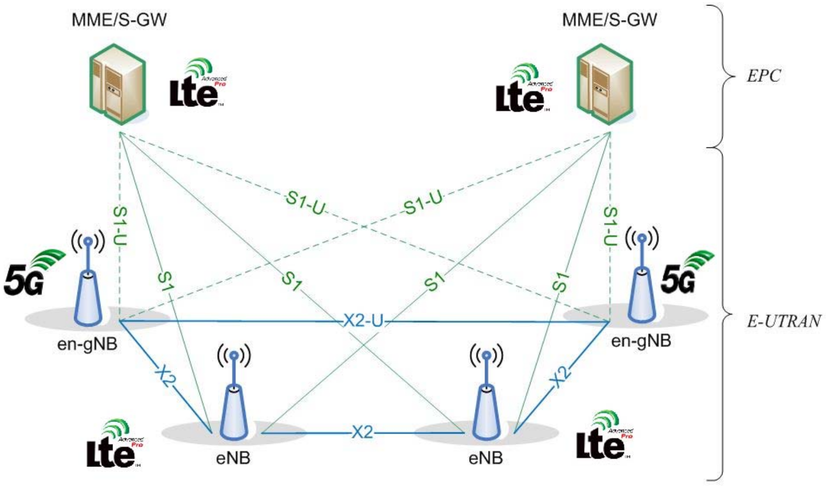


Figure 5.3.2-1: The NSA Architecture

The NSA architecture can be seen as a temporary step towards "full 5G" deployment, where the 5G Access Network is connected to the 4G Core Network. In the NSA architecture, the (5G) NR base station (logical node "en-gNB") connects to the (4G) LTE base station (logical node "eNB") via the X2 interface. The X2 interface was introduced prior to Release 15 to connect two eNBs. In Release 15, it also supports connecting an eNB and en-gNB as to provide NSA.

The NSA offers dual connectivity, via both the 4G AN (E-UTRA) and the 5G AN (NR). It is thus also called "EN-DC", for "E-UTRAN and NR Dual Connectivity".

In EN-DC, the 4G's eNB is the Master Node (MN) while the 5G's en-gNB is the Secondary Node (SN).

This is explained in detail on the dedicated section on NSA of this present document.

The SA architecture is illustrated in the following figure.

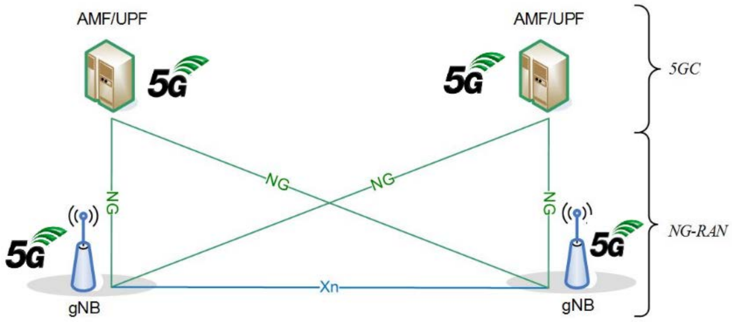


Figure 5.3.3-1: The SA Architecture

The SA architecture can be seen as the "full 5G deployment", not needing any part of a 4G network to operate.

The NR base station (logical node "gNB") connects with each other via the Xn interface, and the Access Network (called the "NG-RAN for SA architecture") connects to the 5GC network using the NG interface.

The continuation of this section refers to the SA architecture, the NSA being addressed in a subsequent, dedicated, section.

5.3.3 Overview of the Core Network

In the SA deployment option, the 5G System (5GS) is composed of the User Equipment, the Access Network (including the "New Radio" or NR) and the Core Network (5GC or 5GCN).

The service requirements, as presented in the previous clause, were used as a basis to define the architecture. The architecture specification (a.k.a. Stage 2) started with a preliminary study in TR 23.799 [4], also called "NextGen TR", before being fully specified in TS 23.501 [1], TS 23.502 [2] and TS 23.503 [3].

The 5GC architecture relies on a so-called "Service-Based Architecture" (SBA) framework, where the architecture elements are defined in terms of "Network Functions" (NFs) rather than by "traditional" Network Entities. Via interfaces of a common framework, any given NF offers its services to all the other authorized NFs and/or to any "consumers" that are permitted to make use of these provided services. Such an SBA approach offers modularity and reusability.

The basic (SA, non-roaming) 5G System architecture is shown below (figure introduced by the editor):

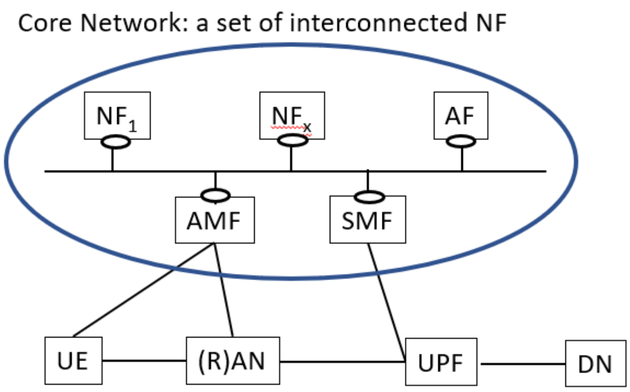


Figure 5.3.3-1: Overview of the 5G System architecture

At this stage, only the following essential Network Functions and elements are highlighted here:

- The User Equipment (UE);
- The (Radio) Access Network [(R)AN];

- The User Plane Function (UPF), handling the user data;
- The (external) Data Network (DN);
- Some remarkable Network Functions (NFs):
  - The Application Function (AF), handling the application(s);
  - The Access and Mobility management Function (AMF), that accesses the UE and the (R)AN;
  - The Session Management Function (SMF), that accesses the UPF.

The other NFs are introduced later.

The SBA approach enables a virtualized deployment. Indeed, a Network Function instance can be deployed as fully distributed, fully redundant, stateless and/or fully scalable. Several Network Function instances can be present within a same NF set. Conversely, the services can be provided from several locations.

In other words, when the services of a specific NF are invoked, this virtualization enables to route the UE's messages to any capable entity (within a pre-defined set of equivalent NFs).

This provides resiliency: any specific instance of the NF can e.g. be turned off for planned maintenance, and there will be auto-recovery without any service disruption.

5.3.4 Overview of the Access Network

As a first approach, the architecture of the 5G AN is extremely simple since it consists in one single entity, the gNB, which connects to the 5G CN via the NG interface. It may also connect to another gNB via the Xn interface and/or to the 4G's eNB via the X2 interface, as shown below in the editor-proposed picture inspired from TS 38.401 [5] and TS 38.420 [6]. It also connects to the UE via the NR interface, not shown on the figure. Note that this AN architecture is rather similar in its principle to what was developed for LTE with the eNB, as can be seen in TS 36.401 [7].

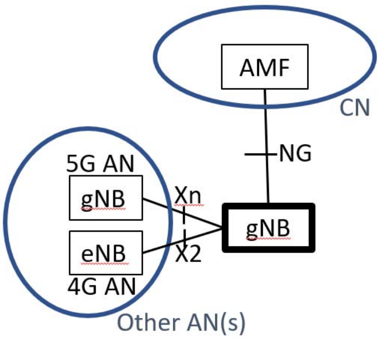


Figure 5.3.4-1: Overview of the AN interfaces

5.3.5 References for 5GS Stage 2

The main Stage 2 specifications for the 5G System are:

[1] TS 23.501, "System Architecture for the 5G System", Stage 2. It specifies the overall 5GS Stage 2: the architecture reference model, including the network functions and the description of high level functions.

[2] TS 23.502, "Procedures for the 5G System", Stage 2. It specifies the 5GS Stage 2 for roaming and non-roaming scenarios, for the policy and charging related control framework.

[3] TS 23.503, "Policy and Charging Control Framework for the 5G System", Stage 2. It is the companion specification to TS 23.501 and TS 23.503, and specifies the Stage 2 procedures and Network Function Services.

[4] TR 23.799 "Study on Architecture for Next Generation System", Stage 2

[5] TS 38.401 " NG-RAN; Architecture description"

[6] TS 38.420 " NG-RAN; Xn general aspects and principles"

[7] TS 36.401 "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Architecture description"

5.5 One step deeper into the 5GS

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750067	New Radio Access Technology	NR_newRAT	R1	RP-171485	NTT DOCOMO

Summary based on the input provided by NTT DOCOMO, INC. in RP-181466 revised in RP-181724.

Abbreviation applicable to this section:

NR	New Radio (5G Radio)
NSA	Non Stand-Alone
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRACH	Physical Random Access Channel
PSS	Primary Synchronisation Signal
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
SA	Stand-Alone
SSS	Secondary Synchronisation Signal

5.5.1 Functional split between Radio and Core

Further to the overall architecture provided above, this clause goes deeper in the functionalities provided by the Core Network (AMF, SMF, etc.) and the ones in the Access Network, i.e. provided by the gNB.

Figure 2-1 of TS 23.501 [1] shows some of the different NFs:

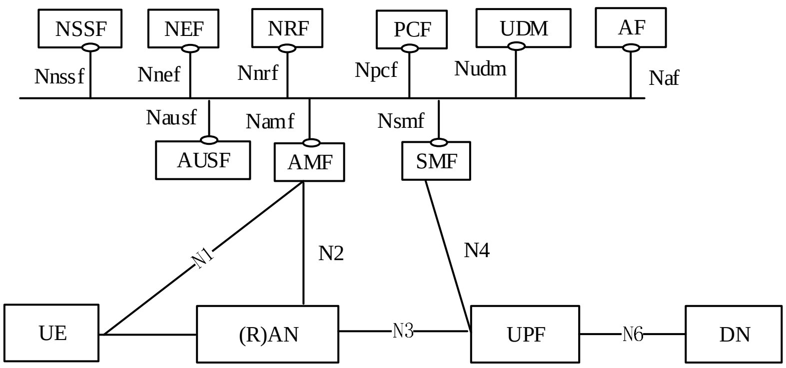


Figure 5.5.1-1: The 5G System architecture

Some NFs are specific to some network aspects and will be presented below, such as the Network Slice Selection Function (NSSF), the Authentication Server Function (AUSF) or the Policy Control Function (PCF). The security-related NFs, i.e. SEAF, AUSF, ARPF, SEPP, are (also) presented in the section on 5G Security.

The NFs exchanging information on the AN/CN interface are, on the Core Network side, the AMF, UPF and SMF, and, on the Access Network side, the gNB. These NFs are shown in the figure below in yellow boxes while the white boxes depict the main tasks they perform.

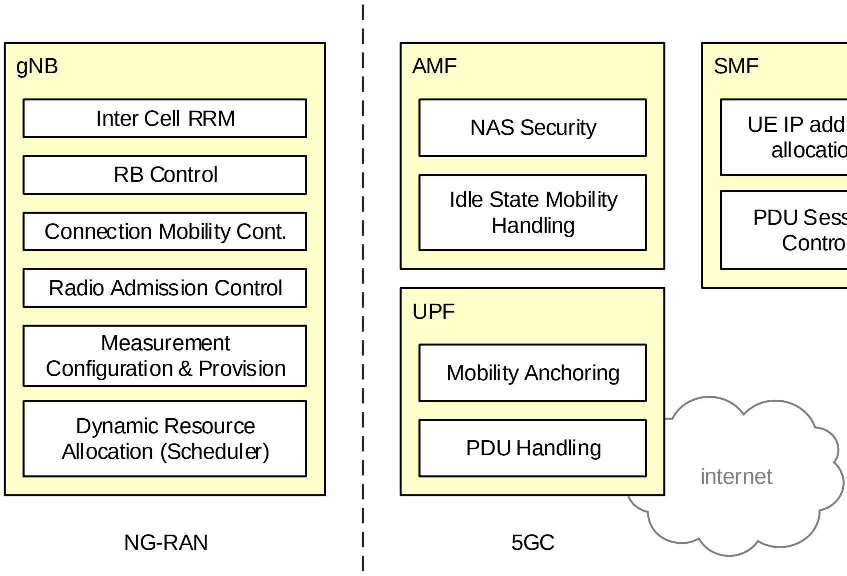


Figure 5.5.1-2: Functional Split between NG-RAN and 5GC

On the Core Network side, the AMF ("Access and Mobility management Function") oversees all the signalling which is not specific to User Data, such as mobility or security. The SMF ("Session Management Function"), takes care of the signalling related to User Data traffic, such as session establishment. Finally, The UPF ("User Plane Function") represents the handling of user data.

On the Access Network side, the gNB (5G Node B) performs all the main AN-related tasks, including Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs, etc.

5.5.2 The 5G Core Network

5.5.2.1 Main NFs

The AMF (Access and Mobility management Function) support UEs with different mobility management needs. It performs the following main tasks:

- The Non-Access Stratum (NAS) signalling termination;
- The NAS signalling security;
- The Access Stratum (AS) Security control;
- Inter CN node signalling for mobility between 3GPP access networks;
- Idle mode UE Reachability (including control and execution of paging retransmission);
- Registration Area management;
- Support of intra-system and inter-system mobility;
- Access Authentication;
- Access Authorization including check of roaming rights;
- Mobility management control (subscription and policies);
- Support of Network Slicing;
- SMF selection.

The SMF (Session Management Function) can support, together with the AMF, customized mobility management schemes such as "Mobile Initiated Connection Only" (MICO) or RAN enhancements like "RRC Inactive" state. It performs the following main tasks:

- Session Management;
- UE IP address allocation and management;
- Selection and control of UPF;
- Configures traffic steering at UPF to route traffic to proper destination;
- Control part of policy enforcement and QoS;
- Downlink Data Notification.

The UPF (User Plane Function) performs the following main tasks:

- Anchor point for Intra-/Inter-RAT mobility (when applicable);
- External PDU session point of interconnect to Data Network;
- Packet routing & forwarding;
- Packet inspection and User plane part of Policy rule enforcement;
- Traffic usage reporting;
- Uplink classifier to support routing traffic flows to a data network;
- Branching point to support multi-homed PDU session;
- QoS handling for user plane, e.g. packet filtering, gating, UL/DL rate enforcement;
- Uplink Traffic verification (SDF to QoS flow mapping);
- Downlink packet buffering and downlink data notification triggering.

The other main Network Functions are:

- The "Network Repository Function" (NRF): it provides support for NF services management including registration, deregistration, authorization and discovery.

- The "Network Exposure Function" (NEF): it provides external exposure of the capabilities of the network functions. External exposure can be categorized as Monitoring capability, Provisioning capability, Application influence of traffic routing and Policy/Charging capability.

- The "Unified Data Management" (UDM): the 5GC supports Data Storage architecture for Compute and Storage separation. The Unified Data Repository (UDR) is the master database. The Unstructured Data Storage Function (UDSF) is introduced to store dynamic state data.

5.5.2.2 Specificities of the 5G Core Network and associated NFs

5.5.2.2.1 Local hosting of services and Edge Computing

As to support the very different types of services, 5G uses "Service Hosting Environment", which is a service platform located inside of an operator's network. It offers Hosted Services closer to the end user to meet specific requirement like low latency, low bandwidth pressure. These Hosted Services contain applications provided by operators and/or trusted third parties. It also supports flexible user plane routing, so that user plane paths can be selected or changed to improve the user experience or balance the network load, when a UE or application changes location during an active communication.

Local hosting of services is provided in particular through the Edge Computing capability. Edge computing is the possibility for an operator and/or a 3rd party to execute the services close to the UE's access point of attachment. This reduces the end-to-end latency and the load on the transport network.

To enable this, the 5GCN selects a UPF close to the UE and executes the traffic steering from the UPF to the local Data Network via a N6 interface. Some of the Edge computing related features are:

- Support concurrent (e.g. local and central) access to a data network, an architectural enabler for low-latency services.
- Application influence on traffic routing.
- Support of URLLC (Ultra Reliable Low-Latency) services.
- Support for different Session and Service Continuity modes.
- Support of Local Area Data Network.

5.5.2.2.2 Network slicing

A network slice is a (set of) element(s) of the network specialised in the provisioning of a certain (type of) service(s). For example, there can be one network slice for IoT, another one for supporting "classic" UEs and another one for V2X. More generally, there can be different requirements on functionality (e.g., priority, policy control), differences in performance requirements (e.g., latency, mobility and data rates), or they can serve only specific types of users (e.g., MPS users, Public Safety users, corporate customers, roamers, or hosting an MVNO). The different slices can be used simultaneously.

End-to-end Network slicing is a major characteristic of the 5G System. It is supported by every deployed PLMN to the extent necessary to interoperate with other PLMNs, e.g. the IoT slice from operator A can interconnect directly with the

IoT slice of operator B. Based on business scenario, the operator can decide how many network slices to deploy and what functions/features to share across multiple slices.

The characteristics of each slice are defined in terms of QoS, bit rate, latency, etc. For a given slice, these characteristics are either predefined in the 3GPP Standard or are operator-defined. There are three types of predefined slices: type 1 is dedicated to the support of eMBB, type 2 is for URLLC and type 3 is for MIoT support. These predefinitions allow inter-PLMN operation with reduced coordination effort between operators. As for the operator-defined slices, they enable more differentiation among network slices.

A dedicated NF is introduced for slices handling: the "Network Slice Selection Function" (NSSF), which enables the selection of the appropriate slice(s). The UEs may use multiple Network Slices simultaneously. The Network Slice Selection policies in the UE links applications to Network slices.

Network slicing also supports roaming scenarios. Finally, Network Slicing Interworking with EPS (with or without 4G's Dedicated Core Networks Selection Mechanism (e)DECOR) is possible.

5.5.2.2.3 Unified access control

When congestion occurs in the 5G System, different criteria are used to determine which access attempt should be allowed or blocked. These criteria depend on operator policies, deployment scenarios, subscriber profiles, and available services. The 5G system provides a single Unified Access Control, where operators control access attempts based on these criteria associated with the so-called "Access Identities and Access Categories".

The Unified Access Control allows for categorizing each UE access attempt into one Access Category. The network can restrict the UE access on a per-access category basis.

The 5GS also offers Mobility Management Congestion Control, DNN-based Congestion Control and network slice-based Congestion Control.

5.5.2.2.4 Support of 3GPP and non-3GPP access

The 5G system supports the 3GPP access technologies, including one or more of 5G's NR and 4G's E-UTRA. It can also support non-3GPP access technologies, even non-trusted ones.

For optimization and resource efficiency, the 5G system can select the most appropriate 3GPP or non-3GPP access technology for a service, potentially allowing multiple access technologies to be used simultaneously for one or more services active on a UE. Seamless mobility among different access is also supported.

The NF called "Authentication Server Function "(AUSF) enables a unified framework for 3GPP and non-3GPP accesses.

When it is registered via both 3GPP and non-3GPP access, the UE is identified by a single 5G Globally Unique Temporary Identifier (5G-GUTI).

5.5.2.2.5 Policy framework and QoS support

A policy framework is supported for Session, Access and Mobility control, QoS and charging enforcement, as well as policy provisioning in the UE.

The UE uses two mechanisms linked to QoS and policy:

- The UE Route Selection Policy (URSP), as to determine if a detected application can be associated with an established PDU Session, can be offloaded to non-3GPP access outside a PDU Session, or can trigger the establishment of a new PDU Session.

- The Access Network Discovery & Selection Policy (ANDSP), to select non-3GPP accesses.

URSP and ANDSP are delivered from the network's Policy Control Function (PCF) to the UE through signalling.

In the network, the NF "Network Data Analytics Function" (NWDAF) is introduced to provide data analytics support, i.e. to provide the load of each network slice.

As for QoS, the system defines a flow-based QoS framework, with two basic modes: with or without QoS-dedicated signalling. For the option without any specific QoS signalling flows, the standardized packet marking is applied, which informs the QoS enforcement functions what QoS to provide. The option with QoS-dedicated negotiation offers more flexibility and QoS support for finer granularity. Also, a new QoS type is introduced: "Reflective QoS", where the UE requests for the uplink traffic the same QoS rules as the ones it received for the downlink. In this mode, symmetric QoS differentiation over downlink and uplink is supported with minimal control plane signalling.

5.5.2.2.6 Network capability exposure

The Service Exposure and Enablement Support (SEES) and (enhanced) Flexible Mobile Service Steering ((e)FMSS) features allow the operator to expose network capabilities (e.g. QoS policy) to third party ISPs/ICPs.

In 5G, new network capabilities are exposed to the third-party e.g. to allow the third-party to customize a dedicated network slice for diverse use cases; to allow the third-party to manage a trusted third-party application in a Service Hosting Environment to improve user experience, and efficiently utilize backhaul and application resources.

About Network capability exposure, see also the clause on "Northbound APIs".

5.5.2.2.7 Other specific services

The following services are also supported by 5GS:

- Short Message Service (SMS). This is supported by "SMS over NAS" (including over non-3GPP access).
- IP-Multimedia Subsystem (IMS) and its services, although, this might not be available in all initial 5G deployments. If IMS services are invoked by a UE connected to an IMS-less 5GS, this triggers a network-based handover towards an appropriate RAT and related EPS. This applies also to the support of IMS emergency services.
- Multi-Operator Core Network (MOCN), in which a RAN is shared by multiple core networks.
- Public Warning System (PWS). This is supported by either using Service-based interfaces between the Cell Broadcast Centre (CBC) Function (CBCF) and the AMF, or using an interworking function between the CBC and the AMF.
- Multimedia Priority Services (MPS). They are supported by MPS-specific exemptions for 5GS mobility management and 5GS session management.
- Mission Critical Services (MCS). They are supported by having a subscription in place for both 5G QoS profile and the necessary policies. Some standardized QoS characteristics are defined for MCS.
- PS Data Off. The 5G's "PS data off" functionality is backward-compatible and provides Control Plane Load Control, Congestion and Overload control. This includes AMF Load balancing, AMF Load-rebalancing, TNL (Transport Network Layer between 5GC and 5G-AN) Load (re-)balancing, as well as AMF Overload Control, SMF Overload Control.

It has to be noted that, in 5GS Phase 1, Location Services are optional and restricted to regulatory (emergency) services.

5.5.2.2.8 Other 5G specificities

Steering of roaming of UEs in a VPLMN allows the HPLMN to provide and update a list of preferred PLMN/access technology combinations to the UE when roaming in a VPLMN. This is achieved using the configuration in the USIM or providing it via NAS signalling.

Interworking between the 5GS and 4G is supported, where 4G is an E-UTRAN connected to the EPC. This is enabled by evolved Packet Data Gateways (ePDGs) connected to the EPC and the 5G System.

Security Edge Protection Proxies (SEPP) are used to secure and hide the topology for inter-PLMN interconnection.

5.5.2.3 CN protocols

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750025	**CT aspects of 5G System - Phase 1**	5GS_Ph1-CT	ct	CP-181081	Song Yue (China Mobile)

Summary based on the inputs provided by China Mobile, Nokia, Ericsson, Huawei in SP-180595.

The services provided by 5G NFs are designed as a set of APIs based on the following protocol stack:

- the transport layer protocol is TCP as specified in IETF RFC 793;
- transport layer security protection is supported with TLS;
- the application layer protocol is HTTP/2 as specified in IETF RFC 7540;
- the serialization protocol is JSON as specified in IETF RFC 8259;
- the OpenAPI 3.0.0 is adopted as the Interface Definition Language.

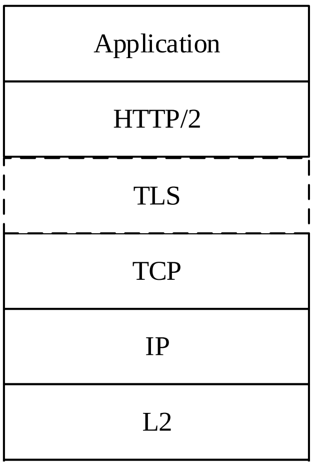


Figure 5.4.6-1: Service Based Interface Protocol Stack

To reduce the coupling between clients and servers, the RESTful framework is applied for the APIs design as follows:

1) the REST-style service operations implement the Level 2 of the Richardson maturity model;

2) Level 3 (HATEOAS) of the Richardson maturity model is optional.

OAuth2 (as specified in IETF RFC 6749) is used for authorization of NF service access, with the NRF acting as the Authorization Server.

The Service Based Interfaces also support procedures for overload control and message prioritisation.

PFCP (Packet Forwarding Control Protocol) is used over the N4 interface for the separation of Control Plane and User Plane in the 5GC. This is the same protocol as supported for CUPS in EPC, with a few extensions to support all the 5GC requirements (e.g. Ethernet traffic, QoS flows).

GTPv2 is used over the N26 interface for mobility between EPC and the 5GC. This is the same protocol as supported over S10 in EPC, with minimal extensions to support 5GS requirements (e.g. 5GS TAI, gNB ID).

For 5G network interworking with external DNs (i.e. N6 interface), those protocols specified in TS 29.061 (IP, non-IP, DHCP, RADIUS and Diameter protocols) are still applicable between the SMF/UPF and the external DNs with possible adaptation. In addition, the Ethernet traffic is also supported by the SMF/UPF for interworking with external DN.

References

The main protocols of the 5G Core Network are specified in:

TS 24.501	Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3
TS 24.502	Access to the 5G Core Network (5GCN) via non-3GPP access networks; Stage 3
TS 24.526	5G System -Phase 1, UE policy; CT WG1 Aspects
TS 23.527	5G System; Restoration Procedures; Stage 2
TS 29.500	5G System; Technical Realization of Service Based Architecture; Stage 3
TS 29.501	5G System; Principles and Guidelines for Services Definition; Stage 3
TS 29.502	5G System; Session Management Services; Stage 3
TS 29.503	5G System; Unified Data Management Services; Stage 3
TS 29.504	5G System; Unified Data Repository Services; Stage 3
TS 29.505	5G System; Usage of the Unified Data Repository services for Subscription Data; Stage 3

TS 29.507	5G System; Access and Mobility Policy Control Service; Stage 3
TS 29.508	5G System; Session Management Event Exposure Service; Stage 3
TS 29.509	5G System; Authentication Server Services; Stage 3
TS 29.510	5G System; Network Function Repository Services; Stage 3
TS 29.511	5G System; Equipment Identity Register 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 29.514	5G System; Policy Authorization Service; Stage 3
TS 29.518	5G System; Access and Mobility Management Services; Stage 3
TS 29.519	5G System; Usage of the Unified Data Repository Service for Policy Data, Application Data and Structured Data for Exposure; Stage 3
TS 29.520	5G System; Network Data Analytics Services; Stage 3
TS 29.521	5G System; Binding Support Management Service; Stage 3
TS 29.522	5G System; Network Exposure Function Northbound APIs; Stage 3
TS 29.531	5G System; Network Slice Selection Services; Stage 3
TS 29.540	5G System; SMS Services; Stage 3
TS 29.551	5G System; Packet Flow Description Management Service; Stage 3
TS 29.554	5G System; Background Data Transfer Policy Control Service; Stage 3
TS 29.561	5G System; Interworking between 5G Network and external Data Networks; Stage 3
TS 29.571	5G System; Common Data Types for Service Based Interfaces; Stage 3
TS 29.572	5G System; Location Management Services; Stage 3
TS 29.594	5G System; Spending Limit Control Service; Stage 3

The corresponding Security aspects of 5G System are defined by SA3 (UID: 750016). The work also serves as the basis for related charging and management, i.e., Data Charging in 5G System Architecture Phase 1 (UID: 780035), Service Based Interface for 5G Charging (UID: 780034), Management and orchestration of 5G networks and network slicing (UID: 760066).

5.5.3 The 5G Access Network

5.5.3.1 Introduction

The figure below, extracted from TS 38.401, shows the overall architecture of the Access Network:

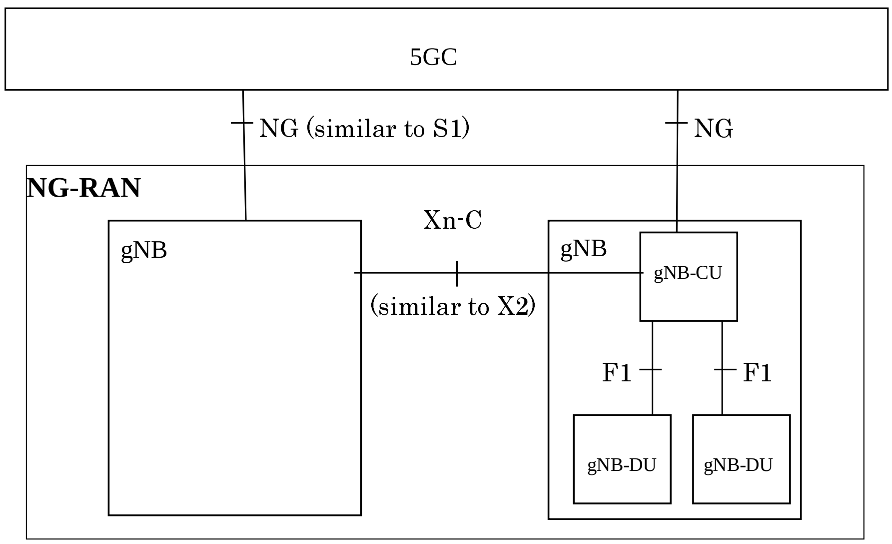


Figure 5.5.3.1-1: Overall NG-RAN architecture

The NG-RAN consists of a set of gNBs connected to the 5GC through the NG interface, based on (and very similar to) the LTE's S1 interface.

The gNB (5G Node B) can be connected to another gNB through the Xn interface, based on (and very similar to) the LTE's X2 interface. The gNB may be further split into a gNB-Central Unit (gNB-CU) and one or more gNB-

Distributed Unit(s) (gNB-DU), linked by the F1 interface. One gNB-DU is connected to only one gNB-CU. See also the section on the AN interfaces.

The gNB performs the following tasks:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
- IP header compression, encryption and integrity protection of data;
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE;
- Routing of User Plane data towards UPF(s);
- Routing of Control Plane information towards AMF;
- Connection setup and release;
- Scheduling and transmission of paging messages;
- Scheduling and transmission of system broadcast information (originated from the AMF or O&M);
- Measurement and measurement reporting configuration for mobility and scheduling;
- Transport level packet marking in the uplink;
- Session Management;
- Support of Network Slicing;
- QoS Flow management and mapping to data radio bearers;
- Support of UEs in RRC_INACTIVE state;
- Distribution function for NAS messages;
- Radio access network sharing;
- Dual Connectivity;
- Tight interworking between NR and E-UTRA.

5.5.3.2 Overview of the AN Control Plane

The figure below shows the protocol stack for the control plane, where:

- The PHY layer (physical layer) is described in clause 5.5.5. Its role is the modulation and demodulation of the signal on the radio interface;

- The PDCP, RLC and MAC sublayers (terminated in gNB on the network side) perform the services listed in the clause on "Layer 2 related aspects";

- The RRC (terminated in gNB on the network side) performs the services listed in the clause on "RRC related aspects";

- The NAS (Non-Access Stratum) control protocol (terminated in AMF on the network side) refers to all the aspects and protocols not linked to the Access Network and transported "transparently" by the Access Network, i.e. without interpretation. These are the services listed in TS 23.501 such as authentication, mobility management and security control.

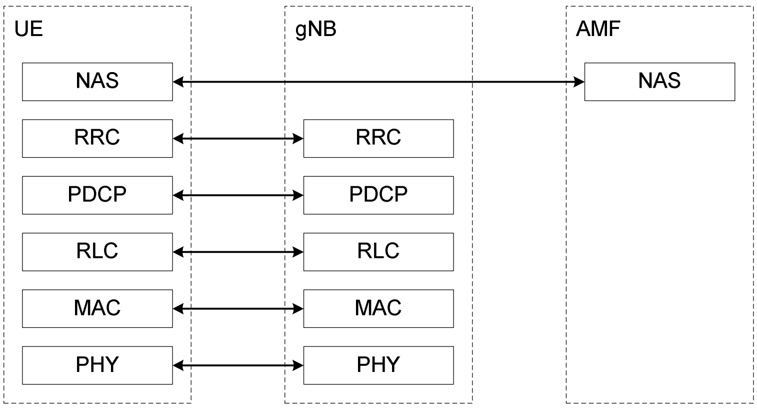


Figure 5.5.3.2-1: Control Plane Protocol Stack

5.5.3.3 Overview of the AN User Plane

The figure below shows the protocol stack for the user plane, where SDAP, PDCP, RLC and MAC sublayers (terminated in gNB on the network side) perform the services listed in the clause on " Layer 2 related aspects".

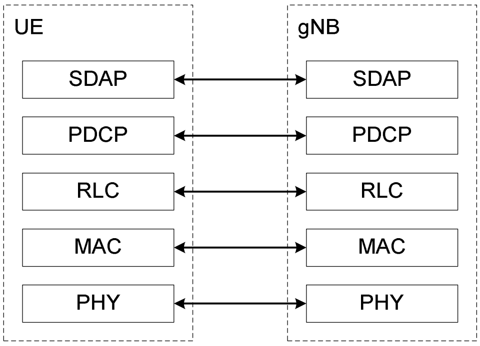


Figure 5.5.3.3-1: User Plane Protocol Stack

5.5.3.4 The higher layers of the AN

5.5.3.4.1 Layer 2 related aspects: MAC, RLC, PDCP user plane, PCP control plane, and SDAP

The main services and functions of the MAC (Medium Access Control) sublayer include:

- Mapping between logical channels and transport channels;
- Multiplexing/demultiplexing of MAC SDUs belonging to one or different logical channels into/from Transport Blocks (TB) delivered to/from the physical layer on transport channels;
- Scheduling information reporting;
- Error correction through Hybrid Automatic Repeat reQuest (HARQ), one HARQ entity per cell in case of Carrier Aggregation;
- Priority handling between UEs by means of dynamic scheduling;
- Priority handling between logical channels of one UE by means of logical channel prioritisation;
- Padding.

The main services and functions of the RLC (Radio Link Control) sublayer depend on the transmission mode and include:

- Transfer of upper layer PDUs;
- Sequence numbering independent of the one in PDCP [only for Unacknowledged Mode (UM) and Acknowledged Mode (AM), not for Transparent Mode (TM)];
- Error Correction through ARQ (AM only);
- Segmentation (AM and UM) and re-segmentation (AM only) of RLC SDUs;
- Reassembly of SDU (AM and UM);
- Duplicate Detection (AM only);
- RLC SDU discard (AM and UM);
- RLC re-establishment;
- Protocol error detection (AM only).

The main services and functions of the PDCP (Packet Data Convergence Protocol) sublayer for the user plane include:

- Sequence Numbering;
- Header compression and decompression: ROHC only;
- Transfer of user data;
- Reordering and duplicate detection;
- PDCP PDU routing (in case of split bearers);
- Retransmission of PDCP SDUs;
- Ciphering, deciphering;
- PDCP SDU discard;
- PDCP re-establishment and data recovery for RLC AM;
- Duplication of PDCP PDUs.

The main services and functions of the PDCP sublayer for the control plane include:

- Sequence Numbering;
- Ciphering, deciphering and integrity protection;
- Transfer of control plane data;
- Reordering and duplicate detection;
- Duplication of PDCP PDUs.

The main services and functions of SDAP (Service Data Adaptation Protocol) include:

- Mapping between a QoS flow and a data radio bearer;
- Marking QoS flow ID (QFI) in both DL and UL packets.

5.5.3.4.2 RRC related aspects

The main services and functions of the RRC (Radio Resource Control) sublayer include:

- Broadcast of System Information related to AS and NAS;
- Paging initiated by 5GC or NG-RAN
- Establishment, maintenance and release of an RRC connection between the UE and NG-RAN including:
- Addition, modification and release of carrier aggregation;
- Addition, modification and release of Dual Connectivity in NR or between E-UTRA and NR.
- Security functions including key management;
- Establishment, configuration, maintenance and release of Signalling Radio Bearers (SRBs) and Data Radio Bearers (DRBs);
- Mobility functions including:
- Handover and context transfer;
- UE cell selection and reselection and control of cell selection and reselection;
- Inter-RAT mobility.
- QoS management functions;
- UE measurement reporting and control of the reporting;
- Detection of and recovery from radio link failure;
- NAS message transfer to/from NAS from/to UE.

5.5.3.5 The Access Network interfaces

5.5.3.5.1 Overview

The different AN interfaces are depicted above. These are Xn, NG and F1.

Each interface includes its own management handling: setup, reset, error indication, removal (for Xn only).

The other functions transiting on each interface are detailed below.

5.5.3.5.2 The Xn and X2 interfaces

The 5G's Xn interface is strongly related to its equivalent 4G interface, the X2 interface. The X2 is updated to include the following added functions:

- The E-UTRA-NR Dual Connectivity function. This function allows the eNB to request another en-gNB to provide radio resources for a certain UE while keeping responsibility for that UE.

- Secondary RAT Data Usage Report function. This function allows eNB to get the uplink and downlink data volumes for the Secondary RAT on a per E-RAB basis.

The XnAP protocol provides the following functions:

- Xn configuration data update function. This function allows two NG-RAN nodes to update application level data at any time.

- Handover preparation function. This function allows the exchange of information between source and target NG-RAN nodes in order to initiate the handover of a certain UE to the target.

- Handover cancellation function. This function allows informing an already prepared target NG-RAN node that a prepared handover will not take place. It allows releasing the resources allocated during a preparation.
- Retrieve UE Context function. The Retrieve UE context function is used for a NG-RAN node to retrieve UE context from another one.
- RAN Paging function. The RAN paging function allows a NG-RAN node to initiate the paging for a UE in the inactive state.
- Data Forwarding control function. The data forwarding control function allows establishing and releasing transport bearers between source and target NG-RAN nodes for data forwarding.
- Energy saving function. This function enables decreasing energy consumption by indication of cell activation/deactivation over the Xn interface.

5.5.3.5.3 The NG and S1 interfaces

The 5G's NG interface is strongly related to its equivalent 4G interface, the S1 interface. The S1 is updated to include the following added function: the Report of Secondary RAT data volumes function. The functionality enables the eNB to report Secondary RAT data usage information in case of EN-DC.

The NGAP protocol provides the following functions:

- Paging function. The paging function supports the sending of paging requests to the NG-RAN nodes involved in the paging area e.g. the NG-RAN nodes of the TA(s) the UE is registered.
- UE Context Management function. The UE Context management function allows the AMF to establish, modify or release a UE Context in the AMF and the NG-RAN node e.g. to support user individual signalling on NG.
- Mobility Management function. The mobility function for UEs in ECM-CONNECTED includes the intra-system handover function to support mobility within NG-RAN and inter-system handover function to support mobility from/to EPS system. It comprises the preparation, execution and completion of handover via the NG interface.
- PDU Session Management function. The PDU Session function is responsible for establishing, modifying and releasing the involved PDU sessions NG-RAN resources for user data transport once a UE context is available in the NG-RAN node.
- NAS Transport function. The NAS Signalling Transport function provides means to transport or reroute a NAS message (e.g. for NAS mobility management) for a specific UE over the NG interface.
- NAS Node Selection function. The interconnection of NG-RAN nodes to multiple AMFs is supported in the 5GS architecture. Therefore, a NAS node selection function is located in the NG-RAN node to determine the AMF association of the UE, based on the UE's temporary identifier, which was assigned to the UE by the AMF. When the UE's temporary identifier has not been yet assigned or is no longer valid the NG-RAN node may instead take into account slicing information to determine the AMF. This functionality is located in the NG-RAN node and enables proper routing via the NG interface. On NG, no specific procedure corresponds to the NAS Node Selection Function.
- Warning Message Transmission function. The warning message transmission function provides means to transfer warning messages via NG interface or cancel ongoing broadcast of warning messages. It also provides the capability for the NG-RAN to inform the AMF that ongoing PWS operation has failed for one or more areas, or that one or more areas may be reloaded by the CBC.
- Configuration Transfer function. The Configuration Transfer function is a generic mechanism that allows the request and transfer of RAN configuration information (e.g. SON information) between two RAN nodes via the core network.
- Trace function. Trace function provides means to control trace sessions in the NG-RAN node.
- AMF Management function. The AMF management function supports AMF planned removal and AMF auto-recovery.
- Multiple TNL Associations Support Function. When there are multiple TNL associations between a NG-RAN node and an AMF, the NG-RAN node selects the TNL association for NGAP signalling based on the usage and

the weight factor of each TNL association received from the AMF, and uses the TNL association. If an AMF releases a TNL association, the NG-RAN node selects a new one

- AMF Load Balancing function. The NG interface supports the indication by the AMF of its relative capacity to the NG-RAN node in order to achieve load-balanced AMFs within the pool area.

- Location Reporting function. This function enables the AMF to request the NG-RAN node to report the UE's current location, or the UE's last known location with timestamp, or the UE's presence in a configured area of interest.

- AMF Re-allocation function. This function allows to redirect an initial connection request issued by an NG-RAN node from an initial AMF towards a target AMF selected by 5GC. In this case the NG-RAN node initiates an Initial UE Message procedure over one NG interface instance and receives the first downlink message to close the UE-associated logical connection over a different NG interface instance.

5.5.3.5.4 The F1 interface

The F1 interface is specified for the case where the en-gNB is further subdivided into a gNB-CU and a gNB-DU logical nodes. In this case, the gNB-CU hosts the RRC and PDCP protocols, while the gNB-DU hosts the RLC, MAC and PHY functions.

The F1AP protocol provides the following functions:

- System Information management function;
- F1 UE context management function;
- RRC message transfer function;
- Paging function.

5.5.4 Radio Physical layer aspects

5.5.4.1 Numerologies, waveform and frame structure

Similar to LTE, OFDM with Cyclic Prefix (CP) is used as the downlink (DL) waveform for NR. In contrast to LTE, OFDM can also be used in the NR uplink (UL) direction. As a complement waveform with lower peak-to-average power ratio (PAPR) to improve UL coverage, DFT-s-OFDM (OFDM with Discrete Fourier Transform precoding) can be used in the uplink although limited to single-layer transmission only.

To cope with various deployment scenarios, NR supports a wide range of carrier frequencies (within two possible ranges) and channel bandwidths, as shown in the table below.

Table 5.5.4.1-1: NR channel bandwidth

Frequency range	Frequency range	Supported channel bandwidth [MHz]
FR1	410 MHz – 7125 MHz	5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 90, 100
FR2	24250 MHz – 52600 MHz	50, 100, 200, 400

To allow for such a flexibility, NR uses a flexible frame structure, with different Subcarrier Spacings (SCS). The SCS is the distance between the centres of two consecutive subcarriers, and the possible values for SCS are (in kHz): 15; 30; 60; 120 and 240. This is referred to as "multiple numerologies".

A consecutive series of 12 subcarriers forms one Resource Block (RB). An NR channel bandwidth consists of a number of RBs. A Resource Element (RE) is defined as a unit of one subcarrier (frequency domain) and one OFDM symbol (time domain).

As for the time domain, it is divided in 10ms radio frames, each on consisting in 10 subframes of 1ms each, as shown in the picture below.

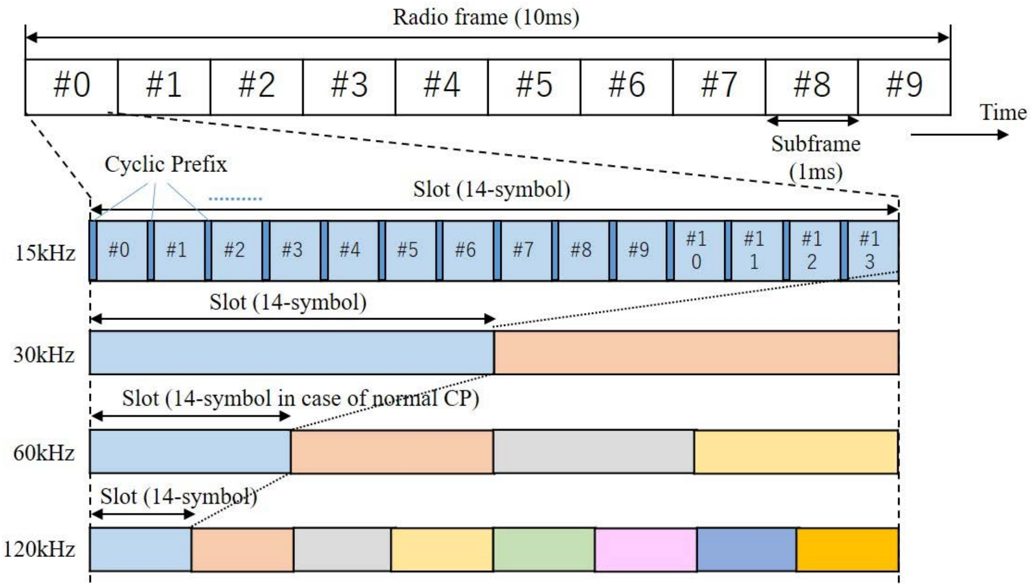


Figure 5.5.4.1-1: Frame structure in NR

In turn, each subframe consists of 1/2/4/8/16 slots -shown in different colors- depending on the selected SCS/numerology. The figure shows the cases of SCS values of 15; 30; 60 and 120 KHz, while the table below provides the full list of possible numerologies in NR. As shown in the figure for the 15 kHz case, each slot consists of 14 OFDM symbols (independently of the SCS) preceded by a cyclic prefix (CP).

Table 5.5.4.1-2: Multiple numerologies in NR

Cyclic Prefix	subcarrier spacing (SCS) [kHz]	Number of subframes per radio frame	Number of slots per subframe	Number of OFDM symbols per slot	Applicable frequency range
normal	15	10	1	14	FR1
normal	30	10	2	14	FR1
normal	60	10	4	14	FR1 and FR2
extended	60	10	4	12	FR1 and FR2
normal	120	10	8	14	FR2
normal	240	10	16	14	FR2

Note: Additional specific numerologies are defined for PRACH, as described in Section 5.5.4.3.

Note that, for the 60 kHz SCS, an extended CP is possible. The extended CP is approximately four times longer than the normal CP and is used for cells having large delay spread. In this case, one slot consists of only 12 OFDM symbols.

The OFDM symbol duration and CP length are inversely proportional of the SCS. E.g. for 15 kHz SCS, the OFDM symbol duration is approximately 66.6 µs and the CP length is approximately 4.7 µs. When the SCS is doubled, i.e. 30 kHz, the OFDM and CP lengths are approximately devided by two compared to the 15kHz SCS.

NR supports both FDD and TDD operation with the same frame structure. In the case of TDD, and as to allow for flexible traffic adaptation, each OFDM symbol in a slot can be classified as 'downlink', 'uplink' or 'flexible' (i.e. either downlink or uplink). This can be configured semi-statically or it can change dynamically as part of the scheduling decision.

Transmissions are usually carried out over one slot. In specific cases, transmissions can be carried out over only a fraction of a slot, with the minimum set to only two symbols. Such very short transmissions mainly target usage cases requiring low latency, such as some URLLC (Ultra Reliable, Low Latency) services.

5.5.4.2 Physical Channels and Signals in NR

Table 5.5.4.2-1 shows the physical channels defined in NR and the corresponding modulation and channel coding schemes.

Table 5.5.4.2-1: Physical channels in NR

DL/UL	Physical channel	Physical channel name	Modulation	Channel coding
DL	PDSCH	Physical Downlink Shared Channel	QPSK, 16QAM, 64QAM, 256QAM	LDPC (Low Density Parity Check) coding
DL	PBCH	Physical Broadcast Channel	QPSK	Polar coding
DL	PDCCH	Physical Downlink Control Channel	QPSK	Polar coding
UL	PUSCH	Physical Uplink Shared Channel	QPSK, 16QAM, 64QAM, 256QAM, pi/2 BPSK when DFT-s-OFDM is selected**	LDPC coding for data, see Table 5.5.4.6-1 for UCI
UL	PUCCH	Physical Uplink Control Channel	pi/2-BPSK, BPSK, QPSK depending on PUCCH format and information bit size	see Table 5.5.4.6-1 for UCI
UL	PRACH	Physical Random Access Channel	N/A*	N/A*

*: see Section 5.5.4.3.

**: DFT-s-OFDM is used to further reduce the peak-to-average power ratio (PAPR) of the UL transmission

The way these different channels are accessed and used is presented in the following sections.

The different physical signals defined in NR are:

Table 5.5.4.2-2: Physical signals in NR

DL/UL	Physical signal	Physical signal name
DL/UL	DM-RS	Demodulation reference signals
DL/UL	PT-RS	Phase-tracking reference signals
DL	CSI-RS	Channel-state information reference signal
DL	PSS	Primary synchronization signal
DL	SSS	Secondary synchronization signal
UL	SRS	Sounding reference signal

The way these different Reference Signals are used is also presented below.

5.5.4.3 Initial access and mobility

The mobile phones synchronise to the mobile network by "listening" to the Primary and Secondary Synchronization Signals (PSS and SSS), shown in respectively blue and orange on the figure below (note that the figure shows an "NR-" prefix which is omitted in the text). The vertical separations are the Ressource Blocks (RB), as defined in the previous section, i.e. a group of 12 subcarriers. The horizontal separations are the OFDM symbols. Four OFDM symbols together with 20 RBs form a so-called "SS/PBCH (Synchronization Signals/ Physical Broadcast Channel) block".

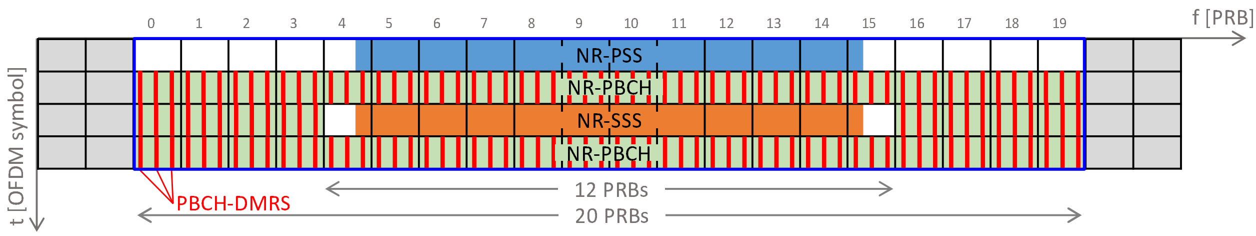


Figure 5.5.4.3-1: a SS/PBCH block

The PSS and NSS are transmitted over 127 subcarriers, i.e. about 10.5 RBs. (They are designed to carry the Physical Cell ID (PCID) selected from 1008 candidates.)

Once synchronised with the PSS and NSS, the mobiles can retrieve the full SS/PBCH structure, and thus "listen" to the Physical Broadcast Channel (PBCH) and its associated Demodulation reference signals (DM-RS).

The PBCH carries only the minimum system information necessary for initial access, such as system frame number (SFN), initial configurations for PDCCH, PDSCH and DM-RS, and information required to determine the frame timing such as SS/PBCH block index and half-frame index. These are referred to as "System Information Block 1 (SIB1)".

One or multiple SS/PBCH blocks can be transmitted by using transmission beamforming within a half frame, with configurable periodicity from 5 ms to 160 ms. The maximum number of SS/PBCH blocks and the applicable subcarrier spacing for SS/PBCH block transmission are dependent on the frequency range, as shown in Table 5.5.4.3-1. They can be identical or different from the subcarrier spacing used for other DL transmissions.

Table 5.5.4.3-1: Maximum number of SS/PBCH block transmissions and applicable subcarrier spacing

Frequency Range	Applicable SCS [kHz]	Maximum number of SS/PBCH blocks
FR1 (below 3 GHz for FDD, below 2.4 GHz for TDD)	15 or 30	4
FR1 (above 3 GHz for FDD, above 2.4 GHz for TDD)	15 or 30	8
FR2	120 or 240	64

SIB1 and other system information (SIB2 and onwards) are carried by PDSCH which is scheduled by PDCCH. SIB1 contains necessary information to perform random access procedure for initial access.

Note: PDCCH/PDSCH for SIB1 can be received by the UE before RRC connection since they are based on default configuration (predefined and based on MIB).

Paging message is carried by PDSCH which is scheduled by PDCCH. Numerology used for SIB1 transmission on a NR cell is indicated in master information block (MIB) carried by PBCH and is commonly applied to transmissions for other system information (SIB2 and onwards), Paging, Msg.2 ("Message 2", as explained below) and Msg.4 transmissions on the same cell.

For random access in NR, a four-step procedure consisting of Msg.1, Msg.2, Msg.3 and Msg.4 is defined. For Msg.1 i.e., PRACH transmission in random access, NR supports two types of PRACH sequences as the preamble sequence:

- one is based on long Zadoff-Chu (ZC) sequences of length 839 only applicable to FR1 and
- another is based on short ZC sequences of length 139 applicable to both FR1 and FR2.

Four different PRACH preamble formats based on the long ZC sequence are defined and corresponding numerology is defined for each PRACH preamble format as shown in Table 5.5.4.3-2.

In addition, nine different PRACH preamble formats based on the short ZC sequence are defined and corresponding numerology is defined for each PRACH preamble format as shown in Table 5.5.4.3-3.

Msg.2 and Msg.4 for random access are carried by PDSCH that are scheduled by PDCCH.

Msg.3 for random access is carried by PUSCH which is scheduled by random access response (RAR) in Msg.2 or PDCCH in case of retransmission.

Table 5.5.4.3-2: PRACH preamble formats based on long ZC sequence

PRACH preamble format	SCS [kHz]	CP length [ms]	PRACH symbol length [ms]	Gap length [ms]
0	1.25	0.1032	0.8006	0.0969
1	1.25	0.6849	0.8006*2	0.7162
2	1.25	0.1527	0.8006*4	0.9533
3	5	0.1032	0.2001*4	0.0969

Table 5.5.4.3-3: PRACH preamble formats based on short ZC sequence

PRACH preamble format	SCS [kHz]	CP length [ms] (in case of 15 kHz SCS)	PRACH symbol length [ms] (in case of 15 kHz SCS)	Gap length [ms] (in case of 15 kHz SCS)
A1	15 or 30 as indicated in SIB1 for FR1, 60 or 120 as indicated in SIB1 for FR2	0.0094	0.0667*2	0
A2		0.0188	0.0667*4	0
A3		0.0281	0.0667*6	0
B1		0.0070	0.0667*2	0.0023
B2		0.0117	0.0667*4	0.0070
B3		0.0164	0.0667*6	0.0117
B4		0.0305	0.0667*12	0.0258
C0		0.0404	0.0667	0.0370
C2		0.0667	0.0667*4	0.0948

For mobility measurement, SS/PBCH block and/or CSI-RS can be utilized in NR. SS/PBCH block based reference signal received power (RSRP), reference signal received quality (RSRQ) and signal-to-noise and interference ratio (SINR) are defined, and CSI-RS based RSRP, RSRQ and SINR are also defined. For radio link monitoring (RLM), SS/PBCH block and/or CSI-RS can be utilized as RLM reference signal in NR. One or multiple SS/PBCH blocks and/or CSI-RS resources are configured to be monitored to evaluate whether the radio link is in-sync status (i.e., in good quality) or out-of-sync status.

5.5.4.4 MIMO aspects

Multiple-input and multiple-output (MIMO) is a key technology to improve the throughput. It uses multiple antenna both on the transmitter and on the receiver sides, as to enable multi-layer data transmission. NR supports multi-layer data transmission for a single UE (single-user MIMO) with a maximum of eight transmission layers for DL and four for UL. NR also supports multi-layer data transmission with multiple UEs on different layers (multi-user MIMO) with a maximum of twelve transmission layers for DL and UL transmission.

Reference Signals (RSs) are specified assuming multi-layer transmissions. For demodulation of date / control information for both uplink and downlink, demodulation RS (DM-RS) is supported. For measurement of channel state information of downlink, channel state information RS (CSI-RS) is supported. CSI-RS is also used for mobility measurement, measurement of gNB transmission beamforming, and frequency/time tracking. The CSI- RS used for the frequency/time tracking is named as tracking RS (TRS). In high frequency range, phase noise is a problem that degrades the transmission performance. Phase tracking reference signal (PT-RS) is supported for PDSCH and PUSCH to enable receiver to track the phase and mitigate the performance loss due to the phase noise. For uplink channel sounding, sounding RS (SRS) is supported.

For UL multi-layer data transmission, both codebook based and non-codebook based precoding is supported. In codebook based UL transmission, precoding matrix applied for PUSCH transmission is selected by gNB. In non-codebook based UL transmission, precoded multiple SRS are transmitted and then gNB selects the desired transmission layers for PUSCH based on the reception of the SRS.

Since NR supports multi beam operation where every signal/channel is transmitted on directional beam, beamforming is an important technique for achieving higher throughput and sufficient coverage especially in high frequency range. For DL transmission beamforming, a gNB applies transmission beamforming to SS/PBCH block and/or CSI-RS transmissions, and a UE measures reference signal received power on physical layer (L1-RSRP) on the configured SS/PBCH block and/or CSI-RS resource. The UE reports the SS/PBCH block or CSI-RS resource with the maximum L1-RSRP value as a L1-RSRP beam reporting. The gNB can decide gNB transmission beamforming for the UE based on the reported L1-RSRP. For PDCCH/PDSCH transmission, gNB informs UE that gNB transmission beamforming applied to a certain SS/PBCH block or CSI-RS resource is applied to the PDCCH/PDSCH transmission so that UE can apply a reception beamforming which fits into the gNB transmission beamforming. For UL transmission beamforming, two mechanisms are supported. In one of the mechanisms, UE transmits multiple SRS symbols with different UE transmission beamforming so that gNB can measure them and can identify the best UE transmission beamforming. In another mechanism, UE generates the UL transmission beamforming which is same as the DL reception beamforming used for SS/PBCH block or CSI-RS resource reception. In addition, beam failure recovery (BFR) is supported to achieve quick recovery from the beam failure. UE can identify the beam failure and informs gNB about the index of SS/PBCH block or CSI-RS resource as new candidate beam.

For DL channel state information (CSI) acquisition, NR supports two precoding matrix indicator (PMI) definitions, the type I and II codebooks providing different levels of CSI granularity.

5.5.4.5 PDCCH and PDSCH

PDCCH is used to carry Downlink Control Information (DCI), and following types of DCI are supported in NR.

- PDSCH assignments to convey TB(s) to a certain UE, including time/frequency-domain resource information
- PUSCH grants for a certain UE to transmit a TB, including time/frequency-domain resource information
- Slot format indication, where how each of symbols within a slot is indicated
- Pre-emption indication, which is used to inform UEs that there is no DL transmissions on the informed time/frequency-domain resources
- UL transmit power control (TPC)

Each device monitors a number of PDCCHs, typically once per slot although it is possible to configure more frequent monitoring to support traffic requiring very low latency. Upon detection of a valid PDCCH, the device follows downlink control information contained in the PDCCH, e.g., the scheduling decision so that the device receives PDSCH (or transmits PUSCH) accordingly.

The PDCCHs are transmitted in one or more control resource sets (CORESETs). A CORESET spans overone, two or three OFDM symbol(s) in time domain and over a configurable bandwidth in the frequency domain. This is needed in order to handle devices with different bandwidth capabilities and also beneficial from a forward-compatibility perspective. One control channel element (CCE) is defined as 6 resource element groups (REGs), where 1 REG is composed of 12 resource elements (REs). In a CORESET, a PDCCH with DM-RS can be mapped on one or more CCEs as shown in Figure 5.5.4.5-1. Different number of CCEs (aggregation level) provides different coding rate for the control channels.

There are different formats for DCI transmitted on a PDCCH as shown in Table 5.5.4.5-1. A UE monitors one or more PDCCH candidates for DCI with CRC scrambled by a certain RNTI in PDCCH common search space (CSS) set and/or UE-specific search space (USS) set. DCI format is distinguished by the PDCCH payload size and the RNTI scrambling the CRC.

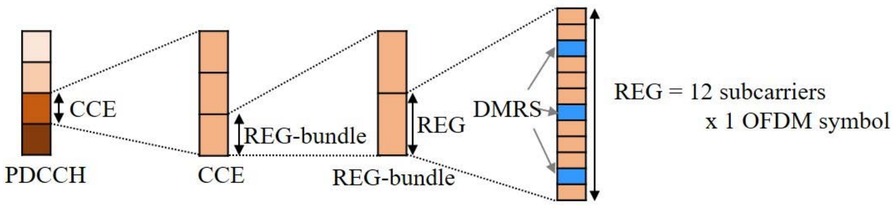


Figure 5.5.4.5-1: General description of NR PDCCH

Table 5.5.4.5-1: NR DCI formats

DCI format	RNTI	Notes
DCI format 0_0	RA-RNTI, TC-RNTI, C-RNTI, CS-RNTI	Monitored on CSS or USS Scheduling PUSCH
DCI format 0_1	C-RNTI, CS-RNTI	Monitored in USS Scheduling PUSCH
DCI format 1_0	SI-RNTI, RA-RNTI, P-RNTI, C-RNTI, CS-RNTI	Monitored in CSS or USS Scheduling PDSCH
DCI format 1_1	C-RNTI, CS-RNTI	Monitored in USS Scheduling PDSCH
DCI format 2_0	SFI-RNTI	Monitored in CSS Indicating slot format for slot(s)
DCI format 2_1	INT-RNTI	Monitored in CSS Indicating pre-emption of DL resource
DCI format 2_2	TPC-PUSCH-RNTI, TPC-PUCCH-RNTI	Monitored in CSS Group-TPC command for PUSCH/PUCCH
DCI format 2_3	TPC-SRS-RNTI	Monitored in CSS Group-command for SRS

PDSCH is used to transmit one or two transport blocks (TBs). A DCI in a PDCCH can assign a PDSCH transmission with DM-RS (and other RS if any). The PDSCH is decoded based on the information in the PDCCH, for example, time/frequency-domain resource, modulation, and layer. PDSCH transmissions are processed with durations from 2 to 14 symbols. The number of layers for PDSCH transmissions is 8. HARQ feedback/retransmission is supported for PDSCH transmissions as mentioned in Section 5.5.4.7.

5.5.4.6 PUCCH and PUSCH

PUCCH is used to carry Uplink Control Information (UCI), and following types of UCI are supported in NR:

- Hybrid automatic repeat request acknowledgement (HARQ-ACK): information to report whether the DL transmission of a TB is successful or not
- Scheduling request (SR): signal to request UL grant to gNB
- Channel state information (CSI): information represents channel condition between gNB and UE

The UCI can be carried by PUCCH or PUSCH. The channel coding schemes for different UCI sizes are shown in Table 5.5.4.2-2.

Table 5.5.4.6-1: Channel coding for uplink control information (UCI)

UCI size including CRC, if present	Channel code
1	Repetition code
2	Simplex code
3-11	Reed Muller code
>11	Polar code

For HARQ-ACK feedback of PDSCH with corresponding DCI, PUCCH resource set(s) containing one or more PUCCH resources are configured. One PUCCH resource is determined based on the UCI payload size and the PUCCH resource indicator field in the DL assignment. For HARQ-ACK feedback of PDSCH without corresponding DCI, SR, and CSI report, a PUCCH resource is configured for each. When multiple PUCCHs are overlapped fully or partially in time, the UCIs are multiplexed in a PUCCH. When a PUCCH is overlapped with a PUSCH fully or partially in time, the UCI is multiplexed (i.e. piggybacked) on the PUSCH.

Each PUCCH resource is configured with a PUCCH format. Various PUCCH formats are specified as in Figure 5.5.4.6-1. Each PUCCH format supports either durations of 1 to 2 symbols, or durations of 4 to 14 symbols. PUCCH formats 0/2 are called as short-PUCCH, which can deliver UCI by 1 or 2 symbols. PUCCH formats 0/2 are beneficial to reduce latency. PUCCH formats 1/3/4 are called as long-PUCCH, which can deliver UCI with any of 4 to 14 symbols. PUCCH formats 1/3/4 are adopted to improve coverage. The frequency/time-domain resources for PUCCH transmissions in NR are flexibly configurable. In PUCCH format 0/1/4, multiple PUCCH resources can be CDMed on the same time/frequency resource. A short-PUCCH can be TDMed with a long-PUCCH or a short PUCCH within a slot.

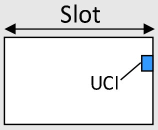
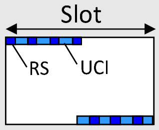
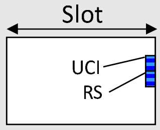
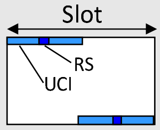
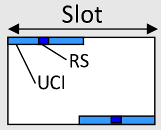
	PUCCH format 0	PUCCH format 1	PUCCH format 2	PUCCH format 3	PUCCH format 4
Conceptual figures					
Use-case	Short-PUCCH HARQ/SR 1-2 bits	Long-PUCCH HARQ/SR 1-2 bits	Short-PUCCH Any UCI > 2 bits	Long-PUCCH Any UCI > 2 bits	Long-PUCCH Any UCI > 2 bits
Duration	1 – 2 symbols	4 – 14 symbols	1 – 2 symbols	4 – 14 symbols	4 – 14 symbols
Starting symbol	Anywhere unless the PUCCH cross slot boundary				
RB size	1 RB	1 RB	1 – 16 RBs	1 – 16 RBs	1 RB
CDM capacity	12	36 or 84	1	1	2 or 4
Mux method	Cyclic shift	Cyclic shift + TD-OCC	-	-	FD-OCC
Coding scheme	-	-	Read-Muller for up to 11 bits, Polar for more than 11 bits		
Note	RS-less format	LTE PF1 analogy	CP-OFDM	LTE PF4 analogy	LTE PF5 analogy

Figure 5.5.4.6-1: NR PUCCH formats

PUSCH is used to transmit one TB. A DCI in a PDCCH can schedule a PUSCH transmission with DM-RS (and other RS if any). The PUSCH is transmitted based on the information in the PDCCH, for example, time/frequency-domain resource including frequency-hopping, modulation, and layer. The number of layers for PDSCH transmissions is 4. HARQ retransmission is supported for PUSCH transmissions as mentioned in Section 5.5.4.7.

5.5.4.7 Scheduling/HARQ

DCI formats 0_0/0_1 and 1_0/1_1 schedule PUSCH and PDSCH, respectively. For each DCI format, frequency-domain and time-domain resource allocation fields are included. For frequency-domain resource allocation, resource block group (RBG)-level bit-map resource allocation (resource allocation Type 0) and contiguous resource allocation (resource allocation Type1) are supported. A UE can be configured with either or both of them. For time-domain resource allocation, the time-domain resource allocation field in the DCI jointly indicates scheduled slot, starting symbol, and the duration (number of consecutive symbols to use for the channel).

For PUSCH and PDSCH, other than DCI-based scheduling, configured grant for PUSCH and semi-persistent scheduling (SPS) for PDSCH are supported. For configured grant PUSCH, once PUSCH resource is configured and activated, the UE can transmit a PUSCH without DCI format 0_0/0_1. There are two types of configured grant PUSCH; with the configured grant Type1, UE can transmit PUSCH on the configured grant resource once RRC configuration is available, while with the configured grant Type2, UE can transmit PUSCH on the configured grant resource after a DCI with CRC scrambled by CS-RNTI activates the configured grant resource. SPS for PDSCH also requires activation DCI with CRC scrambled by CS-RNTI.

For NR, only asynchronous and adaptive HARQ is supported for both PDSCH and PUSCH. A PDSCH or PUSCH can be re-transmitted at any timing and with any transmission configuration. For re-transmission of a PDSCH or PUSCH, DCI formats 0_0/0_1 or 1_0/1_1 is used. HARQ process number and redundancy version are indicated in the DCI scheduling the re-transmission. Initial transmission/retransmission of a TB and soft-buffer store/flush are controlled per HARQ process number. Redundancy version is used to control redundancy of channel coded bits.

UE reports HARQ-ACK feedback for a decoded PDSCH. UE can be configured with reporting one HARQ-ACK bit for each transport block (TB), while if a UE is configured with CBG-based PDSCH transmission, the UE reports one HARQ-ACK bit for each code block group (CBG). A CBG is a group of code-blocks consisting of a TB, where channel coding is applied for each code block. If a UE is configured with CBG-based PDSCH transmission, the DCI scheduling PDSCH includes CBG transmission information (CBGTI) field which indicates which CBG(s) is/are re-transmitted, and the DCI can also include CBG flushing out information (CBGFI) field, which indicates the CBGs being retransmitted can be combined with the earlier received instances of the same CBGs. For PUSCH, CBG-based transmission using CBGTI is also supported.

For reporting multiple HARQ-ACK bits at one time, two types of HARQ-ACK codebook construction are supported; Type 1 HARQ-ACK codebook constructs the codebook based on semi-static configuration only, where HARQ-ACK bits corresponding to all of the possible PDSCHs based on the configuration are contained. Type 2 HARQ-ACK codebook constructs the codebook based on both semi-static configuration and DCI field named downlink assignment index (DAI), where HARQ-ACK bits corresponding to PDSCHs assumed to be assigned are contained.

5.5.4.8 Carrier Aggregation, Bandwidth Parts, and LTE/NR dual connectivity

In NR, the maximum bandwidth of a NR carrier is 100MHz for FR1 and 400MHz for FR2, respectively. In order to achieve wider bandwidth, carrier aggregation (CA) of up to 16 NR carriers is further supported. Both CA within a frequency band (intra-band CA) and CA across frequency bands (inter-band CA) are supported. For the case of inter-band CA, CA with different numerologies, e.g., CA between NR carrier in FR1 and NR carrier in FR2, is also supported.

NR newly defines the concept of bandwidth part (BWP). A UE can be configured with up to four BWPs per NR carrier for DL and UL, respectively. Each BWP has its own parameters including bandwidth and numerology. The bandwidth of the BWP is configured for each UE according to the UE capability on supported maximum bandwidth, and hence multiple UEs having different bandwidth capabilities can be served in a single wideband NR carrier. Also, multiple BWPs with different numerologies can be multiplexed within a single NR carrier to support different types of services. The bandwidth of the BWP can be narrower than the supported maximum bandwidth for the UE so that UE power saving is achieved. In addition, BWP adaptation based on switching between BWPs having different bandwidths and/or numerologies is supported.

For EN-DC operation, simultaneous UL transmissions across LTE and NR are supported. However, for some band combinations, e.g., band combinations where simultaneous UL transmissions are difficult due to inter-modulation issue, an operation based on single UL transmission i.e., either LTE or NR UL transmission at a time is supported.

5.5.4.9 NR-LTE co-existence

NR is designed to support flexible operation taking co-existence with legacy RAT especially LTE into account. Since some NR frequency bands in FR1 have been used for LTE carriers, mechanisms for NR-LTE coexistence, e.g., NR DL/UL transmission within the bandwidth of an LTE carrier without impact on the legacy LTE devices, are supported. For the design of NR-LTE coexistence mechanisms, following two scenarios are considered.

- For both DL and UL, NR carrier and LTE carrier coexist in the same bandwidth
- Only for UL, NR carrier and LTE carrier coexist in the same bandwidth

To achieve NR-LTE coexistence in the same bandwidth, higher-layer signalling is supported in NR to configure reserved resources to be used by LTE. It enables not only the coexistence between NR and normal LTE but also the coexistence between NR and LTE for machine type communication (MTC) and/or narrow band internet of things (NB-IoT).

In NR, DL and UL subcarrier positions are aligned while they are different in LTE. For the coexistence between NR UL and LTE UL in the same bandwidth, it is possible to configure a 7.5 kHz shift for NR UL subcarrier positions so that LTE and NR UL subcarriers are aligned to avoid interference due to non-orthogonal subcarriers between NR and LTE.

5.5.4.10 Supplementary Downlink

Similar as within LTE the concept of supplementary downlink (SDL) is supported wherein a carrier is pure DL carrier without any associated UL carrier. An SDL carrier can be aggregated with CA together with another DL and UL carrier.

5.5.4.11 Supplementary Uplink

The UE can be configured with 2 ULs as normal uplink and supplementary uplink (SUL) for one DL of the same cell. Uplink transmissions on those two ULs are controlled by the network to avoid overlapping PUSCH/PUCCH transmissions in time. Overlapping transmissions on PUSCH are avoided through scheduling while overlapping transmissions on PUCCH are avoided through configuration (PUCCH can only be configured for only one of the 2 ULs of the cell). In addition, initial access is supported in each of the uplink, i.e., random access can be performed on either normal uplink or SUL.

5.5.4.12 UL TPC

NR UL transmit power control (TPC) is designed to allow dynamic power adjustment for PUSCH, PUCCH, SRS, and PRACH. The UE calculates the path loss value based on the RSRP then determines UL transmission power based on several parameters configured by gNB. The reference signal for path loss calculation can be SS/PBCH block or CSI-RS. For PUSCH/PUCCH/SRS transmission, multiple parameter sets can be configured and multiple power control adjustment states can be managed for beam switching purpose. For PRACH, only one parameter set is configured. A parameter set consists of target received power and path loss coefficient. The UE can be configured the linkage between an SRS resource and several parameters about reference signal for path loss calculation, a power control parameter set, and a power control adjustment state. When the linkage is configured, the UE determines UL TPC parameters according to an SRS resource index indicated by DCI. In addition, for FR1 LTE-NR dual connectivity including both EN-DC and NR-E-UTRA dual connectivity (NE-DC), power sharing mechanism between RATs was introduced. When UE supports dynamic power sharing, power allocation for NR is dynamically adjusted on condition that the total transmission power never exceeds allowed value. Dynamic power sharing mechanism is shown in Figure 5.5.4.12-1. When UE does not support dynamic power sharing, the total power is semi-statically split for the two RATs by gNB configuration in order not to exceed the total transmission power, otherwise the UE does not expect to transmit in a slot on the NR when a corresponding subframe on the LTE is an UL subframe.

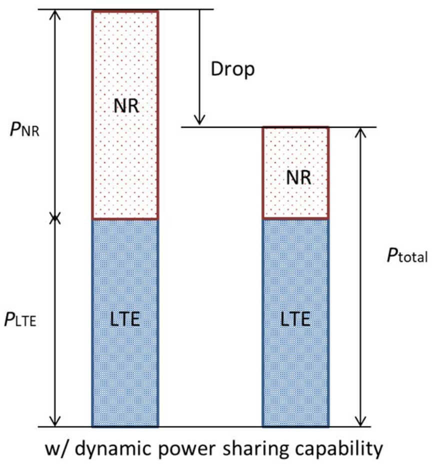


Figure 5.5.4.12-1: Dynamic power sharing between LTE and NR

5.5.5 Frequency aspects

While the physical and higher layers are designed as frequency agnostic, two separate radio performance requirements are specified for two frequency ranges (FRs), namely FR1 and FR2. FR1 is below the 7 GHz range (450 - 7125 MHz) and FR2 is millimetres-wave range (24250 - 52600 MHz).

The RF and RRM requirements are defined for each FR. One big difference between the requirements in FR1 and FR2 is testing methodology. Both so-called "conducted" and "over-the-air (OTA)" methodologies can be utilized in FR1, but only OTA methodology can be utilized in FR2. "Conducted" is a passive method, useable when antenna connectors are still accessible, whereas "OTA" is the be used when the antenna connectors are not accessible, such as in a massive MIMO context.

Four types of bands are specified for NR (note that all the NR bands are defined with a prefix "n" to distinguish them from the bands for the other RATs):

1) LTE "refarming" band: The bands have the corresponding LTE bands. For example, NR band n7 corresponds to LTE band 7. Hence, the bands would be likely to be used by "refarming" (i.e. re-using) the exiting LTE bands.

2) NR new bands in FR1: Completely new frequency bands for NR in FR1 whose corresponding LTE bands do not exist.

3) NR new bands in FR2: new frequency band for NR in FR2.

4) Supplemental uplink (SUL) / downlink (SDL) band: these bands have only uplink/downlink frequency, and they can be deployed with other type of NR bands.

NOTE: The ranges {65 - 256} and {257 - 512} are reserved as band number for NR new bands in FR1 and FR2, respectively. A band number will be assigned to a new frequency range on a "first come first served" basis from the reserved frequency range. During Release 15 definition time frame, 3 bands in FR1 and 4 bands in FR2 were defined as NR new bands considering the spectrum allocation plan in each region/country as shown in figure 5.5.5-1. In addition, some LTE bands were defined as LTE refarming band, and uplink frequencies of some LTE bands were defined as SUL/SDL band. All NR bands specified in this WI are summarized in Table 5.5.5-1. Especially for above new NR bands which have wider bandwidth than LTE, wider channel bandwidths, i.e. 100MHz in FR1 and 400MHz in FR2 at maximum, were defined to improve the spectrum efficiency and reduce the number of component carriers in case of NR CA operation. In addition, the RF requirements for NR bands and band combinations of NR CA were developed based on the market demands.

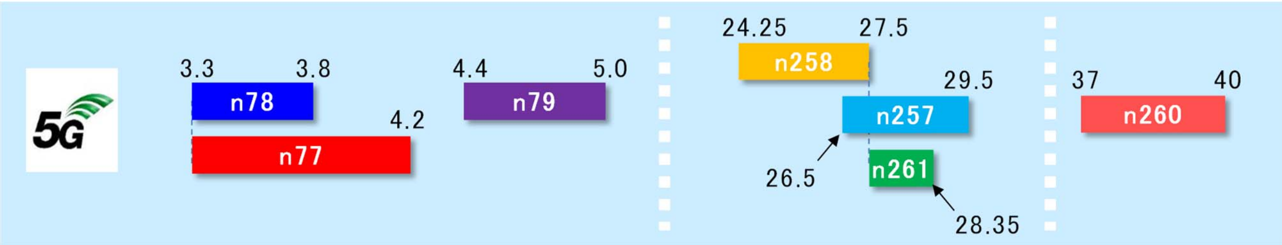


Figure 5.5.5-1: New NR bands in FR1 and FR2 in Rel.15 NR

Table 5.5.5-1: NR bands specified in the Rel-15 time frame

NR operating band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD1
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780MHz	N/A	SUL
n257	26500 MHz – 29500 MHz	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	24250 MHz – 27500 MHz	TDD
n260	37000 MHz – 40000 MHz	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	TDD

5.6 Other 5G aspects

5.6.1 5G AN connected to 4G AN: NSA and EDCE5

5.6.1.1 Overview

In addition of being connectable to the 5G Core Network, the 5G Access Network has been designed so that it can connect also to a 4G (LTE) Core Network, as seen earlier in the NSA-SA presentation.

While section 5.4 focusses on the 5G CN with 5G AN (the SA solution), this section deals with the 5G AN connected to the 4G CN (the NSA solution).

Although limited, the impacts on 4G CN to make it support a 5G AN are not null. These have been studied and covered in the EDCE5 work item, "EPC enhancements to support 5G New Radio via Dual Connectivity".

The NSA is described in clause 4.1.2 of TS 37.340 on " NR; Multi-connectivity; Overall description; Stage-2".

Since the 5G AN is deployed in addition to the (already-deployed) LTE system, both 4G and 5G connectivity are available, so NSA is also referred to as "EN-DC", standing for "4G and 5G Dual Connectivity" (more precisely: "E" for 4G (from eNB, the 4G AN node), "N" for 5G (from NR, the 5G radio) and "DC" for Dual Connectivity).

NSA is also referred to as "Architecture option 3" for "historical reasons": this was the 3rd option when a longer list of different options were discussed for 5G architecture.

5.6.1.2 CN impacts: EPC enhancements to support 5G New Radio via Dual Connectivity (EDCE5)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750035	EPC enhancements to support 5G New Radio via Dual Connectivity	EDCE5	SA2	SP-170583	Chris Pudney, Vodafone Group

Summary based on the input provided by Vodafone in SP-190217.

This section describes the System aspects of the Non-StandAlone option that uses Dual Connectivity with the Evolved Packet Core. The architecture and radio parts of NSA are reminded in the Figure below.

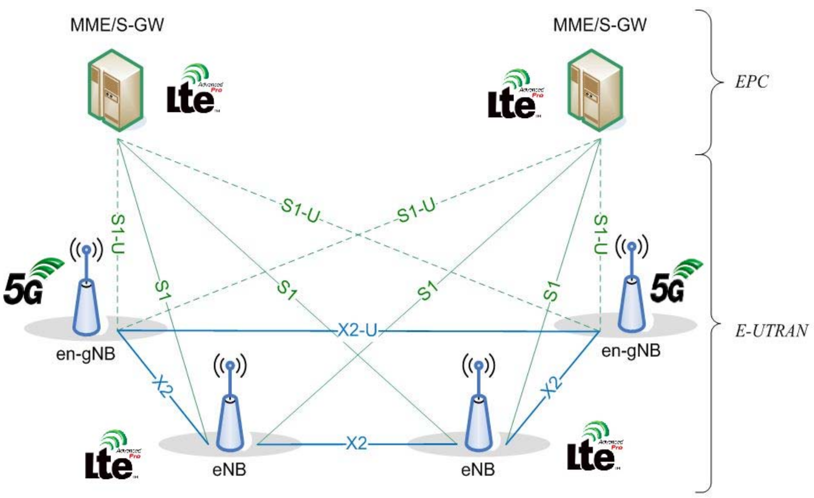


Figure 5.6.1.2-1: The NSA Architecture

The eNB is the master node (MN) while the en-gNB is the secondary node (SN).

The E-UTRAN uses the per-UE information supplied by the MME and local E-UTRAN configuration data to determine whether or not to use Dual Connectivity for that UE. On a per-EPS bearer (4G bearer) basis, the E-UTRAN decides whether to use a Master Cell Group bearer or a Secondary Cell Group bearer, and, whether or not that bearer is a split bearer, as defined in the section on the NSA Access Network.

For example, the Master eNB can decide to use the 5G en-gNB for user data (the "Internet" PDN connection), as to enjoy the 5G "high capacity" aspect, and to use the 4G eNB for IMS Signalling and IMS voice, as to enjoy the 4G "robust coverage layer" aspect.

The following figures illustrate some of the alternative configurations in the context of a Master Cell Group (MCG) and a Secondary Cell Group (SCG) respectively. Note that, as in the above example, one UE can use these configurations simultaneously. Also note that, in general, the EPC has no concrete information about whether the E-UTRAN is using Dual Connectivity, nor what configuration of Dual Connectivity is in use.

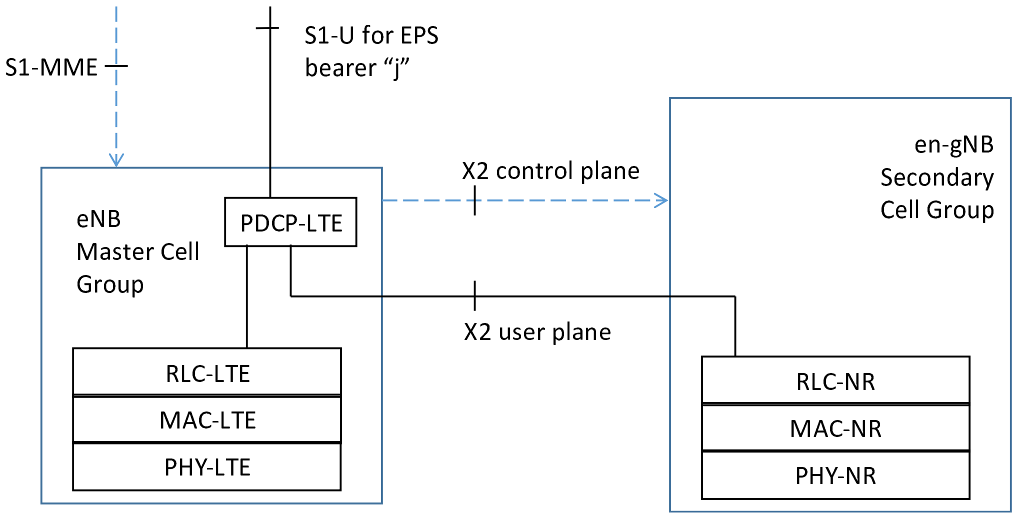


Figure 5.6.1.2-2: MCG split bearer in use for one EPS bearer of one UE (aka " architecture option 3")

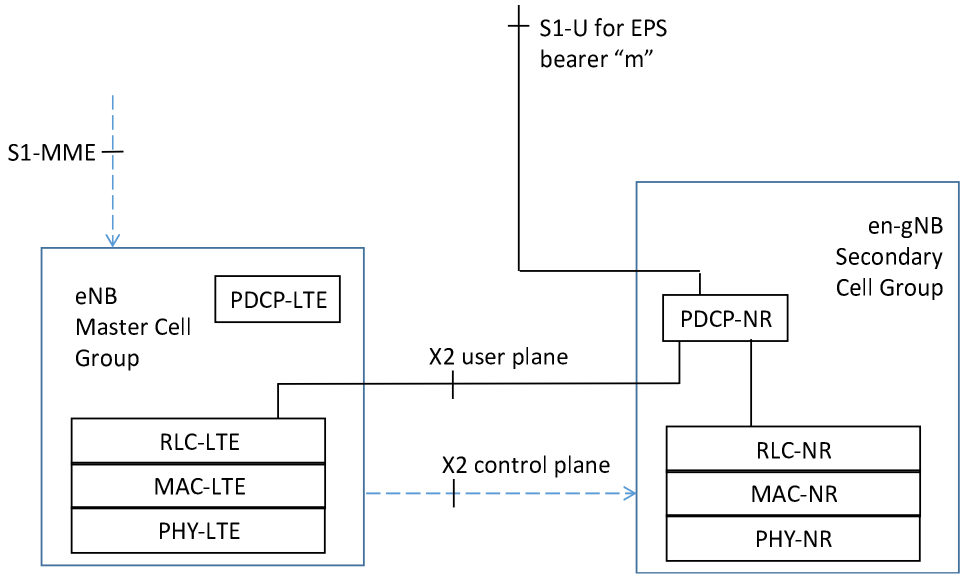


Figure 5.6.1.2-3: SCG split bearer in use for one EPS bearer of one UE (aka "architecture option 3x")

Note that it is also possible to operate NSA with an unmodified pre-Release 15 EPC (4G CN). In order to support the SCG bearer, the EPC does however need to support the Release 12 Dual Connectivity feature.

Several features have been introduced to enhance the functionality of the EPC for use with NR:

a) Support is provided for the HSS or the MME to instruct the RAN to not give access to "NR as a secondary RAT" for that UE.

b) UE core network capability signalling allows the MME (via its DNS) to select the SGW and PGWs that are appropriate for the UE's high data rate. Additional signalling allows the SGW-C and PGW-C to take the UE's NR capability into account when selecting the SGW-U and PGW-U.

c) Storage of very large UE Radio Access Capability Information Elements in the MME is specified (and associated RAN requirements).

d) Higher AMBR (maximum bit rate) values were specified and a new QCI 80 added for e.g. low latency Mobile BroadBand, Two other new QCIs (82, 83) were added for low latency GBR services in which the Packet Error Loss Rate calculation includes those packets that are not delivered within the Packet Delay Budget.

e) The amount of data sent on the Secondary NR RAT can be counted by the RAN and sent to the EPC for inclusion in the SGW CDRs and, optionally, in the PGW-CDRs

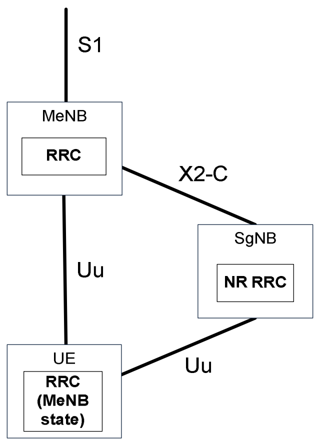
Within SA3, the security aspects were examined and CRs were generated that enabled the existing EPS security algorithms to be reused for signalling confidentiality and integrity protection, and, user plane confidentiality.

5.6.1.3 AN impacts: NSA radio protocol architecture

Summary based on the input provided by NTT DOCOMO on the Radio interface.

5.6.1.3.1 Control Plane

In EN-DC, the UE has a single RRC state, based on the Master Node (MN) RRC and a single Control plane (C-plane) connection towards the Core Network. Figure 5.6.1.3.1-1 illustrates the Control plane architecture for EN-DC. Each radio node has its own RRC entity (E-UTRA version if the node is an eNB or NR version if the node is a gNB) which can generate RRC PDUs to be sent to the UE. RRC PDUs generated by the Secondary Node (SN) can be transported via the MN to the UE. The MN always sends the initial SN RRC configuration via the Master Cell Group (MCG) Signalling Radio Bearers (SRB), a.k.a. SRB1, but subsequent reconfigurations may be transported via the MN or the SN. When transporting RRC PDU from the SN, the MN does not modify the UE configuration provided by the SN.



MeNB= Master eNodeB; SgNB = secondary gNode B

Figure 5.6.1.3.1-1: Control plane architecture for EN-DC (NSA architecture)

5.6.1.3.2 User Plane

In EN-DC, from a UE perspective, three bearer types exist: MCG bearer, Secondary Cell Group (SCG) bearer and split bearer. These three bearer types are depicted in Figure 5.6.1.3.2-1. For EN-DC, the network can configure either E-UTRA PDCP or NR PDCP for MCG bearers while NR PDCP is always used for SCG and split bearers.

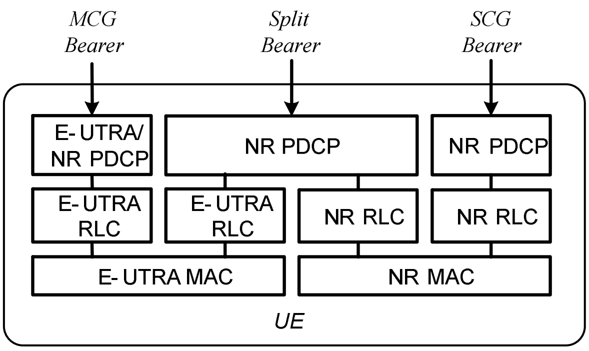


Figure 5.6.1.3.2-1: Radio Protocol Architecture for MCG, SCG and split bearers from a UE perspective in EN-DC

5.6.2 LTE connectivity to 5G-CN (4G AN with 5G CN)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750072	LTE connectivity to 5G-CN	LTE_5GCN_connect	R2	RP-171432	Huawei

Summary based on the input provided by Huawei in RP-180862.

LTE connectivity to 5G-CN does not only allow RAN level interworking but provides a migration path where the core network is 5G-CN whereas the radio remains LTE. This enables utilization of new functionalities provided by the 5G-CN such as QoS, mobility enhancements and slicing even when using the LTE radio interface.

The feature "LTE connectivity to 5G-CN", or the E-UTRA connected to 5GC, is supported as part of NG-RAN. The E-UTRA can be connected to both EPC and 5GC.

The overall architecture of E-UTRA connected to 5GC as part of NG-RAN is described in TS 38.300, where the term "ng-eNB" is used for E-UTRA connected to 5GC. However, here, the term "eNB" is used for both cases unless there is a specific need to disambiguate between eNB and ng-eNB.

The LTE connectivity to 5G-CN feature includes the following key functionalities:

- 5G NAS message transport
- 5G security framework, except that data integrity protection is not supported;
- Unified Access Control
- Flow-based QoS
- Network slicing
- SDAP
- NR PDCP
- Support of UEs in RRC_INACTIVE state.

Generally, the above functionalities are introduced based on similar functionalities as in NR.

For the user plane, the protocol stack is shown in Figure 5.6.2-1, where SDAP and NR PDCP sublayers perform the functions listed in TS 38.300, and RLC and MAC sublayers perform the functions listed in TS 36.300.

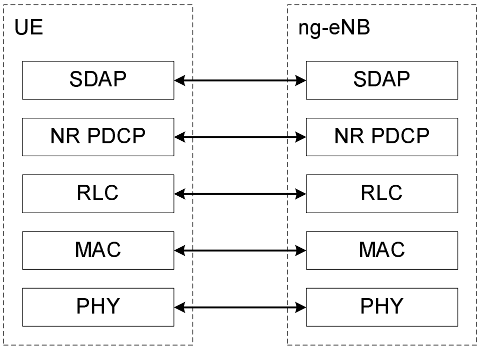


Figure 5.6.2-1: User Plane Protocol Stack

For the control plane, the protocol stack is shown in Figure 5.6.2-2.

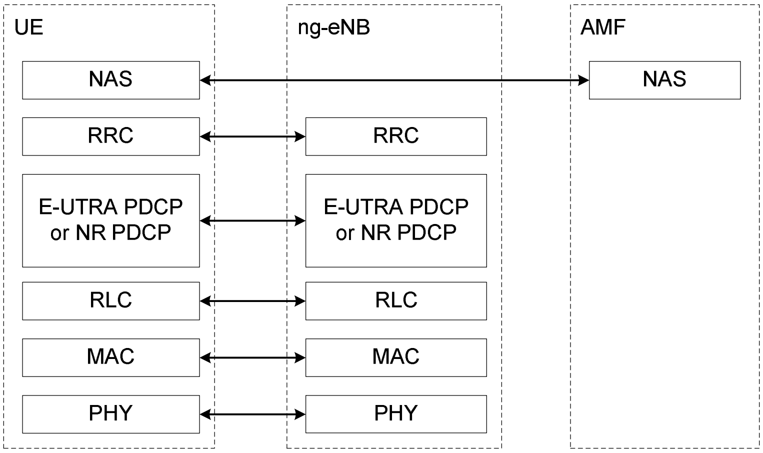


Figure 5.6.2-2: Control Plane Protocol Stack

5.6.3 Security aspects of the 5G System - Phase 1

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750016	**Security aspects of 5G System - Phase 1**	5GS_Ph1-SEC	S3	SP-170881	NTT DOCOMO, Alf Zugenmaier

Summary based on the input provided by NTT DOCOMO in SP-180861.

This work item defines the security aspects of the 5G system. The base requirement was to provide at least the same security features as LTE.

Non-Standalone NR Security

The NSA architecture uses LTE as the master radio access technology, while the new radio access technology (i.e. NR) serves as secondary radio access technology with User Equipment's (UEs) connected to both radios. Except for capability negotiation, security procedures for EN-DC basically follow the specifications for dual connectivity security for LTE. The WI summary for EDCE5 security (cf. corresponding clause above) provides details.

Evolution of the trust model

Moving on from the Non-Standalone deployment, in a Standalone 5G system, the trust model has evolved. Trust within the network is considered as decreasing the further one moves from the core. This has impact on decisions taken in 5G security design, thus we present the trust model in this section.

The trust model in the UE is reasonably simple: there are two trust domains, the tamper proof UICC on which the Universal Subscriber Identity Module (USIM) resides as trust anchor and the Mobile Equipment (ME). The ME and the USIM together form the UE.

The network side trust model for roaming and non-roaming cases are shown in the two following figures respectively, which shows the trust in multiple layers, like in an onion.

The Radio Access Network (RAN) is separated into distributed units (DU, or gNB-DU) and central units (CU, or gNB-CU) - DU and CU together form the gNB, as seen above. The DU does not have any access to customer communications as it may be deployed in unsupervised sites. The CU and Non-3GPP Inter Working Function (N3IWF - not shown in the figures), which terminates the Access Stratum (AS) security, will be deployed in sites with more restricted access.

In the Core Network, the Access Management Function (AMF) serves as termination point for Non-Access Stratum (NAS) security. Currently, i.e. in the 3GPP 5G Phase 1 specification, the AMF is collocated with the SEcurity Anchor Function (SEAF) that holds the root key (known as anchor key) for the visited network. The security architecture is defined in a future proof fashion, as it allows separation of the security anchor from the mobility function that could be possible in a future evolution of the system architecture.

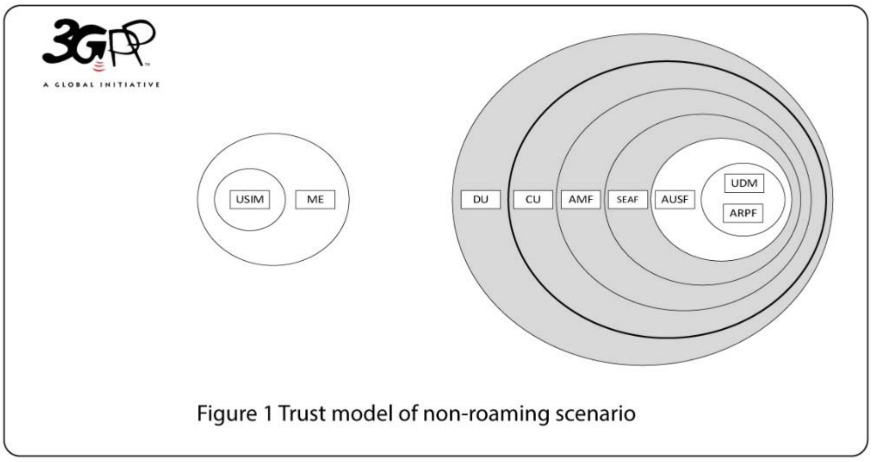


Figure 5.6.3-1: Trust model of non-roaming scenario

The AUthentication Function (AUSF) keeps a key for reuse, derived after authentication, in case of simultaneous registration of a UE in different access network technologies, i.e. 3GPP access networks and non-3GPP access networks such as IEEE 802.11 Wireless Local Area Network (WLAN). Authentication credential Repository and Processing Function (ARPF) keeps the authentication credentials. This is mirrored by the USIM on the side of the client, i.e. the UE side. The subscriber information is stored in the Unified Data Repository (UDR). The Unified Data Management (UDM) uses the subscription data stored in UDR and implements the application logic to perform various functionalities such as authentication credential generation, user identification, service and session continuity etc. Over the air interface, both active and passive attacks are considered on both control plane and user plane. Privacy has become increasingly important leading to permanent identifiers being kept secret over the air interface.

In the roaming architecture, the home and the visited network are connected through SEcurity Protection Proxy (SEPP) for the control plane of the internetwork interconnect. This enhancement is done in 5G because of the number of attacks coming to light recently such as key theft and re-routing attacks in SS7 and network node impersonation and source address spoofing in signalling messages in DIAMETER that exploited the trusted nature of the internetwork interconnect.

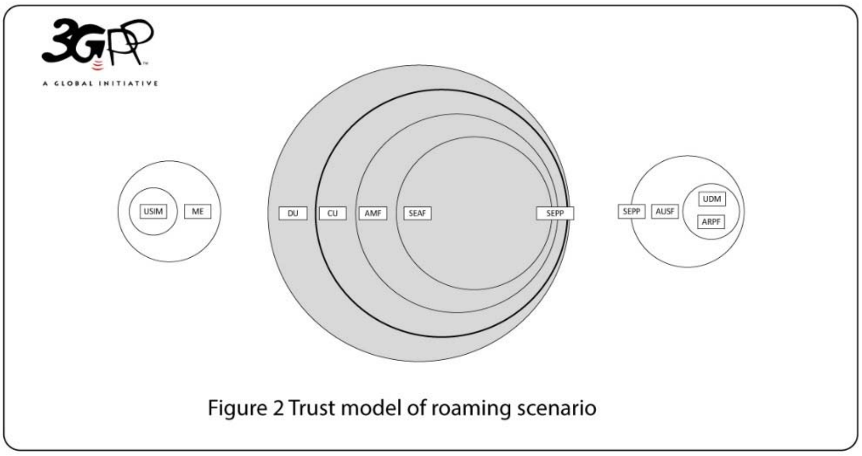


Figure 5.6.3-2: Trust model of roaming scenario

5G Phase 1 Security (Release 15)

5G Phase 1 brings several enhancements to LTE security, some of the key points are presented in this section. Details of 5G Phase 1 security can be found in TS 33.501 [1].

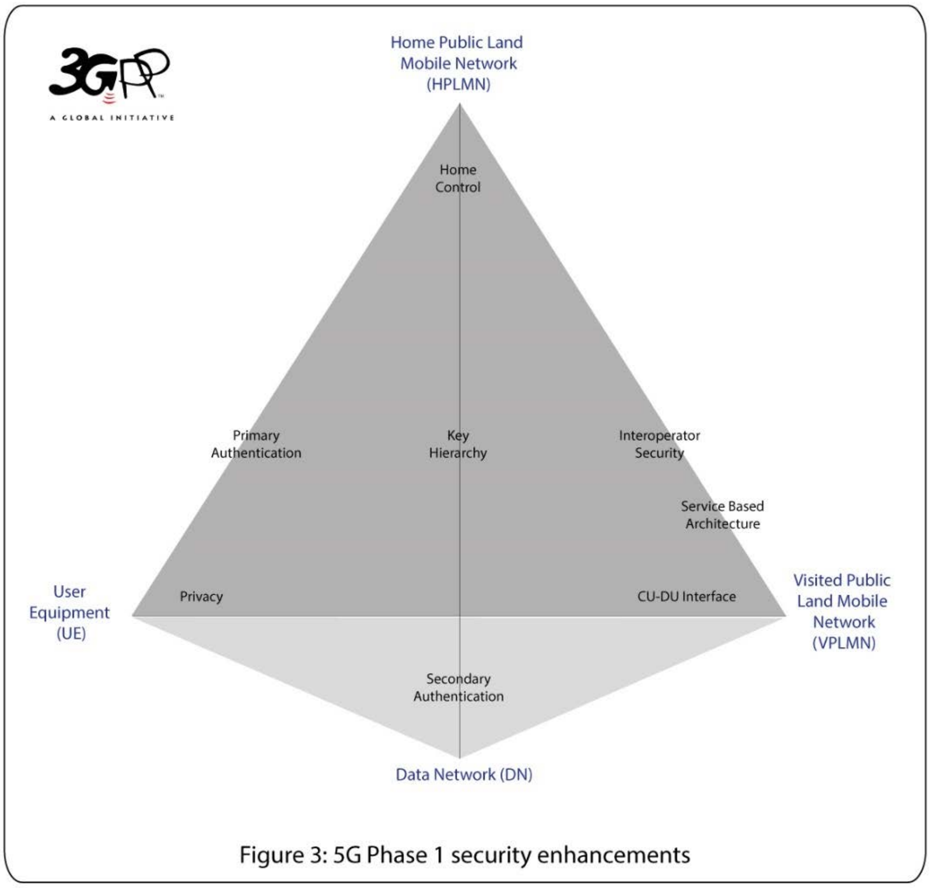


Figure 5.6.3-3: 5G Phase 1 security enhancements

Primary authentication: Network and device mutual authentication in 5G is based on primary authentication. This is similar to LTE but there are a few differences. The authentication mechanism has in-built home control allowing the home operator to know whether the device is authenticated in a given network and to take final call of authentication. In 5G Phase 1 there are two mandatory authentication options: 5G Authentication and Key Agreement (5G-AKA) and Extensible Authentication Protocol (EAP)-AKA', i.e. EAP-AKA'. Optionally, other EAP based authentication mechanisms are also allowed in 5G - for specific cases such as private networks. Also, primary authentication is radio access technology independent, thus it can run over non-3GPP technology such as IEEE 802.11 WLANs.

Secondary authentication: Secondary authentication in 5G is meant for authentication with data networks outside the mobile operator domain. For this purpose, different EAP based authentication methods and associated credentials can be used. A similar service was possible in LTE as well, but now it is integrated in the 5G architecture.

Inter-operator security: Several security issues exist in the inter-operator interface arising from SS7 or Diameter [5,6] in the earlier generations of mobile communication systems. To counter these issues, 5G Phase 1 provides inter-operator security from the very beginning.

Privacy: Subscriber identity related issues have been known since LTE and earlier generations of mobile systems. In 5G a privacy solution is developed that protects the user's subscription permanent identifier against active attacks. A home network public key is used to provide subscriber identity privacy.

Service based architecture (SBA): The 5G core network is based on a service based architecture, which did not exist in LTE and earlier generations. Thus 5G also provides adequate security for SBA.

Central Unit (CU) - Distributed Unit (DU): In 5G the base-station is logically split in CU and DU with an interface (the F1) between them. Security is provided for the CU-DU interface. This split was also possible in LTE, but in 5G it is part of the architecture that can support a number of deployment options (e.g. co-located CU-DU deployment is also possible). The DUs, which are deployed at the very edge of the network, don't have access to any user data when confidentiality protection is enabled. Even with the CU-DU split, the air interface security point in 5G remains the same as in LTE, namely in the radio access network.

Key hierarchy: The 5G hierarchy reflects the changes in the overall architecture and the trust model using the security principle of key separation. One main difference in 5G compared to LTE is the possibility for integrity protection of the user plane.

Mobility: Although mobility in 5G is similar to LTE, the difference in 5G is the assumption that the mobility anchor in the core network can be separated from the security anchor.

References

[1] TS 33.501, "Security architecture and procedures for 5G system".

5.6.4 Charging and OAM aspects of 5G System - Phase 1

5.6.4.1 Data Charging in 5G System Architecture Phase 1

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780035	**Data Charging in 5G System Architecture Phase 1**	5GS_Ph1-DCH	S5	SP-170952	Gardella, Maryse, Nokia

Summary based on the input provided by Nokia Shanghai Bell in SP-181182.

This work introduces the charging solution for a set of 5G System Architecture phase 1 key functionalities for data connectivity, allowing 5GS first commercial deployments. This solution relies on the new generic converged charging architecture with CHF (CHarging Function) exhibiting Nchf service-based interface, specified under the Service Based Interface for 5G Charging work SP-170951 [3].

Description

The 5G Data Connectivity domain charging specified in TS 32.255 [4] is based on Network functionalities defined in TS 23.501, TS 23.502 and TS 23.503, and covers converged charging from SMF for PDU session connectivity in different scenarios.

The following network scenarios are covered:

- The different Session and Service Continuity modes: SSC mode1, SSC mode 2, SSC mode 3 multiple PDU Sessions and IPv6 Multi-homed PDU Session. The changes of PDU Session configurations (addition/removal PDU session Anchor and Branching Point or UL CL) are also addressed.

- Network slicing through indication of Network Slice identifier associated to the PDU session.
- 5GS interworking with EPC when N26 interface is used, achieved by converged charging from the combined "PGW-C + SMF" dedicated to interworking.
- Roaming in Home routed scenario with roaming Qos Flow Based Charging functionality introducing a "Roaming Charging Profile" exchanged between PLMNs.
- Access Type differentiated between 3GPP access non-3GPP access.
- UE Presence in Presence Reporting Area(s) (PRA).
- Secondary RAT usage reporting in options 4&7.

The 5G data connectivity charging solution includes the applicable options in converged charging architecture:

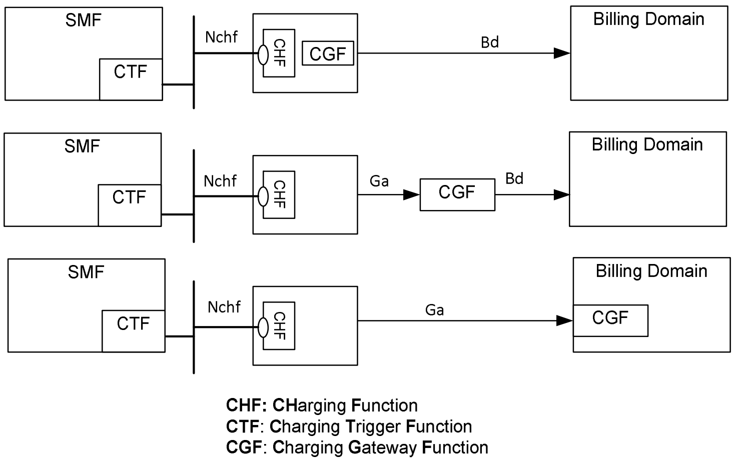


Figure 5.6.4.1-1

It also defines the following functionalities:

- Flow Based Charging (FBC) based on PCC Rules, and associated triggers in SMF for interaction with CHF.
- Qos Flow Based Charging (for roaming QBC) based on associated triggers in SMF for interaction with CHF.
- CHF capability to enable/disable SMF triggers.
- CHF CDR generation mechanisms for FBC and roaming QBC.
- Charging information specific to 5G data connectivity (for PDU session FBC and roaming QBC) are specified on top of generic charging information for:
- Converged charging behavior across Nchf
    - CHF CDRs content.

References

[1] SP-170952, New WID on Data Charging in 5G System Architecture Phase 1
[2] TR 32.899, Study on charging aspects of 5G system architecture phase 1
[3] SP-170951, Service Based Interface for 5G Charging
[4] TS 32.255, 5G Data connectivity domain charging; stage 2

5.6.4.2 Other 5G System Charging aspects

Other 5G System Charging aspects are presented in clause 14 on OAM improvements.

6 Critical Communications

6.1 EPC support for E-UTRAN Ultra Reliable Low Latency Communication

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770037	EPC support for E-UTRAN Ultra Reliable Low Latency Communication	EPS_URLLC	S2	SP-170811	Chris PUDNEY

Summary based on the input provided by Vodafone in SP-190229.

The QCI mechanism, introduced in 4G, handles the QoS per bearer, as shown in the table below.

In 5G, two new QoS Class Identifier (QCIs), namely 84, 85, are added for Ultra Low Latency GBR services, and some more example services are added for QCIs 82 and 83.

For these four QCIs, the Packet Error Loss Rate calculation includes those packets that are not delivered within the Packet Delay Budget.

Their characteristics are summarised in the table below.

Table 6.1-1: Standardized QCI characteristics (extract from Table 6.1.7-B of TS 23.203)

QCI	Resource Type	Priority Level	Packet Delay Budget	Packet Error Loss Rate	Maximum Data Burst Volume	Data Rate Averaging Window	Example Services
82	GBR	1.9	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation
83		2.2	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation
84		2.4	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent Transport Systems
85		2.1	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution-high voltage

6.2 Highly Reliable Low Latency Communication for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750061	Highly Reliable Low Latency Communication for LTE	LTE_HRLLC	R1	RP-171489	Ericsson

Summary based on the input provided by Ericsson in RP-180693 revised in RP-181869.

The LTE_HRLLC work item provides solutions to support ultra-reliable and low latency communication for LTE. The solutions that have been specified include:

- Semi-static CFI configuration
- PDSCH repetition
- UL SPS repetition
- PDCP packet duplication
- Granular time reference provision.

These solutions support configurable reliability and latency combinations and have been specified on top of the existing LTE air interface for Frame Structure type 1 (FS1) and Frame Structure type 2 (FS2), including various LTE TTI lengths (1ms, slot and subslot for FS1, 1ms and slot for FS2) as well as existing LTE latency reduction techniques.

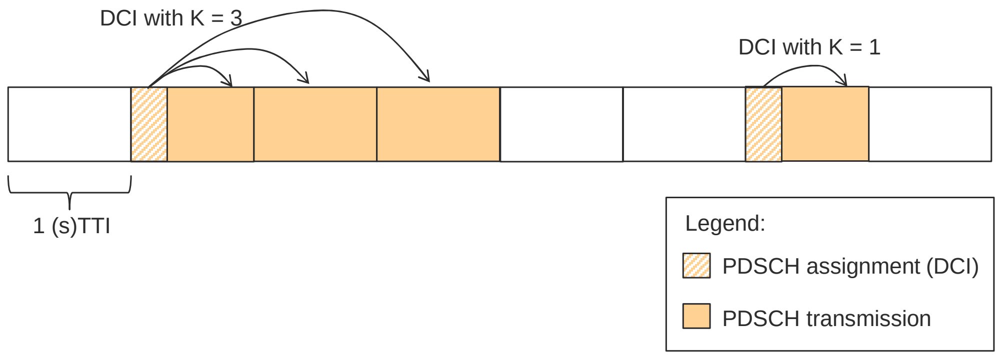
An overview of the specified solutions is provided in the following.

Semi-static CFI

Control Format Indicator (CFI) indicates how many OFDM symbols are used for the Physical Downlink Control Channel (PDCCH). In most cases, CFI is obtained by decoding the Physical Control Format Indicator Channel (PCFICH). To ensure that PCFICH decoding does not degrade the overall downlink and uplink reliability, RRC configuration of CFI for any serving cell has been introduced in this work item. It is a separate CFI configuration for different Transmission Time Interval (TTI) lengths. If CFI is semi-statically configured for TTIs of different lengths, the UE does not expect the configured CFI values to be different. The semi-static CFI value can be configured separately for Multicast Broadcast Single Frequency Network (MBSFN) and non-MBSFN subframes for each cell. When a UE is configured with a semi-static CFI for a given TTI length, the UE is not expected to decode PCFICH for that TTI length.

PDSCH repetition

To improve the reliability of the DL data channel, PDSCH (Physical Downlink Shared Channel) repetition can be configured to a UE for a given TTI length. If configured, the PDSCH DCI format 1A or 7-1x monitored by the UE on the user specific search space indicates K consecutive PDSCH transmissions with the same Resource Block (RB) allocation, Modulation and Coding Scheme (MCS) and HARQ process, where K takes a value in {1, 2, 3, 4 or 6}. Thus, the number of PDSCH transmissions for a given transport block is changed dynamically as shown in the figure below. The HARQ-ACK feedback for the transport block is sent only once with the timing given by the Kth PDSCH transmission. Only the Redundancy Version (RV) can be different within the window of K transmissions, if configured accordingly. A maximum rank of 2 is supported with slot/subslot PDSCH repetition and DMRS sharing cannot be used with subslot PDSCH repetition.



NOTE: The figure does not intend to capture the exact resource mapping of DCI and rate-matching rules of PDSCH).

Figure 6.2-1: Illustration of PDSCH repetition and dynamic signalling of the number of PDSCH transmissions

As one method to increase the probability of successful decoding of the DL assignment, further DL assignments can be transmitted in the (s)TTIs following the (s)TTI where a DL assignment for K PDSCH transmissions has been transmitted. The specification clarifies the UE behaviour for this case. The UE discards any further DL assignment scrambled with C-RNTI in a (s)TTI where a PDSCH that is part of a window of K transmissions is being received.

The specification defines how subframes/slots/subslots are counted as part of the K PDSCH transmissions in case consecutive PDSCH transmissions are not possible. The specification also clarifies rate-matching rules around SPDCCH resources for the last K-1 slot/subslot PDSCH transmissions of a transmission window.

RRC configuration enables to set fixed values to some bits in the DCI, enabling thereby the possibility to reduce the false alarm probability.

UL SPS (uplink Semi-Persistent Scheduling) repetition

In addition to PDSCH repetition, the specifications support UL SPS repetition where K >1 UL transmissions of the same transport block can be configured as part of the SPS configuration for subframe/slot/subslot PUSCH (Physical Uplink Shared Channel). The number of UL transmissions, K, is to be chosen so that the aggregated time of K UL transmissions does not exceed the configured SPS periodicity, P. The initial transmission of the transport block can only occur on the first transmission occasion of the transmission window. This guarantees that K transmissions are performed for a given transport block. There is only one exception. In case a dynamic UL grant is sent for a PUSCH transmission in a subframe/slot/subslot where a SPS PUSCH transmission part of a repetition was prepared, the colliding PUSCH SPS transmission may be dropped. The exact dropping rules for such collision cases were defined following the principles applied for UL SPS without repetition. If dropped, only the colliding SPS PUSCH transmission is dropped, while the remaining PUSCH transmissions within the transmission window are performed.

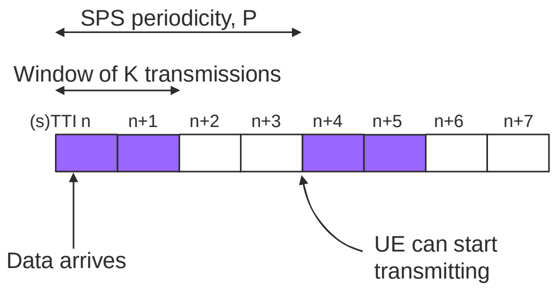


Figure 6.2-2: UL SPS repetition on one SPS configuration

In case of new data arrival, a UE has to wait for the next first (s)TTI of the transmission window before being able to transmit new data (as depicted in Figure 2). With a single UL SPS configuration, this induces a maximum delay of P (s)TTIs. To shorten this delay, the specifications allow multiple SPS configurations for the same TTI length to be activated on the same serving cell. By appropriate setting of P, K and the number of SPS configurations for a given TTI length, it is possible to reduce the maximum delay for the UE to be able to transmit UL data to 1 (s)TTI. Different HARQ processes are associated with different SPS configurations for a given (s)TTI length and the cyclic shift for the UL Demodulation Reference Signal (DMRS) can be configured independently for each SPS configuration.

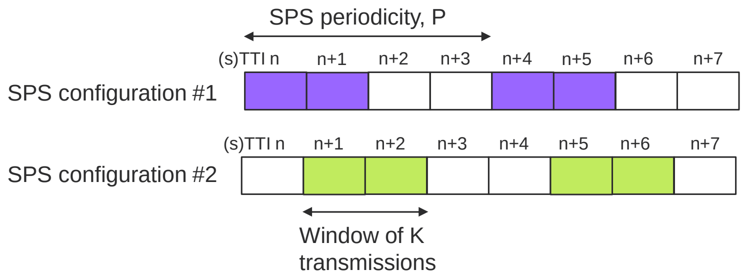


Figure 6.2-3: UL SPS repetition with two SPS configurations

PDCP packet duplication

In case of Carrier Aggregation (CA) or in case of Dual Connectivity (DC), PDCP (Packet Data Convergence Protocol) packet duplication can be applied to improve the overall reliability for downlink and possibly for uplink depending on UE power limitation. PDCP packet duplication is configured for a radio bearer by RRC where two logical channels are configured for the radio bearer. The two logical channels can either belong to the same MAC entity (CA case) or different MAC entities (DC case). When activated, PDCP packet duplication allows sending the same PDCP Protocol Data Unit (PDU) on two independent transmission paths: via the primary RLC entity and a secondary RLC entity, thereby increasing reliability.

PDCP packet duplication is supported in the following cases:

- for Signalling Radio Bearers (SRBs) using RLC AM.
- for Data Radio Bearers (DRBs) using RLC UM or AM.

For DRBs, PDCP packet duplication is first RRC configured and then activated and deactivated by a MAC CE. In addition, for DRBs, PDCP packet duplication can also be immediately activated upon configuration by RRC signalling. For SRBs, once duplication is configured, it is always activated.

When PDCP packet duplication is activated, both the original logical channel and the duplicated logical channel are RRC configured with a cell restriction list. The data from one logical channel is not allowed to be sent on the cells in the cell restriction list. The cell restriction lists associated with the original and the duplicated logical channel are mutually-exclusive so that duplicates are sent on different cells. The restriction is lifted when PDCP packet duplication is deactivated.

At the receiver, PDCP enables reordering and duplication detection when PDCP packet duplication is configured.

Granular time reference provision

The specifications support granular time reference provision from the network to end user equipment. The time reference provided by the network to users has a granularity of 0.25 us and uses the GPS/UTC time format (like in SIB16). In addition, an inaccuracy indication of the time reference is optionally sent. If the inaccuracy indication is absent, then the inaccuracy is not specified.

The time reference can be broadcasted (via SIB16) and be unicasted (via dedicated RRC signalling). For broadcast solution, the time refers to the same reference point in SIB16, i.e., the system frame number (SFN) boundary at or immediately after the ending boundary of the system information (SI)-window in which SystemInformationBlockType16 is transmitted. For unicast solution, the time refers to the ending boundary of one system frame number whose value is indicated in the RRC message.

7 Machine-Type of Communications (MTC) and Internet of Things (IoT)

7.1 Improvements of Machine-Type of Communications (MTC) and Internet of Things (IoT)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750066	Further NB-IoT enhancements	NB_IOTenh2	R1	RP-171428	Huawei

Summary based on the input provided by Huawei, HiSilicon in RP-180851 revised in RP-181838.

This work item is a collection of additions and enhancements of functionalities related to NB-IoT, primarily focusing on reducing UE power consumption and on enhancing the parts of the Rel-13/14 NB-IoT air interface and protocol layers to respond to feedback from early deployments.

Additional new features include support for small cells, extensions to NB-IoT standalone operation mode, and TDD.

Wake-up signalling for IDLE mode (FDD)

When a UE is in DRX or eDRX, it has to regularly check if a paging message is arriving from the core network. At most possible occasions for paging, no message arrives for the UE and the power the UE consumed could have been saved. This feature allows the eNB to send the UE a 'wake-up signal' (WUS) to instruct the UE that it has to monitor NPDCCH for paging, and otherwise allows the UE to skip the paging procedures. This allows the UE to potentially keep parts of its hardware switched off for more of the time, and save the power of decoding NPDCCH and NPDSCH for paging. Depending on how long the network allows for the UE to 'wake up' after receiving a WUS, the UE may be able to keep switched on only a receiver dedicated to WUS detection, allowing much of the UE's conventional hardware to remain in a very low-power state.

Scheduling request (FDD)

In Rel-13/14 NB-IoT, scheduling request (SR) exists only as a higher-layer procedure, which triggers a random access procedure to request sufficient UL resource to send a buffer status report (BSR). Rel-15 has added new, more resource and power efficient, ways to achieve this goal which can be configured by the eNB.

For a connected mode UE, eNB is able to configure by RRC periodic NPUSCH resources for the UE to send BSR, so the eNB is informed when pending traffic has arrived in the UE's buffer. The resources are activated and de-activated ('released') by dynamic signalling on NPDCCH.

A connected mode UE is able to send, in the physical layer, a request to the eNB to be granted NPUSCH resources to send a BSR. This can be done either by a dedicated signal using a pre-configured NPRACH transmission, or via 'piggybacking' the request onto HARQ ACK or NACK transmission from the UE if one is available, by applying a cover code to the ACK or NACK symbols.

Early data transmission (FDD)

An idle mode UE is able to transmit data in Msg3 of the random access procedure, carrying between 328 and 1000 bits. After successful reception by eNB, the random access procedure terminates and the UE does not transition to connected mode. The UE requests a grant for EDT if its pending data is smaller than a maximum permitted size configured by eNB, by using a pre-configured set of NPRACH resources for its preamble transmission. The eNB can allow the UE to transmit a smaller amount of data than the maximum permitted size, in order to reduce the power spent transmitting padding bits.

Quick release of RRC connection (FDD and TDD)

A NB-IoT UE has to wait up to 10 seconds, after the receipt of the RRCConnectionRelease message, in case lower layers do not indicate successful acknowledgement of the reception. This feature allows that, in case the UE is not polled, the UE can consider the receipt of the RRCConnectionRelease message to be successfully acknowledged as soon as the UE has sent HARQ ACK. This feature was introduced from the Rel-14 specifications.

Relaxed monitoring for cell reselection (FDD and TDD)

This feature allows much of the RRM monitoring to be avoided in cases where an NB-IoT UE is stationary and/or the network topology is not changing, and UE battery life can be correspondingly extended. The network configures the UE with a 'NRSRP delta' threshold, and while the change in RSRP its current cell is less than the threshold, the UE does not need to monitor neighbouring cells for 24 hours. This feature was introduced from the Rel-14 specifications.

RLC UM (FDD and TDD)

Rel-15 adds support for RLC unacknowledged mode (UM) to complement the acknowledged mode (AM) and transparent mode (TM) introduced in Rel-13. This reduces the need to send RLC signalling over the air for IoT traffic which may be latency and/or loss tolerant, or recoverable by the application layer.

Narrowband measurement accuracy improvement (FDD)

The narrowband secondary synchronization signal (NSSS) or, on the serving cell, transmissions of MIB-NB on the narrowband physical broadcast channel (NPBCH) can be used for making NRSRP measurements, as alternatives to using narrowband reference signals (NRS). NSSS and NPBCH use more resource elements for their transmission than NRS, and this should reduce the amount of subframes the UE needs to process to achieve a given measurement accuracy.

NPRACH range enhancement (FDD)

NB-IoT is sometimes deployed in cells with radius of up to around 100 km. Rel-13 NPRACH supports cell radii up to 40 km with unambiguous determination of UE range. Beyond that distance, because NPRACH is a pure sine wave transmission, there can be ambiguities for the eNB to determine the UE's range. A new NPRACH format is introduced with a subcarrier spacing of 1.25 kHz and a cyclic prefix of 800 μs, together with frequency hopping, which is sufficient to allow unambiguous range determination up to 120 km.

Small cell support (FDD and TDD)

eNB power classes are defined in NB-IoT to allow deployment of eNBs as microcells, picocells and femtocells, which use lower maximum transmit power than macro eNBs.

Reduced system acquisition time (FDD)

In FDD, when SIB1-NB is being transmitted with 16 repetitions (the maximum supported), eNB can transmit additional subframes containing SIB1-NB repetitions on anchor carriers and non-anchor carriers to allow faster decoding of SIB1-NB and reduce the UE's power consumption during cell access. Compared to Rel-13 which supports up to 8 SIB1-NB repetitions, Rel-15 allows 16 repetitions.

UE differentiation (FDD and TDD)

The network is able to collect and store in the MME information about the UE and its traffic profile. This can be used to improve the scheduling of the UE according to e.g. its battery life or power supply, mobility, and when it tends to have traffic to transmit.

Access barring enhancement (FDD and TDD)

In Rel-13, the network can bar UEs at times of high load on a cell-specific basis. This feature allows UEs to be barred on a per-coverage level basis, so that UEs in deeper coverage levels and needing more repetitions of their transmissions, can be barred separately from other, less resource-intensive, UEs.

Mixed standalone operation (FDD)

In Rel-13, a standalone anchor or non-anchor NB-IoT carrier can only be configured together with another standalone carrier. This feature allows configuration of standalone anchor carriers with in-band and guard-band non-anchor carriers, and of in-band and guard-band anchor carriers with standalone non-anchor carriers. This allows small slices of non-LTE spectrum to be used as a standalone NB-IoT carrier and be linked with NB-IoT carriers associated to LTE spectrum.

Power headroom reporting enhancement (FDD)

In Rel-13, power headroom reports (PHR) are made by the UE from one of two tables depending on coverage, each containing four entries. This feature improves the granularity of PHR transmitted in Msg3 to have 16 levels.

TDD

Support for TDD is introduced, incorporating the Rel-13 NB-IoT feature together with Rel-14 features: UE category NB2, 2 UL/DL HARQ processes, multi-carrier RACH and paging, and OTDOA [1]. All LTE UL/DL subframe configurations are supported, except for configurations 0 and 6, and all LTE special subframe configurations are supported. In addition, some Rel-15 features described above are agnostic to FDD/TDD and thus can be used for both.

7.2 Further enhancements for Extended Coverage GSM for support of Cellular Internet of Things

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790053	Further enhancements for Extended Coverage GSM for support of Cellular Internet of Things	CIoT_EC_GSM_fenh	R6	RP-180541	Nokia

Summary based on the input provided by Nokia in RP-181976.

7.2.1 Introduction

Extended Coverage GSM for support of Internet of Things (EC-GSM-IoT) is an evolution of EGPRS providing a streamlined protocol implementation, reducing MS complexity while supporting energy efficient operation with extended coverage compared to GPRS/EGPRS. EC-GSM-IoT improves the coverage performance of Cellular IoT devices by 20 dB compared to EGPRS along and enables long battery life time achieved by energy efficient methods over the radio interface. The extended coverage is achieved by a high number of blind physical layer transmissions along with modified channel coding schemes.

In Release 13, the base station supporting EC-GSM-IoT requires minimum 4 consecutive timeslot resources reserved for packet data operation to support extended coverage operation. Furthermore, the coverage improvement for low power EC-GSM-IoT devices with 23 dBm output power is limited to 10 dB in this release.

In Release 14, as part of radio interface enhancements, EC operation with a reduced number of 2 consecutive timeslot resources both on DL and UL specified. In addition, a new uplink coverage class CC5 is added to improve the MCL performance in uplink by 4 dB compared to Release 13, which can be mapped both to 4 and 2 consecutive time slot resources.

In Release 15, as part of further enhancements, a paging indication channel for EC operation is introduced as well as the deferred system information acquisition procedure for EC operation both targeting the improvement of energy consumption of the device in idle mode. The deferred system information acquisition procedure was also specified for Power Efficient Operation (PEO) devices that operate in normal coverage with increased power consumption efficiency in idle mode due to adoption of Extended DRX and relaxed mobility requirements.

7.2.2 Energy Efficient Paging Reception with EC Paging Indication channel

The network may configure an EC Paging Indication Channel (EC-PICH) for a mobile station capable to receive EC-PICH in higher coverage class condition (i.e. in extended coverage using CC3 or CC4) which occurs prior to the corresponding paging block of the mobile station to optimise the energy consumption for paging reception.

Separate EC-PICH blocks are used for paging indication for mobiles in coverage class CC3 or CC4. An EC-PICH block for CC4 contains the paging indication for single paging block of CC4 within four 51 multiframes (see Figure 7.2-1), whereas an EC-PICH block for CC3 serves for indicating a page to one or two CC3 mobile stations per two 51-multiframes (see Figure 7.2-2). The mobile stations in CC3 or CC4 coverage condition checks the EC-PICH block corresponding to its paging block whether containing a wake-up indication, and if yes, listens to the paging block. If the EC-PICH block indicates that no paging message is scheduled in its paging block, the mobile stations enters into sleep mode until the next paging occasion after completion of current (e)DRX cycle thus reducing energy consumption by up to around 15% due to avoiding reading the long paging block for these higher coverage classes which may or not contain a matching page, i.e. require the mobile station to send a paging response. This is illustrated in Figure 7.2-1 and Figure7.2-2 below.

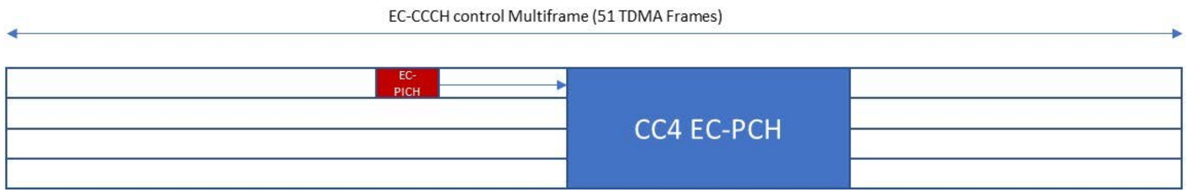


Figure 7.2-1: EC-PICH block in first 51 MF indicates whether mobile station should wake up or sleep for CC4 paging block

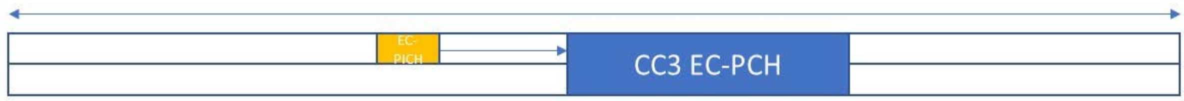


Figure 7.2-2: EC-PICH block in first 51 MF indicates whether mobile station should wake up or sleep for CC3 paging block

The message sent on EC-PICH to convey wake-up or sleep indications is designed such that it can be received by legacy EC-GSM-IoT mobile stations in CC1 condition, expecting an EC-AGCH, without decoding failure, i.e. the legacy EC-GSM-IoT mobile station detects an unknown message type.

7.2.3 Deferred System Information Acquisition in EC operation and for PEO

In order to reduce energy consumption in packet idle mode, the network may broadcast information to assist the MS to apply deferred system information acquisition.

To this purpose it reconfigures EC System Information type 2 for a cell to include an Idle Mode Mobility cell group description comprising cells, geographically adjacent or close to each other, with shared cell parameters related to cell (re)selection, Routing Area assignment, paging monitoring, DL Coverage class selection, mobility support and cell barring and assigns it a broadcast frequency list containing BCCH carriers allocated in these cells. To better match cell deployments, some cell parameters may deviate from the common values and are separately indicated on a per cell basis.

To allow for different settings of shared cell parameters in geographic adjacent areas, different Idle Mode Mobility cell groups are defined with an identifier to distinguish one from the other, thus providing a spatially definite assignment of cells to Idle Mode Mobility cell groups. Since values of shared or non-shared cell parameters in a particular Idle Mode Mobility cell group are subject to change in time, a change mark is assigned to the Idle Mode Mobility cell group. An increment of the change mark for a particular Idle Mode Mobility cell group hence indicates to the MS to acquire the complete EC SI in the serving cell.

To enable fast detection if a cell is part of a specific Idle Mode Mobility cell group or not, the MS identifies from EC-SCH reception the Idle Mode Mobility cell group identifier and the related change mark. Thus, an MS reselecting to a cell in the same IMM cell group as the last serving cell has read the EC-SCH and decoded both the IMM cell group identifier and the IMM cell group change mark. If both values match with those of the last serving cell, it will not need to read the EC-BCCH for this cell prior to the decision for cell reselection, neither after cell reselection to this cell for subsequent cell reselections and for paging monitoring in packet idle mode. Only in case a valid page is received, that requires to send a paging response, or the MS needs to perform an uplink data transmission, or a timeout since the last reading of the complete EC SI in a different than the current serving cell is expired, the MS is required to read the complete EC System Information in the current serving cell.

The network may choose to deactivate deferred SI acquisition in network deployments for which EC System Information needs to be reconfigured more frequently or for which adjacent cells' idle mode mobility parameters differ too much. The support of deferred system information acquisition is broadcasted in EC System Information.

For PEO devices, that operate in normal coverage, a similar concept was designed, that includes the PEO IMM Cell Group definition in the System Information type 13 (SI 13) message and reuses cell parameters broadcasted in SI 2 and SI 3. For fast detection if a neighbour cell belongs to the same PEO IMM Cell Group or not, the MS monitors paging request and immediate assignment messages on downlink CCCH, where the PEO IMM cell group identifier and the PEO IMM change mark are sent and evaluates whether they are identical to those of the current serving cell. In this case it defers reading of system information for that cell, similar to a device in EC operation. Power savings up to around 20% related to the radio module power consumption of the device have been estimated.

References

[1] RP-180541, "New WID on Further Enhanced EC-GSM-IoT", source Nokia et al., RAN#79
[2] RP-181886, "Status Report for WI Further enhancements for EC-GSM-IoT", source Nokia (rapporteur), RAN#81

7.3 Even further enhanced MTC for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750059	Even further enhanced MTC for LTE	LTE_eMTC4	R1	RP-171427	Ericsson

Summary based on the input provided by Ericsson in RP-181213 revised in RP-181872, further revised in RP-182592.

This work item builds on the LTE features for Machine-Type Communications (MTC) introduced in Rel-13 and Rel-14 (e.g., low-complexity UE categories M1 and M2, and Coverage Enhancement Modes A and B) by adding support for new use cases and general improvements with respect to latency, power consumption, spectral efficiency, and access control.

The following clauses describe the new MTC features for LTE in Rel-15. All features are optional for the UE and can be supported by Cat-M1 and Cat-M2 and by normal LTE UEs supporting CE mode unless otherwise stated. All features are applicable to both CE modes (A and B) in all duplex modes (HD-FDD, FD-FDD, and TDD) unless otherwise stated.

7.3.1 Support for new use cases

The MTC features introduced in LTE Rel-13 focused on applications with relatively modest requirements in terms of data rates, latency, mobility, etc. The range of use cases that can be addressed was extended in Rel-14 by improving the support for higher data rates, multicast, positioning, VoLTE, and mobility measurements. This work item introduces the following additional enhancements for support of new use cases.

- Support for higher UE velocity: To enable support of use cases associated with potentially relatively high velocity (e.g. logistics), enhanced performance requirements are introduced for CE mode A. These requirements are defined for 200 Hz Doppler spread, corresponding to around 240 km/h at 1 GHz and 120 km/h at 2 GHz.

- Lower UE power class: To enable support of use cases associated with small device form factor and low power consumption (e.g. wearables), a new lower UE power class with a maximum transmission power of 14 dBm is introduced for Cat-M1 and Cat-M2, together with signaling support for the lower maximum transmit power with appropriate coverage relaxations.

- New gaps for dense PRS configurations: Downlink transmission of dense positioning reference signals (PRS) was introduced already in Rel-14, and this work item introduces new gap patterns that will enable the UE to perform measurements in connected mode when the duration of said PRS is longer than 6 subframes.

7.3.2 Reduced latency

Reduced latency is achieved by the improvements for reduced system acquisition time listed in this section. Furthermore, note that the EDT feature and the HARQ feedback feature listed in the next clause may also help reduce latency.

- EARFCN pre-provisioning: Initial cell search can be speeded up by pre-provisioning the UE with the E-UTRA absolute radio frequency channel number (EARFCN) and the geographical area where the EARFCN pre-provisioning configuration is applicable.

- Resynchronization signal (RSS): When a UE needs to re-acquire time and frequency synchronization towards a cell, it can save time and energy by using the denser RSS instead of the legacy PSS/SSS (the latter is still used for initial synchronization to new cells).

- Improved MIB demodulation performance: Reduced MIB acquisition time is enabled by enhanced CGI (i.e. cell global identity) reading delay requirements based on accumulation of transmissions within two 40-ms MIB periods.

- Improved SIB demodulation performance: Reduced SIB1/SIB2 acquisition time is enabled by enhanced CGI reading delay requirements based on accumulation of transmissions within one modification period.

- SI update indication: A flag bit is introduced in MIB to let the UE know whether the SIB information has been updated during the last N hours (where N is the system information validity time, which is 3 or 24 hours). This typically means that the UE can save time and energy since it does not need to re-acquire SIB1 as often. The SI update indication is also replicated in RSS, implying that the UE may also be able to re-acquire MIB less often.

7.3.3 Reduced UE power consumption

Reduced UE power consumption is achieved through reduced downlink monitoring, reduced signalling and reduced uplink transmission by the features listed in this section. Furthermore, note that the features for reduced system acquisition time listed in the previous clause and the uplink sub-PRB allocation feature mentioned in the next clause may also help reduce power consumption.

- Wake-up signals (WUS): Reduced UE power consumption in idle mode is enabled by the introduction of WUS, a compact signal transmitted a configurable time before the paging occasion (PO) when a UE is being paged, allowing the UE to maximize its sleep time during periods when there is no paging. The configurable time can be as large as 2 seconds, which facilitates UE implementations with a wake-up receiver (WUR).

- Early data transmission (EDT): For scenarios where the UE only needs to transmit a small amount of data, the EDT feature enables the UE to transmit up to (slightly more than) 100 bytes of data already in message 3 during the random-access procedure, and to receive data already in message 4. In this release, only mobile-originated (MO) EDT access is supported. If needed, eNB can order fallback to legacy random-access procedure during the EDT procedure.

- HARQ feedback for UL data: A possibility to carry a positive HARQ-ACK in an UL DCI over MPDCCH is introduced. This allows eNB to indicate to a UE that UL data has been successfully received and may enable early termination of downlink (MPDCCH) monitoring or (in case of FD-FDD or TDD but not HD-FDD) early termination of uplink (PUSCH) transmission.

- Relaxed monitoring for cell reselection: When this feature is enabled and the criteria for relaxed monitoring are fulfilled, the UE can reduce its neighbor cell measurements to as seldom as every 24 hours. This can reduce the power consumption substantially especially for stationary UEs in challenging coverage conditions.

7.3.4 Increased spectral efficiency

Increased spectral efficiency is achieved through higher order modulation, more efficient resource allocation and reduced inter-cell interference by the features listed in this section. Furthermore, note that the EDT feature described in the previous clause may also help increase spectral efficiency.

- Downlink 64QAM support: Support for 64QAM modulation is introduced for PDSCH unicast transmission without repetition in CE mode A to increase the downlink spectral efficiency. The UE peak rate is not increased.

- CQI table with large range: An alternative CQI table spanning a larger range is introduced. Downlink 64QAM can only be used together with the new CQI table, but the new CQI table can also be used by UEs not configured with 64QAM support and even by UEs not supporting 64QAM. In the latter case, the large range of the CQI table can help reduce the need for RRC reconfigurations when the UE experiences varying channel conditions.

- Uplink sub-PRB allocation: Uplink spectral efficiency is improved by the introduction of PUSCH sub-PRB resource allocation in connected mode. New allocation sizes are ½ PRB (6 subcarriers) or ¼ PRB (3 subcarriers). In the latter case, a new $\pi/2$-BPSK modulation using 1 at a time out of 2 of the 3 allocated subcarriers can be used to achieve near 0 dB baseband peak-to-average power ratio (PAPR), which may be beneficial for uplink data coverage and for UE power consumption.

- Flexible starting PRB: To facilitate efficient scheduling of MTC-related data transmissions side by side with other transmissions (e.g. MBB-related PDSCH transmissions in downlink and PUCCH/PRACH in uplink), PDSCH/PUSCH resource allocation with a more flexible starting PRB (not restricted by 6-PRB narrowbands) is introduced for UEs that are configured in CE mode with max 1.4 MHz PDSCH/PUSCH channel bandwidth.

- Frequency-domain CRS muting: Cat-M1 and Cat-M2 UEs can indicate support of CRS muting outside their 6-PRB narrowband or 24-PRB wideband, respectively, so that the network can take this information into account when deciding whether and how to perform CRS muting to reduce downlink inter-cell interference in the network.

7.3.5 Improved access control

The legacy access barring mechanisms (ACB and EAB) do not distinguish between different coverage enhancement (CE) levels. In high load situations, it may be desired to temporarily bar access e.g. to the highest CE levels, since UEs in high CE levels may be associated with higher resource consumption due to dozens, hundreds or even thousands of repetitions.

- CE-level-based access barring: A new mechanism for CE-level-based access barring is introduced, which enables eNB to bar access per CE level. Note that if access is barred to a CE level, then access is also barred to all higher CE levels. The legacy barring mechanisms (ACB and EAB) are not affected by the new mechanism and they can be configured independently.

References

[1] RP-172811, Revised WID for Even Further Enhanced MTC for LTE
[2] RP-181871, Status Report for Even Further Enhanced MTC for LTE
[3] RP-181174 & RP-181791, RAN1 CR packs for Even Further Enhanced MTC for LTE
[4] RP-181224 & RP-181944, RAN2 CR packs for Even Further Enhanced MTC for LTE
[5] RP-181242, RAN3 CR pack for Even Further Enhanced MTC for LTE
[6] RP-181083 & RP-181899, RAN4 CR packs for Even Further Enhanced MTC for LTE
[7] RP-171441, Summary for Rel-14 WI Further enhanced MTC for LTE

7.4 Other MTC related work

74.1 AT Commands for CIoT-Ext

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780016	AT Commands for CIoT-Ext	AT_CIoT-Ext	C1	CP-173083	Bakker, John-Luc (Blackberry)

Summary based on the input provided by BlackBerry UK Ltd. sent by e-mail.

AT-commands and response codes that can be used to:

- configure the CIoT and MTC extensions, in the AS or NAS layers of the MT; and
- present to the CIoT and MTC Rel-14 applications;

have been specified.

74.2 Battery Efficient Security for very low Throughput MTC Devices

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
730050	Battery Efficient Security for very low Throughput MTC Devices	BEST_MTC_Sec	S3	SP-160569	Evans, Tim, VODAFONE Group Plc.

Summary based on the input provided by Vodafone, sent by e-mail.

The BEST_MTC_Sec Work Item delivers battery efficient user data security mechanisms for very low Throughput Machine Type Communication Devices. These devices are characterised by communicating with infrequent small data packets, with a long life in the market and with the capability of being powered from a single small battery.

This work item delivered a new TS, TS 33.163 [1] which is based on the study results in TS 33.863 [2].

The work item delivered a standalone specification that specifies:

- Integrity protection, and optionally confidentiality protection, for small data packets between the UE and a service in the home network.
- Integrity protection, and optionally confidentiality protection, for small data packets between the UE and a service in the enterprise IT space.
- Key agreement service between the UE and a service in the enterprise IT space.

3GPP TS 33.863 [2] studied the security requirements for user data transfer in battery constrained devices and concluded that a new protocol was needed for end to middle security (E2M) (UE to Home Network) and for end to end (E2) (UE to Enterprise application).

3GPP TS 33.163 (BEST) delivers a small, infrequent, user plane data security model and an optimised protocol (EMSDP) that achieves telecom grade security with a low overhead. Whilst initially specified for LTE, EMSDP is equally applicable for all 3GPP technologies as re-uses 3GPP authentication and includes support for integrity protection, confidentiality protection, replay protection, end point authentication and E2E key distribution. EMSDP has been designed with the flexibility to extend it with other security methods, counter schemes and endpoints whilst being fully self-contained in the 3GPP user plane traffic.

BEST is realised using a client in the UE and a new entity, the HPLMN Security Endpoint (HSE) which is located in the home network core.

References

[1] 3GPP TS 33.163: "Battery Efficient Security for very low Throughput Machine Type Communication (MTC) devices (BEST)"

[2] 3GPP TR 33.863: "Study on battery efficient security for very low throughput Machine Type Communication (MTC) devices".

8 Vehicle-to-Everything Communications (V2X) Improvements

8.1 Enhancement of 3GPP support for V2X scenarios

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750003	**Enhancement of 3GPP support for V2X scenarios**	eV2X		SP-170158	Chun, SungDuck, LG Electronics

Summary based on the input provided by LG Electronics in SP-180467.

Through the works done in Rel-14, 3GPP system starts to support various V2X services by use of LTE technology. The target of Rel-14 work to support V2X service is mostly to provide data transport service for basic road safety service such as Cooperative Awareness Messages (CAM), Decentralised Environmental Notification Messages (DENM), Basic Safety Message (BSM) and so on.

On top of the work done in Rel-14 to support V2X services based on LTE, the Rel-15 work eV2X further specifies service requirements to enhance 3GPP support for V2X scenarios. Requirements for the following areas are covered in this work and specified in TS 22.186 [1]:

- Vehicle Platooning: Vehicles platooning enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven.

- Advanced Driving: Advanced Driving enables semi-automated or fully-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or manoeuvres. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer travelling, collision avoidance, and improved traffic efficiency.

- Extended Sensors: Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.

- Remote Driving: Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.

- General aspects

Reference

[1] TS 22.186: "Enhancement of 3GPP support for V2X scenarios; Stage 1".

8.2 Enhancements on LTE-based V2X Services

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750062	**Enhancements on LTE-based V2X Services**	LTE_eV2X	R1	RP-171740	Huawei

Summary based on the input provided by Huawei, HiSilicon in RP-180858.

In Rel-14, TSG RAN completed the WI "Support for V2V services based on LTE sidelink" and the WI "LTE-based V2X services". With these the completion of these two WIs, TSG RAN had specified V2X communication in order to provide basic safety services.

In Rel-15, the LTE_eV2X work item enhances the Cellular-based V2X services (V2V, V2I/N, and V2P) to support advanced V2X services as identified in TR 22.886 in a holistic and complementary manner to Release 14 V2X. This work item specifies 3GPP V2X Phase 2 to support advanced V2X services in a fully backward compatible manner with Rel-14 V2X.

These studies concluded to specify and introduce the following key functionalities:

- Support of Carrier Aggregation (CA) for mode-4. CA was already supported for mode-3 in Rel-14. In Rel-15, CA for mode-4 was specified. The resource allocation procedure of Rel-14, which was based on sensing, was expanded to support multi-carrier transmission, while relying on the same core principles. Rules for power sharing, and to include priority were derived. A synchronization procedure for multiple carriers was derived. It includes priority rules for determining the synchronization resources. Sidelink packet duplication was introduced in the case of CA to improve the transmission reliability.

- Support for 64-QAM. New transport block sizes and transport block size scaling were introduced to support 64-QAM. In addition, transmission uses rate-matching instead of the Rel-14 procedure where the last symbol was punctured.

- Reduction of the maximum time between packet arrival at Layer 1 and resource selected for transmission. This value was reduced to 10ms, compared to 20ms for Rel-14 V2X.

- Radio resource pool sharing between mode-3 and mode-4 UEs. Changes in the SCI content for mode-3 UEs were introduced to improve performance when resource pools are shared. Sensing and reporting for mode-3 UEs is supported.

- Transmit diversity. After studies, it was concluded that transmit diversity was a valuable feature to have. The transmit diversity technique used is Small Delay Cyclic Delay Diversity.

- RF requirements for new CA scenarios, 64QAM and transmit diversity were introduced in TS 36.101.

- RRM requirements. The delay/interruption requirements due to V2X CC addition/release and V2X synchronization reference source selection/reselection requirements for V2X CA was introduced.

Finally, it can be noted that the introduction of a short Transmission Time Interval (TTI) was studied but was not standardized in Rel-15.

References

Last approved work item description: RP-171740, "Revision of WID:V2X phase 2 based on LTE"
Last status report: RP-180856

9 Improvements of Mission Critical (MC)

9.1 Enhancements to MCPTT

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750021	Enhancements to MCPTT functional architecture and information flows	enhMCPTT	S6	SP-170248	Dom Lazara, Motorola Solutions

Summary based on the input provided by Motorola Solutions in SP-181215.

For Release 15, the enhancements for the MCPTT feature were specified in two work items: enhMCPTT for stage 2 and enhMCPTT-CT for stage 3. Those features that have been completed are described below.

Enhancements to the MCPTT service impact the following areas of the architecture and protocols: call control and media handling, configuration, and security.

The following features have been introduced:

A) Remotely initiated MCPTT call request: This feature gives the ability for an authorized MCPTT user to target another MCPTT user's client and have the target client initiate an MCPTT call. The target MCPTT client can be instructed to initiate a private call (to a single MCPTT user), or the target MCPTT client can be instructed to initiate a group call (to a set of MCPTT users). For the remotely initiated private call, the existing private call authorizations for the target MCPTT client are used. For remotely initiated group call, the existing group call authorizations for the target MCPTT client (including affiliation) are used.

B) Location of current talker: This feature allows the initiator of a group call transmission to share his current location with every transmission. Based on privacy settings, the talker's location is delivered to the other affiliated members of the group during the group call.

C) Entering or exiting an emergency alert area: This feature allows an authorized MCPTT user to define a geographical area for the purposes of causing the target MCPTT client to send an emergency alert when within this geographic area. Upon leaving the geographic area the target MCPTT client sends an emergency alert cancel. The MCPTT system keeps track of the MCPTT user's location and sends an indication to the target MCPTT client upon entering or exiting the emergency alert area.

D) Geographical affiliation and de-affiliation: This feature allows an authorized MCPTT user to define a geographical area for the purposes of causing the target MCPTT client to affiliate to a group when within this geographic area. Upon leaving the geographic area the target MCPTT client is sent an indication to de-affiliate. The MCPTT system keeps track of the target MCPTT user's location and sends an indication to the MCPTT client upon entering or exiting the geographic area.

E) Application group paging: This feature enables the MCPTT system to send an application level message to the MCPTT clients affiliated to a group over an MBMS application level signalling channel.

F) Subscription to group dynamic data: This feature enables the MCPTT system to allow an authorized MCPTT user to subscribe to a set of dynamic data that is associated with the group. This allows the MCPTT client to get real time updates of changes to any of the elements of this dynamic data set. These include affiliation status of individual members of the group, and group call status (whether a call is ongoing or not). The subscription data can be sent via unicast or multicast.

The architecture, protocol, and security aspects of the MCPTT service related to these enhancements are described in the following specifications:

1. The architecture (including information flows, procedures, and configuration) is specified in TS 23.379 and TS 23.280;

2. The security aspects are specified in TS 33.180;

3. The protocol aspects for call control and media plane are specified in TS 24.379 and TS 24.380 respectively;

4. The protocol aspects for group configuration, identity management, and general configuration are specified in TS 24.481, TS 24.482, TS 24.483, and TS 24.484 respectively;

5. The protocol aspects for codecs and media handling are specified in TS 26.179;
6. The protocol aspects for policy and charging control are specified in TS 29.213 and TS 29.214;
7. The protocol aspects for data management related to MC service user profile are specified in TS 29.283;
8. The stage 2 aspects of the Proximity-based services (ProSe) enabler are specified in TS 23.303; and
9. The stage 2 aspects of the Group Communication System Enabler (GCSE) for multicast communication as part of the MCPTT service are specified in TS 23.468.

References

[1] TS 22.179 Mission Critical Push To Talk (MCPTT) over LTE; Stage 1;
[2] TS 22.280 Mission Critical Services Common Requirements (MCCoRe); Stage 1;
[3] TS 23.379 Functional architecture and information flows to support Mission Critical Push To Talk (MCPTT); Stage 2;
[4] TS 23.280 Common functional architecture to support mission critical services; Stage 2;
[5] TS 23.303 Proximity-based services (ProSe); Stage 2;
[6] TS 23.468 Group Communication System Enablers for LTE (GCSE_LTE); Stage 2;
[7] TS 24.379 Mission Critical Push To Talk (MCPTT) call control; Protocol specification;
[8] TS 24.380 Mission Critical Push To Talk (MCPTT) media plane control; Protocol specification;
[9] TS 24.481 Mission Critical Services (MCS) group management; Protocol specification;
[10] TS 24.482 Mission Critical Services (MCS) identity management; Protocol specification;
[11] TS 24.483 Mission Critical Services (MCS) Management Object (MO);
[12] TS 24.484 Mission Critical Services (MCS) configuration management; Protocol specification;
[13] TS 26.179 Mission Critical Push To Talk (MCPTT); Codecs and media handling;
[14] TS 29.213 Policy and Charging Control signalling flows and Quality of Service (QoS) parameter mapping;
[15] TS 29.214: Policy and Charging Control over Rx reference point;
[16] TS 29.283: Diameter data management applications;
[17] TS 33.180: Security of the mission critical service.

9.2 Enhancements to MC Data

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750022	Enhancements to MC Data Functional architecture and information flows	eMCData		SP-170462	David Freeman, Home Office

Summary based on the input provided by Motorola Solutions in SP-181216.

For Release 15, the enhancements for the MCData service were contained in two work items: eMCData for stage 2 and eMCData-CT for stage 3. Those features that have been completed are described in the following clause.

Enhancements to the MCData service impact the following areas of the architecture and protocols: call control and media handling, configuration, and security.

The following features have been introduced:

A) Accessing a list of deferred data communications: This feature enables the MCData service to temporarily store data communications for the case where the download of the data has been deferred by an MCData user. The MCData user may request the list and retrieve the deferred data communications at a later time. This is an on-network procedure.

B) Communication release with prior indication: This feature enables an authorized MCData user to send a release indication to the MCData service to terminate an ongoing MCData communication. This action can be accomplished for an ongoing MCData communication over the media plane, or over HTTP. The authorized MCData user may have been monitoring the ongoing MCData communication. Prior to the communication release, the target MCData user is given a notification that ongoing MCData communication release is pending. The target MCData user may request an extension from the authorized MCData user before release. If the extension is granted the MCData communication will continue. If no extension is given, the MCData communication is released. This is an on-network procedure.

C) Communication release without prior indication: This feature is similar to the feature described in (B) above, except that no notification is given to the target MCData user before the release which terminates the MCData communication is executed by the MCData system. An authorized MCData user can initiate the communication release. No extension can be requested or granted in this case. This is an on-network procedure.

D) MCData server initiated release: This feature allows the MCData system to release an ongoing MCData communication after some triggering criteria (e.g. lack of bearer capacity, limit for the maximum amount of data or time that a MCData participant may transmit in a single request is exceeded) has been met. Similar to (B) and (C) above the release of MCData communication can be preceded by a notification or not. This is an on-network procedure.

E) Enhanced status (on-network): This feature delivers the capability for an MCData user to set, and for the MCData service to track, the current MCData system defined status of the MCData user. The enhanced status captures a status specific to the activities performed by the MCData users during their normal course of operation (e.g. available, on site, in route to the site, unavailable). The enhanced status can be shared by the MCData user with an MCData group using the Short Data Service (SDS) capability.

F) Enhanced status (off-network): This feature extends the enhanced status feature in (E) above for off-network SDS communication.

G) Extension of the MCData application identifier: The application identifier field used in the MCData service has been extend to include an additional formats: text and URI. This gives greater flexibility for configuration of the application identifier within the MCData service.

The architecture, protocol, and security aspects of the MCData service related to these enhancements are described in the following specifications:

1. The architecture (including information flows, procedures, and configuration) is specified in TS 23.282 and TS 23.280;
2. The security aspects are specified in TS 33.180;
3. The protocol aspects for call control and media plane are specified in TS 24.282 and TS 24.582 respectively;
4. The protocol aspects for group configuration, identity management, and general configuration are specified in TS 24.481, TS 24.482, TS 24.483, and TS 24.484 respectively;
5. The protocol aspects for policy and charging control are specified in TS 29.213 and TS 29.214;
6. The protocol aspects for data management related to MC service user profile are specified in TS 29.283;
7. The stage 2 aspects of the Proximity-based services (ProSe) enabler are specified in TS 23.303.

References

[1] TS 22.282 Mission Critical Data services; Stage 1;
[2] TS 22.280 Mission Critical Services Common Requirements (MCCoRe); Stage 1;
[3] TS 23.282 Functional architecture and information flows to support Mission Critical Data (MCData); Stage 2;
[4] TS 23.280 Common functional architecture to support mission critical services; Stage 2;
[5] TS 23.303 Proximity-based services (ProSe); Stage 2;
[6] TS 23.468 Group Communication System Enablers for LTE (GCSE_LTE); Stage 2;
[7] TS 24.282 Mission Critical Data (MCData) signalling control; Protocol specification;
[8] TS 24.582 Mission Critical Data (MCData) media plane control; Protocol specification;
[9] TS 24.481 Mission Critical Services (MCS) group management; Protocol specification;
[10] TS 24.482 Mission Critical Services (MCS) identity management; Protocol specification;
[11] TS 24.483 Mission Critical Services (MCS) Management Object (MO);
[12] TS 24.484 Mission Critical Services (MCS) configuration management; Protocol specification;
[13] TS 29.213 Policy and Charging Control signalling flows and Quality of Service (QoS) parameter mapping;
[14] TS 29.214: Policy and Charging Control over Rx reference point;
[15] TS 29.283: Diameter data management applications;
[16] TS 33.180: Security of the mission critical service.

9.3 Enhancements to MC Video

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760048	Enhancements to MC Video Functional architecture and information flows	eMCVideo	S6	SP-170401	Niranth Amogh, Huawei India

Summary based on the input provided by Huawei in SP-181222.

The Mission Critical Video service, introduced in an earlier Release, is enhanced in Rel-15 has to offer the set of improvements listed below, both for on-network and off-network operations.

For on-network operations, the following enhancements are introduced:

1. Ambient viewing
2. Video push
3. Video pull
4. Use of UE-to-network relay and Service continuity
5. Support for multiple devices
6. Location procedures
7. Application group paging

For off-network operations, the following enhancements are introduced:

1. Video push
2. Video pull

References

The stage 1 requirements are specified in TS 22.281 and TS 22.280 (for applicable MC common requirements). The stage 2 aspects for eMCVideo (signalling control and transmission & reception control) are specified in TS 23.280 and TS 23.281. The stage 3 aspects for eMCVideo are specified in TS 24.281 and TS 24.581. The stage 3 procedures for common services (e.g. configuration management, group management) are specified in TS 24.481, TS 24.482, TS 24.483 and TS 24.484. The codec and media handling procedures are specified in TS 26.281.

[1] TS 22.280 Mission Critical Services Common Requirements (MCCoRe); Stage 1;
[2] TS 22.281 Mission Critical video services over LTE (MCVideo); Stage 1;
[3] TS 23.280 Common functional architecture to support mission critical services; Stage 2;
[4] TS 23.281 Functional architecture and information flows to support Mission Critical Video (MCVideo); Stage 2;
[5] TS 24.481 Mission Critical Services (MCS) group management; Protocol specification;
[6] TS 24.482 Mission Critical Services (MCS) identity management; Protocol specification;

9.4 Other Mission Critical Enhancements

9.4.1 MC Security Enhancements

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760067	MC Security Enhancements	eMCSec	S3	SP-170415	Haigh, Peter, NCSC, summary from Colin Whorlow

Summary based on the input provided by NCSC in SP-19xxxx (received by e-mail without SA number).

This work item enhances the security solutions defined for MCPTT in TS 33.179 to support the common functional architecture (MC_ARCH), enhancements to MCPTT (eMCPTT), data services (MCData), video services (MCVideo) and migration and interconnect services with partner systems (MCSMI).

In each case, an analysis of the threats to the service is performed, then the security requirements to mitigate those threats are proposed, as well as an evaluation of possible technical solutions designed to meet the security requirements of the service.

Specific aspects for which solutions are recommended are:

1. Distribution of key material to protect signalling
2. Multiple Security Domains
3. Key management for first-to-answer call
4. Mission critical video (MCVideo) architecture
5. Inter-Domain Identity Management
6. Encryption of entire XML signalling content
7. Protection of MCData
8. KMS Discovery
9. Signalling Proxies
10. Security Gateways
11. Signalling authentication and authorisation
12. Interworking security data transport

9.4.2 MBMS usage for MC communication services

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750023	MBMS usage for MC communication services	MBMS_Mcservices	S6	SP-170686	Magnus Tränk, Ericsson

Summary based on the input provided by Ericsson in SP-190198.

For Release 15, the MBMS usage for MC services was enhanced by the introduction of further features or the enhancement of existing features.

The following features have been completed in Release 15 for the MBMS usage for MC services:

A) Multi-server bearer coordination: To avoid allocating duplicate bearers for an MBMS service area, a single MC service server may manage all the MBMS media transmission for all groups and users within a particular MBMS service area. For that, two procedures have been introduced. The first one is the MBMS bearer coordination independent on broadcasted media procedure to be used when there are multiple MC service servers serving users in one specific area covered with one MBMS bearer, but the servers broadcast media independent of each other. The second procedure is the MBMS bearer coordination within one group call. This one is used when multiple MC service servers of the same kind participate in the same group communication. The MC service servers could be different MC service servers assigned the participating role within one MC system. This feature is specified in 3GPP TS 23.280.

B) MBMS bearer event notification: This feature includes an activation of an MBMS bearer and different types of events that may occur during the lifetime of the MBMS bearer. The different events notified to the MC service server include the MBMS bearer start result (e.g. when the first cell successfully allocated MBMS resources), including information if any cells fail to allocate MBMS resources to a specific MBMS bearer, the current status of the MBMS bearer, MBMS bearer suspension/resume or overload scenarios. This feature is specified in 3GPP TS 23.280. Further required aspects to this feature are specified in 3GPP TS 23.468, 3GPP TS 23.246 and 3GPP TS 36.300.

C) Use of FEC to protect MBMS transmissions: Application layer FEC (Forward Error Correction) has been introduced as an optional feature to recover the packet losses when delivering a MC service over MBMS. Hence, the required level of QoS can be reached. For that, two procedures on how FEC can be applied for MBMS usage were introduced. This feature is specified in 3GPP TS 23.280. Further required aspects to this feature are specified in 3GPP TS 23.468 and 3GPP TS 23.246.

D) Header compression over MBMS with ROHC: Header compression can decrease the required bandwidth for service communications. Therefore, the support of ROHC (RObust Header Compression) over MBMS has been introduced as an optional feature for the MC service servers and MC service clients. If header compression and FEC are both applied to a communication over MBMS, the header compression has to be performed after the FEC encoding. For that, two procedures on how ROHC can be applied for MBMS usage were introduced. Further required aspects to this feature are specified in 3GPP TS 24.380, 3GPP TS 23.246, 3GPP TS 23.468 and 3GPP TS 36.300.

References

[1] 3GPP TS 23.280 Common functional architecture to support mission critical services; Stage 2 (Release 15);
[2] 3GPP TS 23.468 Group Communication System Enablers for LTE (GCSE_LTE); Stage 2 (Release 15);
[3] 3GPP TS 23.246 Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description (Release 15);
[4] 3GPP TS 24.380 Mission Critical Push To Talk (MCPTT) media plane control; Protocol specification (Release 15);
[5] 3GPP TS 36.300 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 15).

10 Features related to WLAN and unlicensed spectrum

10.1 WLAN direct discovery

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750010	Inclusion of WLAN direct discovery technologies as an alternative for ProSe direct discovery	ProSe_WLAN_DD		SP-160957	Intel Corporation; Ana Lucia Pinheiro

Summary based on the input provided by Intel in SP-180227.

3GPP has defined the Proximity Services (ProSe) framework in TS 23.303 [1]. While the overall ProSe framework is largely independent from the actual technology used on the direct UE-to-UE interface (i.e. on PC5), up to and including Rel-14 the ProSe Direct Discovery could only be performed using PC5 interface based on the E-UTRA technology.

To extend the reach of the ProSe framework to a larger consumer population, and given that WLAN support is already available in devices, this feature proposes to integrate selected WLAN direct discovery technologies as an alternative technology for ProSe Direct Discovery. An example of WLAN technologies is the Wi-Fi Neighbour Awareness Networking (NAN) [2] that provides a low-power consumption discovery alternative for discovery of adjacent devices.

Stage 2 work (TS 23.303 [1]) focused on the following:

- Clarification of scope, PC5 definition and ProSe Direct Discovery definition to include WLAN-based PC5.
- Changes to authorisation and provisioning for ProSe to include WLAN-based PC5 and to clarify that some existing provisioning information is only relevant for E-UTRA based PC5.
- Addition of Informative Annex(es) describing how specific WLAN technologies are used for transport of the ProSe Protocol message and/or information elements. In this release of the specification the only WLAN technology that has been specified for use with ProSe Direct Discovery is Wi-Fi NAN (Neighbour Awareness Networking) [2].

The procedural impact on PC5 (UE to UE) and PC3 (UE to ProSe function) interfaces defined in TS 24.334 [3] has been kept to the minimum. Where necessary, a new parameter PC5_tech has been introduced indicating whether ProSe Direct Discovery is performed via E-UTRA-based PC5 or WLAN-based PC5 or both.

Stage 3 aspects of WLAN-based ProSe Direct Discovery are defined in TS 24.334 [3] (addition of PC5_tech in PC3 procedures), TS 24.333 [4] (addition of a new branch to the ProSe Direct Services Provisioning MO), TS 29.345 [5] (addition of PC5_tech in PC6/PC7 procedures), TS 29.230 [6] (new AVP due to PC5_tech) and TS 23.008 [7] (storage of PC5_tech).

Charging aspects of WLAN-based ProSe Direct Discovery are defined in TS 32.277 [8] (enhancement to charging description), TS 32.298 [9] (enhancement to the Charging Data Record (CDR), and TS 32.299 [10] (enhancement to the Diameter charging application).

References

[1] TS 23.303: "Proximity-based services (ProSe); Stage 2".

[2] Wi-Fi Alliance Technical Task Group: "Wi-Fi Neighbor Awareness Networking Technical Specification", Version 1.0.

[3] TS 24.334: "Proximity-services (ProSe) User Equipment (UE) to ProSe function protocol aspects; Stage 3".

[4] TS 24.333: "Proximity-services (ProSe) Management Objects (MO)".

[5] TS 29.345: "Inter-Proximity-services (Prose) function signalling aspects; Stage 3".

[6] TS 29.230: "Diameter applications; 3GPP specific codes and identifiers".

[7] TS 23.008: "Organization of subscriber data".

[8] TS 32.277: "Telecommunication management; Charging management; Proximity-based Services (ProSe) charging".

[9] TS 32.298: "Telecommunication management; Charging management; Charging Data Record (CDR) parameter description".

[10] TS 32.299: "Telecommunication management; Charging management; Diameter charging applications".

10.2 Voice services over WLAN

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760020	Complementary Features for Voice services over WLAN	VoWLAN	S2	SP-170378	Nokia

Summary based on the input provided by Nokia at SA#83 in SP-19xxxx.

This feature provides enhancements required for the support of VoIMS via Trusted and Untrusted WLAN access by providing end-to-end QoS differentiation for better user experience.

This feature includes for untrusted WLAN:

- The establishment of child security associations allowing QoS differentiation;
- The one-to-one mapping between S2b bearers and child security associations in the ePDG;
- The signalling by the network to the UE of the Traffic Flow Template and of the bearer QoS during the creation/modification of the child security association for the uplink direction.

This feature includes for trusted WLAN:

- The establishment of "WLCP bearers" using extensions of the WLCP protocol;
- The one-to-one mapping between S2a bearers and WLCP bearers in the TWAG;
- The signalling by the network to the UE of the Traffic Flow Template and of the bearer QoS during the creation/modification of the WLCP bearer for the uplink direction.

References

[1] TR 23.751, Study on Support of voice over WLAN enhancements

[2] CP-181083, CT aspects of voice over WLAN

10.3 Unlicensed Spectrum Offloading System

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
710006	Unlicensed Spectrum Offloading System	USOS	S2	SP-160117	Edward Hall and Haris Zisimopoulos, Qualcomm Incorporated

Summary based on the input provided by Qualcomm in SP-18xxxx.

USOS enables a network operator to identify and charge for traffic transported over unlicensed access separately to traffic transported over licensed access.

In Release 14, service requirements were agreed for differentiating traffic transported over licensed and unlicensed spectrum for charging and analysis purposes. As part of Release 15, the following procedures have been agreed to enable the core network to instruct the RAN on how & when to track data volume for traffic transported on unlicensed spectrum:

- Initiation of data counting at eNB on UE context initiation based on Subscriber information, local MME policy, and/or per PLMN basis:
    - This ensures that traffic volumes are recorded per operator policy from the earliest opportunity.
- Enforcement of Secondary RAT Restriction for use of unlicensed spectrum:
    - This ensures that operator policy on the use of any of LWA/LWIP/LAA is enforced at the eNB.
- Reporting of data volume to the SGW via the MME during S1-release.
- Reporting of data volume to the SGW via the MME during S1-based handover.
- Reporting of data volume to the SGW via the MME during X2-based handover:
    - These procedures ensure that reporting to the SGW is done when the context is released for any reason.
- Optional reporting of data volume from SGW to PGW.

References

[1] TS 22.101, "Service Principles", clause 33
[2] TS 23.401, "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access"
[3] TR 23.729, "Study on unlicensed spectrum offloading system enhancements"

10.4 Enhancements to LTE operation in unlicensed spectrum

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750065	Enhancements to LTE operation in unlicensed spectrum	LTE_unlic	R1	RP-170848	Nokia

Summary based on the input provided by Nokia in RP-180948.

This work item enhanced UL support for LAA SCell operation in unlicensed spectrum further by specifying support for multiple UL starting and ending point in a subframe, and support for autonomous UL transmission, including channel access mechanisms, core and RF requirements for base stations and UEs, and RRM requirements [1], [2]. Channel access related aspects including physical layer procedures, as well as UE and eNodeB requirements and conformance test are captured into newly introduced specifications TS 37.213, TS 37.106, and TS 37.107, respectively, while changes triggered by other aspects of the work item are captured into TS 36-series specifications [6], [7].

The work item used the Rel-13 study and work items on licensed-assisted access to unlicensed spectrum [3], [4], as well as Rel-14 WI Enhanced LAA for LTE [5] as the basis of the work. This work item was needed to enable more efficient use of UL resources on unlicensed spectrum.

The key functionalities introduced in this work item include the following:

- Additional starting and ending point for PUSCH transmissions on an LAA SCell
    - Starting the PUSCH transmissions at the slot boundary.
    - Ending the PUSCH transmission after symbol #3, or at the slot boundary.

    - Selecting by the UE the starting point for PUSCH transmission at the subframe or slot boundary depending on e.g. successful channel access.

- Autonomous UL Access (AUL)

    - A UE can be RRC configured with a set of subframes and HARQ processes that it may use for autonomous PUSCH transmissions.

    - AUL operation is activated and released with DCI format 0A (TM1) or 4A (TM2).

    - A UE skips an AUL allocation if there is no data in UL buffers.

    - PRB allocation, MCS, as well as DMRS cyclic shift and orthogonal cover code are indicated to the UE with AUL activation DCI.

    - The UE indicates to the eNodeB along with each AUL transmission the selected HARQ-process ID, new data indicator, redundancy version, UE ID, PUSCH starting and ending points, as well as whether the UE-acquired channel occupancy time (COT) can be shared with the eNodeB.

    - The eNodeB may provide to the UE HARQ feedback for AUL-enabled HARQ processes, transmit power command, and transmit PMI.

References

[1] RP-180402, Revised WID: Enhancements to LTE operation in unlicensed, Nokia, RAN#79
[2] RP-180946, Status Report for Work Item on Enhancements to LTE operation in unlicensed spectrum, Nokia, RAN#80
[3] TR 36.889, Feasibility Study on Licensed-Assisted Access to Unlicensed Spectrum V13.0.0
[4] RP-151045, New Work Item on Licensed-Assisted Access to Unlicensed Spectrum, Ericsson, Huawei, Qualcomm, Alcatel-Lucent, RAN#68
[5] RP-162235, Revised Work Item on enhanced LAA for LTE, Ericsson, Huawei, RAN#74
[6] RP-181180, Introduction of enhancements to operation in unlicensed spectrum, RAN1, RAN#80
[7] RP-181249, RAN2 CRs to Enhancements to LTE operation in unlicensed spectrum, RAN2, RAN#80

10.5 Other functionalities related to WLAN and unlicensed spectrum

Charging aspects of WLAN access in EPC (WAEPC_CH) in SP-181186 by Nokia Shanghai Bell

This work introduces the charging extensions in EPC connectivity for UE served under trusted and untrusted WLAN.

The following extensions are introduced in EPC charging:

- A new "IMSI Unauthenticated Flag" added to ePDG and TWAG CDRs for unauthenticated UEs in emergency cases based on Rel-14 "Phase 2 of the Support of Emergency services over WLAN" (SEW2) functionality.

- Enhancement of both trusted and untrusted WLAN user location information with the line identifier, civic address and WLAN Operator, and with the TCP port for untrusted WLAN.

- New "User location Change" trigger for e.g. change in UE local IP address within the ePDG.

In IMS charging, the Access Network information description is extended to also incorporate the trusted and untrusted WLAN user location full definition.

References

[1] SP-180078: Charging aspects of WLAN access in EPC
[2] TS 32.251: Packet Switched (PS) domain charging
[3] TS 32.260: IP Multimedia Subsystem (IMS) charging
[4] TS 32.299: Diameter charging applications
[5] TS 32.298: Charging Data Record (CDR) parameter description

11 Other new features

11.1 Mobile Communication System for Railways

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750007	Mobile Communication System for Railways	MONASTERY		SP-170163	Merkel, Juergen, Nokia

Summary based on the input provided by Nokia in SP-180854.

This work item introduces a first set of requirements to support the specific communication needs of railways within the MCX specification set.

This work item made two additions to the Mission Critical Push To Talk (MCPTT) and the Mission Critical Core (MCCore) functionality. MCCore now supports a limited functional alias functionality, a role based addressing for railways. MCPTT now supports multi user talker control, an additional way of floor control allowing a defined number of talkers talking at the same time in a group communication rather than just one talker at a time.

This work initially started off in 2014 in the International Railway Union (UIC) by an activity to collect the user scenarios to be supported by a Future Railway Communication System (FRMCS). As those user scenarios could not be mapped easily onto use cases in 3GPP based on the input of the UIC a Technical Report (TR22.889) was written summarising 3GPP style use cases, to come up with requirements for introduction in normative specifications.

The term FRMCS is used in UIC still and includes more than just the Mobile Communication System for Railways standardised by 3GPP, see figure below, the light gray dotted boxes are in scope of 3GPP. The darker gray cross hatched boxes are also taken care of by 3GPP in maintaining the GSM legacy.

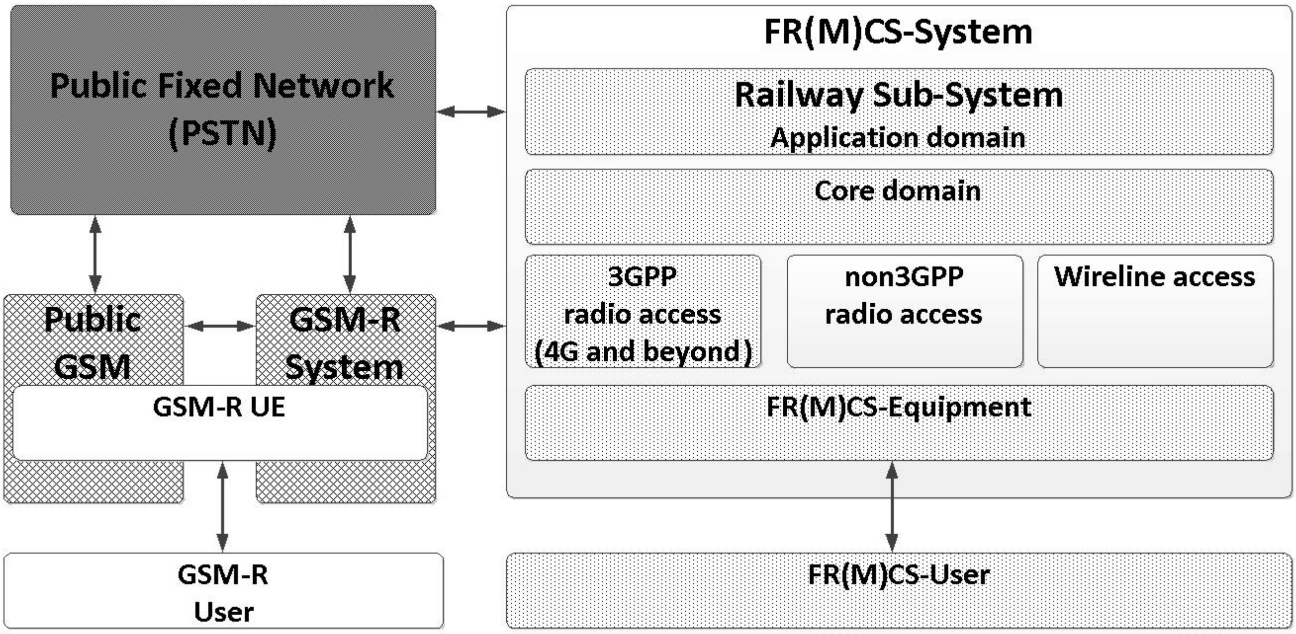


Figure 11.1-1: High-level relation of the Mobile Communication System for Railways / FRMCS and legacy systems

The work item to introduce the findings of TR 22.889 into normative is called "Mobile Communication System for Railways" (MONASTERY) an adapts 3GPP to provide communication to railway users. The Mobile Communication System for Railways eventually will resemble GSM-R and other legacy system in use nowadays and will additionally provide communication capabilities beyond what those systems support. It will provide higher data rates, lower data latencies, multimedia communication, and improved communication reliability.

To facilitate smooth migration from legacy communication systems to the Mobile Communication System for Railways, interworking requirements between legacy communication systems and the Mobile Communication System for Railways are provided.

Amongst others, Mobile Communication System for Railways provides emergency group communication, low latency and high reliable data and video service in high speed train environment. Amongst others it has the following important features:

- Prioritized emergency group communication, train control data and video service
- Seamless connectivity in high speed railway moving environments
- Low latency and high reliable data and video service
- Real time train monitoring and management for safe train operation
- Reliable location tracking including tunnel condition
- Legacy railway communication interworking to GSM-R system
- Specialised forms of addressing used for railway communication

Basically, railway communication services can be categorized into:

- Train control services
- Maintenance services
- Railway specific services (such as Railway Emergency Call, functional addressing, and location-based addressing)
- Other services (providing train crews or train Drivers with information of train operation and interworking with the existing railway communication systems)

In Rel-15 only two additions have been introduced to the Mission Critical Push To Talk (MCPTT) and the Mission Critical Core (MCCore) functionality. MCCore now supports a limited functional alias functionality, a role based addressing for railways. MCPTT now supports multi user talker control, an additional way of floor control allowing a defined number of talkers talking at the same time in a group communication rather than just one talker at a time.

11.2 Northbound APIs related features

11.2.1 Common API Framework for 3GPP Northbound APIs

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770049	Common API Framework for 3GPP Northbound APIs	CAPIF	S6	SP-170798	Suresh Chitturi, Samsung

Summary based on the input provided by Samsung in SP-180862.

In 3GPP, there is a growing interest in the specification of northbound APIs for service exposure of underlying 3GPP functions. This will enable broader range of verticals to integrate with 3GPP systems. Currently, multiple northbound API-related specifications already exist (e.g. APIs for Service Capability Exposure Function (SCEF) defined in TS 23.682 [1], APIs for the interface between MBMS service provider and BM-SC defined in TR 26.981 [2]).

For API consumers or invokers (in particular for 3rd party API developers), a consistent and uniform API framework across multiple northbound API specifications is necessary. In 3GPP Release-15, a Common API Framework (CAPIF) was introduced to support the common API aspects (e.g. authentication, authorization, publishing, discovery, access control policy, etc.), which allows the northbound service APIs to be integrated into CAPIF, such that the API invokers can utilize a single framework for accessing and invoking the 3GPP northbound APIs.

TR 23.722 [3] is a (Stage 2) technical report that analyses existing API frameworks, and identifies requirements and potential architecture solutions to support a common approach for API development within 3GPP, including recommendations for the normative work.

TS 23.222 [4] specifies the (Stage 2) functional architecture model, procedures and information flows needed to support the CAPIF, and guidelines for a consistent development of northbound API (service and CAPIF APIs) in 3GPP.

TS 29.222 [5] specifies the detailed (Stage 3) APIs messages and protocols needed to support CAPIF, based on the Stage 2 functional architecture.

The CAPIF functional model is illustrated in Figure 2-1. The functional model describes the CAPIF core function (CCF) and API provider domain functions i.e. API exposing function (AEF), API publishing function (APF) and API management function (AMF), and as well as the reference points between these functions and the API invoker/consumer.

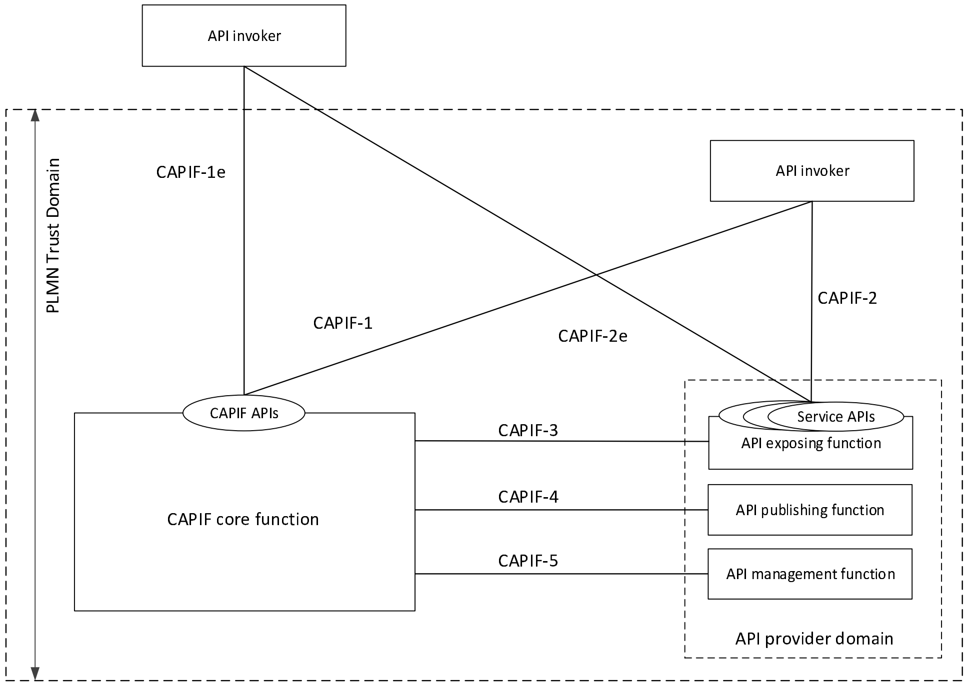


Figure 11.2-1: Functional model for the CAPIF

The functional model as described in TS 23.222 [4], specified architecture-level procedures and information flows for common API aspects, including onboarding, offboarding, publishing, unpublishing, update of service APIs, discovery, registration, authentication, authorization, logging, auditing, monitoring, and topology hiding.

It further specified the application of the functional model to CAPIF deployments (both centralized and distributed deployment), and also CAPIF relationship with network exposure functions defined in 3GPP systems (EPS and 5GS).

The detailed API specification (Stage 3) supporting the CAPIF functional model is provided in TS 29.222 [5], which translates the procedures and interactions over the reference points into following 9 API services (8 CAPIF core function services and 1 API exposing function service):

1. CAPIF_Discover_Service_API - for an API invoker to discover APIs published on the CAPIF core function.
2. CAPIF_Publish_Service_API - for an API publishing function to publish and manage published APIs on CAPIF core function.
3. CAPIF_Events_API - for API invoker and API provider domain functions to subscribe and get notified of CAPIF core function events.
4. CAPIF_API_Invoker_Management_API - for an API invoker to on-board to or off-board from a CAPIF core function.
5. CAPIF_Security_API - for API invoker and API provider domain functions to manage authentication and authorizations of an API invoker for CAPIF core function and service APIs.
6. CAPIF_Logging_API_Invocation_API - for an API exposing function to log service API invocations on CAPIF core function.
7. CAPIF_Auditing_API - for an API management function to retrieve service API invocation logs stored on CAPIF core function
8. CAPIF_Access_Control_Policy_API - for an API exposing function to retrieve access control policies stored on CAPIF core function.
9. AEF_Authentication_API - for an API invoker to intiate authentication by triggering retrieval of authentication credentials from the CAPIF core function by the API exposing function

References

[1] TS 29.122: "T8 reference point for northbound Application Programming Interfaces (APIs)".

[2] TR 26.981: "MBMS Extensions for Provisioning and Content Ingestion".
[3] TS 23.722: "Study on Common API Framework for 3GPP Northbound APIs".
[4] TS 23.222: "Functional architecture and information flows to support Common API Framework for 3GPP Northbound APIs; Stage 2".
[5] TS 29.222: "Common API Framework for 3GPP Northbound APIs".

11.2.2 Northbound APIs for SCEF – SCS/AS Interworking

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760035	Northbound Application Program Interfaces (APIs) for SCEF – SCS/AS Interworking	NAPS	S6	SP-170240	Vaidya, Maulik, Huawei

Summary based on the input provided by Huawei, HiSilicon in SP-171032.

Starting from Rel-13, 3GPP defined the Service Capabilities Exposure Function (SCEF) framework for exposure of those 3GPP network capabilities to the application domain. However, up until Rel-15, 3GPP specified neither the SCEF functional architecture nor its interactions with Service Capability Servers or Application Servers (SCS/AS), i.e. with the application domain. 3GPP was relying on other standardization fora such as OMA or oneM2M.

Triggered by interactions with oneM2M, 3GPP started with Rel-15 to specify the northbound APIs from SCEF to support oneM2M specifications to facilitate a useable end-to-end M2M architecture.

The services and capabilities offered by SCEF to Service Capability Servers or Application Servers (application domain) include:

- Group Message Delivery using MBMS, SCS/AS deliver a payload to a group of UEs
- Monitoring events, for monitoring of specific events in 3GPP system and making such monitoring events information available to SCS/AS,
- High latency communication, handle mobile terminated (MT) communication with UEs being unreachable while using power saving functions like Power Save mode (PSM) or extended idle mode DRX (eDRX), e.g. SCS/AS is notified when the UE becomes available after a Data transmission failure.
- Informing about potential network issues, SCS/AS request to be notified about the network status, e.g. congestion or not, in a geographical area.
- Resource management of background data transfer, SCS/AS requests a time window and related conditions for background data transfer to a set of UEs.
- E-UTRAN network resource optimizations based on communication patterns provided to the MME, the SCS/AS provide the predictable communication patterns (CP) of a UE to the network.
- Support of setting up an AS session with required QoS, SCS/AS request a data session is set up with a specific QoS (e.g. low latency or jitter) and priority handling.
- Change the chargeable party at session set-up or during the session, SCS/AS request to start or stop sponsoring a data session for a UE.
- Non-IP Data Delivery (including the Reliable Data Service and Group Message Delivery via unicast MT NIDD), handle mobile originated (MO) and mobile terminated (MT) communication with UEs, where the data used for the communication is considered unstructured from the EPS standpoint.
- Packet Flow Description management, SCS/AS request to create, update or remove PFDs in the PFDF.
- Enhanced Coverage restriction control, SCS/AS provides the Enhanced Coverage Restriction Control per individual UEs.
- Network Parameter Configuration, SCS/AS issue network parameter configuration requests to suggest parameter values used for Maximum Latency, Maximum Response Time and Suggested Number of Downlink Packets.
- Accessing MTC-IWF Functionality via T8, including Device triggering and MSISDN-less MO-SMS.

The interface between the SCEF and the SCS/AS is referred to as "T8" interface. This feature specifies the architectural description (including message flows, and parameters) of the T8 interface.

The T8 interface supports offline and online charging. The charging architecture and scenarios specific to Northbound API, as well as the mapping of the common 3GPP charging architecture onto the Northbound API, are specified in TS 32.240 [2].

The Northbound API charging architecture, charging principles and scenarios, definition of charging information and content of the CDRs for offline charging are specified in TS 32.254 [3].

The corresponding AVPs and ASN.1 are specified in TS 32.298 [4] and TS 32.299 [5].

References

[1] TS 23.682, Architecture enhancements to facilitate communications with packet data networks and applications.
[2] TS 32.240, Charging architecture and principles
[3] TS 32.254, Exposure function Northbound Application Program Interfaces (APIs) charging
[4] TS 32.298, Charging Data Record (CDR) parameter description
[5] TS 32.299, Diameter charging applications

12 System enhancements

12.1 Control plane - user plane separation

12.1.1 Separation of CP and UP for Split Option 2 of NR

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780071	Separation of CP and UP for Split Option 2 of NR	NR_CPUP_Split	R3	RP-172831	Ericsson

Summary based on the input provided by Ericsson in RP-181149.

The WI specified a new interface, namely E1, that enables interconnecting a gNB-CU-CP (control plane part of the gNB central unit) and a gNB-CU-UP (user plane part of the gNB central unit) [1]. The split of control plane and user plane via E1 interface enhances the split between gNB-CU (gNB central unit) and gNB-DU (gNB distributed unit) defined within the NR WI. It offers the possibility of:

(1) optimizing the location of different RAN functions based on the deployment scenario, (2) support efficient radio resource isolation for network slicing, (3) independent scaling of CP and UP capacity.

In the NR WI, a split of the gNB into a gNB-CU and a gNB-DU is defined. The gNB-CU hosts the RRC, SDAP and PDCP radio protocols, while the gNB-DU hosts the PHY, MAC and RLC radio protocols. The gNB-CU and the gNB-DU are connected via the F1 interface. This WI complements the split defined in the NR WI by enabling to split the gNB-CU into a gNB-CU-CP and a gNB-CU-UP. The gNB-CU-CP hosts the RRC and the instance of the PDCP protocol serving the control plane, while the gNB-CU-UP hosts the SDAP and the instance of the PDCP protocol serving the user plane. The gNB-CU-CP and the gNB-CU-UP are connected via the E1 interface. The gNB-CU-CP is connected to the gNB-DU via the control plane part of the F1 interface (F1-C), while the gNB-CU-UP is connected to the gNB-DU via the user plane part of the F1 interface (F1-U). The resulting gNB architecture inclusive of both the CU-DU split and the CP-UP split, is illustrated in Figure 12.1-1.

The architecture shown in Figure 1 enables the following deployment scenarios [2]:

- Centralized gNB-CU-CP and gNB-CU-UP: The gNB-CU-CP and gNB-CU-UP are deployed in a centralized location, either as one or separate entities. The gNB-CU-CP coordinates the operation of several gNB-DUs. The gNB-CU-UP provides a central termination point for UP traffic in dual-connectivity (DC) configurations.

- Distributed gNB-CU-CP and centralized gNB-CU-UP: The gNB-CU-CP is deployed in a distributed manner and co-located with the gNB-DU. The gNB-CU-CP supervises the operation of a single gNB-DU or of a local cluster of gNB-DUs. The gNB-CU-UP is centralized to provide a central termination point for UP traffic in DC configurations. In this scenario, the latency of the control signalling toward the UE is reduced as the gNB-CU-CP is co-located with the gNB-DU.

- Centralized gNB-CU-CP and distributed gNB-CU-UP: The gNB-CU-CP is centralized to coordinate the operation of several gNB-DUs. The gNB-CU-UP is distributed and co-located with a single gNB-DU or with a local cluster of gNB-DUs and provides low UP latency to support latency-critical services.

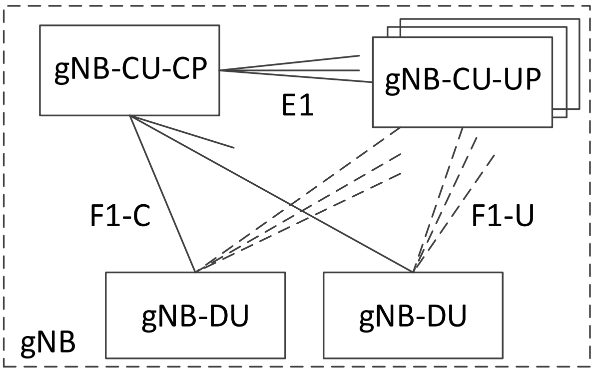


Figure 12.1-1: Architecture with gNB-CU-CP and gNB-CU-UP split

The call-flows showing the most relevant procedures involving the E1 interface (e.g., initial UE attach, handover, bearer context setup and release) are captured in TS 38.401 [3]. The E1 functions and procedures are described in TS 38.460 [4]. The E1 physical layer and the signalling transport, which is based on the SCTP/IP protocol stack, are described respectively in TS 38.461 [5] and TS 38.462 [6]. The E1 application protocol (E1AP) is specified in TS 38.463 [7] and includes the description of: (1) the E1 interface management procedures, which allow to setup the E1 interface and to exchange the relevant configuration data between a gNB-CU-CP and a gNB-CU-UP; (2) the bearer context management procedures, which allow to setup and configure user plane resources to serve UEs.

References

[1] RP-180326, "WID: Separation of CP and UP for Split Option 2 of NR", Ericsson.
[2] TR 38.806, "Study of separation of NR Control Plane (CP) and User Plane (UP) for split option 2".
[3] TS 38.401, "NG-RAN; Architecture Description".
[4] TS 38.460, "NG-RAN; E1 general aspects and principles".
[5] TS 38.461, "NG-RAN; E1 layer 1".
[6] TS 38.462, "NG-RAN; E1 signalling transport".
[7] TS 38.463, "NG-RAN; E1 Application Protocol (E1AP)".

12.1.2 Management Enhancement for EPC Control and User Plane Separation (CUPS)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780036	Management Enhancement for EPC CUPS	ME_CUPS	S5	SP-170954	Huawei (ZHU, Lei)

Summary based on the input provided by Huawei in SP-190029.

This work item specified management enhancements to support EPC CUPS, including performance measurements related to split S/P-GW architecture in TS 32.426, EPC Network Resource Model (NRM) Integration Reference Point (IRP) Information Service (IS) and Solution Set (SS) modifications in TS 28.708 and TS 28.709.

This work item implemented the conclusion of the study on Management Enhancement of CUPS of EPC Nodes (FS_MECUPS). The management enhancement introduced by this work item is based on CUPS architecture specified in TS 23.214.

By introducing those management enhancements, the management specifications include NRM Information Object Class (IOC) definitions to support EPC CUPS and support the performance measurements when the CUPS architecture in TS 23.214 is introduced.

This work item specified the following management enhancements for EPC CUPS:

- Performance measurements related to split S/P-GW architecture in TS 32.426;
- Enhancements for EPC CUPS on NRM IRP; Information Service (IS) in TS 28.708;

- Enhancements for EPC CUPS on NRM IRP: Solution Set (SS) in TS 28.709.

References

[1] SP-170954 "Management Enhancement for EPC CUPS"

[2] TS 23.214 "Architecture enhancements for control and user plane separation of EPC nodes".

[3] TS 32.426 "Telecommunication management; Performance Management (PM); Performance measurements Evolved Packet Core (EPC) network".

[4] TS 28.708 "Telecommunication management; Evolved Packet Core (EPC) Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)".

12.2 Quality of Experience (QoE) related Features

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760038	Enhanced QoE Reporting for MTSI	EQoE_MTSI	S4	SP-170333	Gunnar Heikkilä, Ericsson LM

Summary based on the input provided by Ericsson LM in SP-180037.

QoE reporting is a functionality which allows quality-related metrics feedback from a media client in the UE. In a previous Rel-14 work item IQoE [1], this QoE functionality was enhanced for the DASH streaming specification TS 26.247 [2], giving the operator better possibilities to control such metrics feedback. The current Rel-15 work item EQoE_MTSI [3] introduced the same enhancements also to the MTSI specification TS 26.114 [4], keeping the QoE functionalities for DASH and MTSI services aligned.

The enhancements introduced by EQoE_MTSI in TS 26.114 are:

- Enable QoE configuration and reporting over the control plane.

- Enable geographical filtering of QoE reporting.

- Enhance the content of the QoE reports for the EVS and H.265 codecs.

References

[1] SP-160082, "Work Item Improved Streaming QoE Reporting in 3GPP Services and Networks", 3GPP SA#71, Gothenburg, Sweden, 9-11 March, 2016

[2] TS 26.247, "Progressive Download and Dynamic Adaptive Streaming over HTTP (3GP-DASH)"

[3] SP-170333, "Work Item Enhanced QoE Reporting for MTSI", 3GPP SA#76, Busan, Korea, 7-9 June, 2017

[4] TS 26.114, "Multimedia Telephony; Media handling and interaction"

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750070	Quality of Experience (QoE) Measurement Collection for streaming services in E-UTRAN	LTE_QMC_Streaming	R2	RP-170786	China Unicom

Summary based on the input provided by China Unicom, Huawei, China Telecom in RP-172192 revised in RP-181821.

The benefit of understanding customers' experience, e.g. throughput, data loss, latency, for streaming services has attracted operators' attention. ITU-T P.NATS has released the standards on the model and evaluation of MOS models for streaming services in December 2016. SA4 has specified information about Dynamic Adaptive Streaming over HTTP, DASH, services to be collected from the DASH application on the UE and agreed to support MDT enhancement option for both QoE metrics configuration and QoE metrics reporting [1].A WI on QoE Measurement Collection for streaming services in UTRAN was approved at RAN#73 and a 'container based solution' has been specified [2]. SA5 has studied the management solution for collection of QoE information and proposed use cases, potential requirements and possible solutions. A WI was approved to specify the function Management of QoE measurement collection [3].

Based on the work above, the operators can collect and utilize the QoE measurement information of streaming services to better understand the user experience and optimize their network in E-UTRAN. This work item specified the core requirement for Quality of Experience (QoE) Measurement Collection for streaming services in E-UTRAN [4].

This feature enables the network to collect QoE measurement information from the UE. The feature is activated by Trace Function from the MDT framework. Both signalling based and management based initiation cases are allowed. For the signalling based case, the QoE Measurement Collection is initiated towards a specific UE from CN nodes using the MDT mechanism; for the management based case, the QoE Measurement Collection is initiated from OAM targeting an area (without targeting a specific UE).

The QoE measurement configuration from OAM or CN in E-UTRAN is included in a container of RRCConnectionReconfiguration message and forwarded to the UE similar to in UTRAN. For transferring the QoE measurement report, a new SRB4 and a new uplink RRC message "application layer measurement report" are introduced. SRB4 is configured via RRCConnectionReconfiguration meassage. A container in the new message is defined to send the QoE measurement report.

The QoE measurement configuration and measurement reporting are supported in RRC_CONNECTED state only. E-UTRAN can release the QoE measurement configuration towards the UE at any time. If not explicitly released by the eNB, QoE measurement will be continued in case of intra-eNB HO and inter-eNB HO and both source and target cell belong to defined same measurement reporting area.

References

[1] SP-160082, WID of Improved Streaming QoE Reporting in 3GPP Services and Networks.

[2] RP-161917, New WI proposal: Quality of Experience (QoE) Measurement Collection for streaming services in UTRAN.

[3] SP-170483, New WID on Management of QoE measurement collection

[4] last approved WID: RP-170956.

[5] CRs:
RAN2: TS 36.300 CR1073, TS 36.306 CR1519, TS 36.331 CR3144
RAN3: TS 36.413 CR1543r2, TS 36.423 CR1045r1

12.3 Security-related improvements

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
730051	Security Assurance Specification for eNB network product class	SCAS_eNB	S3	SP-160570	Marcus Wong, Huawei Technologies

R15 was completed with the addition of enhancements to eNB requirements and test cases to support NSA architecture Option 3 to the SCAS_eNB specification.

12.4 Virtual Reality (VR), TV, Codec and multimedia-related improvements

12.4.1 Test Methodologies for the Evaluation of Perceived Listening Quality in Immersive Audio Systems

Unique_ID	Name	Acronym	WG	WG	WID	WI Rapporteur
770022	Test Methodologies for the Evaluation of Perceived Listening Quality in Immersive Audio Systems	LiQuImAS	S4	SP-170609	Qualcomm	China Unicom

Summary based on the input provided by Qualcomm Incorporated in SP-171006.

This work item developed objective and subjective test methodologies for the assessment of Immersive Audio Systems. A focus was given in objective and subjective test methodologies suitable for Virtual Reality Streaming applications in support of the VRStream work item.

Within this work item [1], subjective and objective test methodologies for the assessment of immersive audio, including audio rendering aspects with motion tracking, were developed and documented in the new TS 26.259 and TS 26.260.

The work item also generated an internal technical report in TR 26.861 documenting studies and different approaches for the assessment of immersive audio.

12.4.2 Addition of HDR to TV Video Profiles

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770023	Addition of HDR to TV Video Profiles	HDR	S4	SP-170610	Thomas Stockhammer, Qualcomm

Summary based on the input provided by Qualcomm Incorporated in SP-171006.

This summary reports on the normative specification progress accomplished during the course of the HDR work item [1]. Primarily, the TV Video Profile specification in TS.26.116 [2] was updated to support High Dynamic Range (HDR) video. In addition, the media capabilities are enabled in PSS and MBMS by updates of the specifications TS 26.234 [3] and TS 26.346 [4], respectively.

HDR is one of the biggest movements in mobile devices recently. It's following a trend that's been tearing through the TV industry over the past few years. While it is still early days for this emerging technology, it is also making a difference for mobile video and it requires consistent standardized technologies. HDR stands for high dynamic range and it's been a buzzword in TV for the past couple of years. HDR is often assigned to display capabilities, i.e. that the display is able to produce a wider range of colours, bringing greater authenticity, but also about brightness and contrast. In order to feed such new display technologies, consistent and efficient delivery formats have been established in the TV world. The work item supports the move of such experience to mobile devices to create the same stunning experience: richer colors, better contrast and brighter highlights.

The work item addresses the definition of consistent and efficient HDR video signals and receiver capabilities for TV centric services in 3GPP. To this end, the experiences and technologies in the TV centric markets have been reviewed and adapted to 3GPP Video. The work item defines the relevant extensions to support High Dynamic Range in 3GPP TV Video Profiles. Specifically, an HDR video profile based on the Perceptual Quantizer (PQ) is defined, following the recommendations in ITU-R BT.2100. This includes the use of H.265 (HEVC) for compression, the definition of transfer functions and color primaries, the definition of relevant metadata as well as the integration into PSS and MBMS services. The completion of the work brings the 3GPP TV Video Profile specification on par with other TV Video standards, e.g. the ones defined for example by DVB and ATSC.

References

[1] Tdoc SP-170610, "Addition of HDR to TV Video Profiles (HDR)"
[2] TS 26.116, "Television (TV) over 3GPP services; Video profiles"
[3] TS 26.234, "Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs"
[4] TS 26.346, "Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs"

12.4.3 Virtual Reality Profiles for Streaming Media

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770025	Virtual Reality Profiles for Streaming Media	VRStream	S4	SP-170612	Thomas Stockhammer, Qualcomm

Summary based on the input provided by Qualcomm Incorporated in SP-180746.

This summary reports on the normative specification progress accomplished during the course of the VRStream work item [1]. Primarily, the "Virtual Reality Profiles for Streaming Media" specification in TS.26.118 [2] was developed to support Virtual Reality (VR) in streaming applications. In addition, the media capabilities are enabled in Packet Switched Streaming (PSS) Services and Multimedia Broadcast Multicast Service (MBMS) by updates of the specifications TS 26.234 [3] and TS 26.346 [4], respectively. The characterization results for audio media profile proponents are documented in TR 26.818 [5].

Based on the findings in TR 26.918 [6], the work item developed the first set of Virtual Reality Profiles for Streaming Media. Virtual Reality (VR) is the ability to be virtually present in a space created by the rendering of natural and/or synthetic image and sound correlated by the movements of the immersed user allowing interacting with that world. Virtual reality typically assumes a user to wear a head mounted display (HMD), to completely replace the user's field of view with a simulated visual component, and to wear headphones, to provide the user with the accompanying audio. In the first set of technologies defined in TS 26.118, VR users are expected to be able to look around from a single observation point in 3D space, also referred to as three degrees of freedom (3DoF). It allows the user to (i) tilt side to side (Rolling), (ii) tilt forward and backward (Pitching), and (iii) turning left and right (Yawing). The specification defines a 3GPP 3DOF reference and coordinate system as well as an end-to-end architecture. In the reference client, it is assumed that pose information, i.e. the position derived by the head tracking sensor expressed by (azimuth; elevation; tilt angle), is continuously available to the VR renderer in order to render the viewport. Based on the system model, video and audio technologies are defined including system technologies (DASH and file format), suitable codecs and rendering technologies.

Specifically on video, three operation points (combination of elementary stream and rendering metadata) and three corresponding media profiles are defined, namely:

- Basic Video: Based on H.264/AVC High Profile Level 5.1 for mono only, single stream, and reuse of single stream DASH streaming. This profile addresses legacy service and devices. This profile allows reuse of existing file format and DASH implementations also for VR Streaming.

- Main Video: Based on H.265/HEVC High Profile Level 5.1 allowing mono and stereo, single stream, but either a single or multiple independent Adaptation Sets may be offered, such that a client can choose based on its current pose. This profile allows reuse of existing file format and DASH implementations also for VR Streaming.

- Advanced Video: based on H.265/HEVC High Profile Level 5.1, but in addition to the Main Video features, it permits to stream and combine multiple tiles at the receiver for improved quality.

For PSS, all three profiles are added, the first one is mandatory ('shall'), the second one recommended ('should') and the third one allowed ('may'). For MBMS, the first two profiles are added, the first one is mandatory ('shall'), the second one is recommended ('should') and constrained to non-viewport adaptive streaming.

For audio, one solution was selected and is documented in TS 26.118, namely MPEG-H 3D Audio Baseline profile. This technology enables the distribution of channel, object and scene-based 3D audio. Additional interesting technologies enabling the distribution of channel, object and scene-based 3D audio were considered, and the characterization results of all proposed technologies are documented in TR 26.818 [5].

In addition to media specific metadata, system metadata is added to TS 26.118 to support rendering of 360 experiences on 2D screens, including the aspects of rendering without pose information. Basic requirements for a full audio-visual experience are documented under the umbrella of VR Presentations.

The completion of the work item provides a set of consistent technologies for Virtual Reality in Rel-15 for 5G Phase 1. It is providing a response to the demand identified during the successful joint 3GPP/VR-IF Workshop on Virtual Reality that took place in December 2017 [7], which was an integral part of the development of 3GPP Virtual Reality Profiles for Streaming Applications.

References

[1] Tdoc SP-170612, "3GPP Virtual Reality Profiles for Streaming Media"
[2] TS 26.118, "3GPP Virtual Reality Profiles for Streaming Applications"
[3] TS 26.234, "Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs"
[4] TS 26.346, "Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs"
[5] TR 26.818, "Virtual Reality (VR) streaming audio; Characterization test results"
[6] TR 26.918, "Virtual Reality (VR) media services over 3GPP"
[7] http://www.3gpp.org/news-events/3gpp-news/1903-virtual-reality-ws

12.4.4 FEC and ROHC Activation for GCSE over MBMS

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790020	FEC and ROHC Activation for GCSE over MBMS	FRASE	S4	SP-180206	Bouazizi, Imed, Samsung Electronics Co., Ltd

Summary based on the input provided by Samsung Electronics Co., Ltd . in SP-180881.

As part of extensions to the GCSE framework, this work adds the capability to perform Forward Error Correction and/or Robust Header Compression.

As part of this work item, the capability to perform FEC and ROHC for MBMS traffic using the GC or the Transport delivery method are added. Both tools can be configured through the external interfaces to the BM-SC, namely the MB2 and xMB. Currently, activation at service level is allowed, so that FEC/ROHC can be applied to all streams of the service or to none of them.

References

[1] TS 26.346, Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs

[2] TS 23.468, Group Communication System Enablers for LTE (GCSE_LTE); Stage 2

[3] TS 29.116, Representational state transfer over xMB reference point between content provider and BM-SC

12.4.5 Media Handling Aspects of 5G Conversational Services

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790021	Media Handling Aspects of 5G Conversational Services	5G_MTSI_Codecs	S4	SP-180033	Oyman, Ozgur, Company: Intel

Summary based on the input provided by Intel in SP-180669.

This summary reports on the normative specification progress accomplished during the course of the 5G_MTSI_Codecs work item [1]. The related agreed CRs can be found in Tdocs S4-180570 (CR 26.114-0431) [2], S4-180493 (CR 26.223-0011) [3], S4-180651 (CR 26.114-0433) [4] and S4-180883 (CR 26.114-0434) [5].

The work item specified a few key media handling aspects of 5G conversational services. More specifically, this work item conducted normative work in TS 26.114 and TS 26.223 addressing the codec requirements for a 5G MTSI and IMS Telepresence UE, including the following aspects, as aligned with the agreed conclusions in TR 26.919:

1. For video, mandate support for H.265/HEVC, as per the CRs in Tdocs S4-180570 (CR 26.114-0431) [2] and S4-180493 (CR 26.223-0011) [3]

2. For speech, mandate support for narrow-band (NB), wideband (WB) and super-wideband (SWB) communication as per the CR in S4-180964 (CR 26.114-0433) [4].

In addition, the MTSI procedures for basic NR access and RAN assisted codec adaptation over NR access were also specified, as per the CR in S4-180883 (CR 26.114-0434) [5].

References

[1] Tdoc SP-180033, New WID on "Media Handling Aspects of 5G Conversational Services" (5G_MTSI_Codecs)

[2] Tdoc S4-180570, CR 26.114-0431, "Video Codec Requirements for 5G MTSI Client"

[3] Tdoc S4-180493, CR 26.223-0011, "Video Codec Requirements for 5G Devices"

[4] Tdoc S4-180964, CR 26.114-0433, "Speech Codecs for 5G MTSI Clients"

[5] Tdoc S4-180883, CR 26.114-0434, "Adding NR and ANBR Support"

12.5 Codec and multimedia-related improvements

12.5.1 Receive acoustic output test in the presence of background noise

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780020	Receive acoustic output test in the presence of background noise	RAOT	S4	SP-170835	ISBERG, Peter, Sony Mobile Communications

Summary based on the input provided by Sony Mobile Communications in SP-180460.

This work item developed requirements and test method for receive loudness rating RLR in the presence of background noise. The work was initiated following a liaison statement [3] concerning acoustic safety limits, expressing a need for a test that covers not only silent lab conditions but also noisy scenarios.

The new test described in a change request [2] to TS 26.132 uses:

- background noise playback in a lab environment, reusing methods which are already specified for other 3GPP test cases
- speech playback in the receive (downlink) direction, using standardized signals
- synchronization mechanisms enabling repeatable stimuli to the UE
- artificial ear recordings using a head and torso simulator
- cancelation of noise components for accurate measurement of the UE output signal, despite the noisy measurement situation

The requirements described in a change request [2] to TS 26.131 specify a limit for the receive loudness rating RLR in the presence of background noise, for the maximum setting of the volume control, in handset and headset modes for all speech bandwidths (narrowband, wideband and super-wideband/fullband). The limit is the same as already specified for the case where no background noise is applied.

References

[1] SP-170835, New WID on Receive acoustic output test in the presence of background noise
[2] SP-180273, CRs to TS 26.131 and TS 26.132 on Receive acoustic output test in the presence of background noise (Release 15) (RAOT), TSG S4
[3] S4-171243, LS on Acoustic Safety Limits, CTIA CPWG
[4] S4-180616, LS reply on receive acoustic output test (RAOT), TSG S4

12.5.2 Server and Network Assisted DASH for 3GPP Multimedia Services

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
740011	Server and Network Assisted DASH for 3GPP Multimedia Services	SAND	S4	SP-170031	Ozgur Oyman, Intel

Summary based on the input provided by Intel in SP-180687.

This summary reports on the normative specification progress accomplished during the course of the SAND work item [1]. The related agreed CRs can be found in Tdocs S4-170404 (CR26233-0013) [2] and S4-170732 (CR26247-0099) [3].

MPEG has developed a set of technologies under the name Server and Network assisted DASH (ISO/IEC 23009-5) [SAND]. MPEG SAND defines message formats and interfaces among server, client, edge proxy and network elements toward enhancing streaming quality of experience (QoE). During Rel-14, 3GPP SA4 conducted the study item FS_SAND toward identifying enhancements offered by MPEG SAND in the 3GPP environment, and recommend necessary modifications to the 3GPP specifications including DASH to enable these enhancements. Relevant architectures, use cases, gap analysis and potential solutions pertaining to 3GPP enhancements based on MPEG SAND have been documented in TR 26.957.

Aligned with the conclusions of the FS_SAND study item documented in clause 11 of TR 26.957, the Rel-15 work item on SAND was conducted and the following functionality based on MPEG SAND in ISO/IEC 23009-5 was introduced into 3GPP DASH:

- Streaming enhancements via intelligent caching, processing and delivery optimizations on the server and/or network side, based on feedback from clients on anticipated DASH Segments, accepted alternative DASH Representations and Adaptation Sets, client buffer level and requested bandwidth.

- Improved adaptation on the client side, based on network/server-side information such as cached Segments, alternative Segment availability, recommended media rate and network throughput/QoS.

In particular, normative work on TS 26.247 was completed to introduce SAND support with the definition of three SAND modes, namely 'Proxy Caching', 'Network Assistance' and 'Consistent QoE/QoS'. SAND messages and protocols to use with 3GPP DASH were defined for each of these SAND modes, and normative behaviours for SAND message handling for the 3GP DASH client and DASH-aware network element (DANE) were specified. Procedures for DANE discovery have also been described in TS 26.247. In addition, use of SAND functionality for enabling network assistance, proxy caching and consistent QoE/QoS have been described in detail in TS 26.247, with the specification of relevant SAND message usage and extensions where necessary, and the inclusion of example workflows. Finally, TS 26.233 has also been updated to describe SAND support in PSS and the impacts on related system architecture functions. The related agreed CRs can be found in Tdocs S4-170404 (CR26233-0013) and S4-170732 (CR26247-0099).

References

[1] Tdoc SP-160779, New work item on "Server and Network Assisted DASH for 3GPP Multimedia Services (SAND)"

[2] Tdoc S4-170404, CR26233-0013 rev1 "SAND Support in PSS"

[3] Tdoc S4-170732, CR26247-0099 rev3 "SAND Support in 3GPP DASH"

12.5.3 SAND for MBMS

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770021	SAND for MBMS	SAND4M	S4	SP-170827	Thomas Stockhammer, Qualcomm Inc

Summary based on the input provided by Qualcomm Incorporated in SP-180521.

This summary reports on the normative specification progress accomplished during the course of the SAND4M work item [1]. Primarily, a SAND mode was defined in TS 26.247 [2] to support SAND for multiple network access (SAND4M). In addition, consistent support of hybrid MBMS services in TS 26.346 [3] was added, supporting also unicast-supplemented services. The interface/API between MBMS client and DASH client in TS 26.347 [4] was updated to add the SAND4M mode to the MBMS client and DASH client. The now outdated MBMS User Service Guidelines in TR 26.946 [5] are updated as well.

For the operation of the DASH client on top of an MBMS client, in particular for the case of MBMS Operation on Demand (MooD) and for MBMS/unicast service continuity, a need was identified to have API level communication between the MBMS client and the DASH client. Based on the 3GPP requirements, initially documented in TR 26.946 [5], MPEG initiated and completed the work on Server and Network Assisted DASH (SAND) in ISO/IEC 23009-5, which provides enablers for a consistent network assistance for DASH. With completion of the work in MPEG, the guidelines in TR26.946 are migrated to normative specification in 3GP-DASH in TS 26.247 [2] and TS 26.347 [4] to support of MBMS Operation on Demand (MooD) and for MBMS/unicast service continuity.

In addition, unicast-supplemented service offerings in MBMS, for which certain resources are only available on unicast and these resources provide an additional user experience, are added in addition to the already existing unicast fallback mode to support consistent support for these services. This for example permits to offer an MBMS service for which a second language is only available over unicast and therefore needs to be made available to the DASH client even if the DASH client is in broadcast coverage.

In order to provide a consistent support for the above features a SAND mode for multiple network support is defined in TS 26.247 [2] and the relevant enablers for the MBMS client and the interface between DASH client and the MBMS client are defined. In addition, consistent support of hybrid MBMS services in TS 26.346 [3] was added, supporting also unicast-supplemented services.

References

[1] Tdoc SP-170608, "SAND for MBMS (SAND4M)"

[2] TS 26.247, "Transparent end-to-end Packet-switched Streaming Service (PSS); Progressive Download and Dynamic Adaptive Streaming over HTTP (3GP-DASH)"

[3] TS 26.346, "Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs"

[4] TS 26.347, "Multimedia Broadcast/Multicast Service (MBMS); Application Programming Interface and URL"

[5] TR 26.946, "Multimedia Broadcast/Multicast Service (MBMS); User Service Guidelines"

12.5.4 Framework for Live Uplink Streaming

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760037	Framework for Live Uplink Streaming	FLUS	S4	SP-170824	Park, Kyungmo, SK Telecom

Summary based on the input provided by Samsung Electronics Co., Ltd. in SP-180535.

The FLUS Work Item [1] introduces a new framework that can be used to receive live captured streams from UEs, potentially connected to external camera systems. FLUS can be realized as an extension to the existing MTSI service, allowing the live streaming of immersive media such as 360 video. Alternatively, FLUS can be accessed through a RESTful API that allows UEs to identify a receiver for their live streams during a live streaming session.

The Framework for Live Uplink Streaming is a framework that offers the following functionalities to the UE:

- A definition of typical source (capture) systems and their metadata.
- An extension to MTSI to enable integration of live captured streams, such as VR streams, as part of a video call.
- A flexible framework that can be used to realize live streaming sessions offering:
  - A RESTful-based Control Plane to select an end point for the live stream, negotiate session parameters, and establish and terminate a session.
  - A flexible user plane that allows users of the FLUS framework to deploy their preferred instantiation with full control of the protocols and media formats.
  - A documentation of a selected set of instantiations as part of TR 26.939 [2] that is based on fragmented MP4 files.

The FLUS framework comes with placeholders for descriptions of any following processing and distribution of the received live streams. This can for instance indicate that content is to be stitched into a 360 VR video and then distributed through PSS DASH.

The following figure summarizes the key functions of the FLUS Framework:

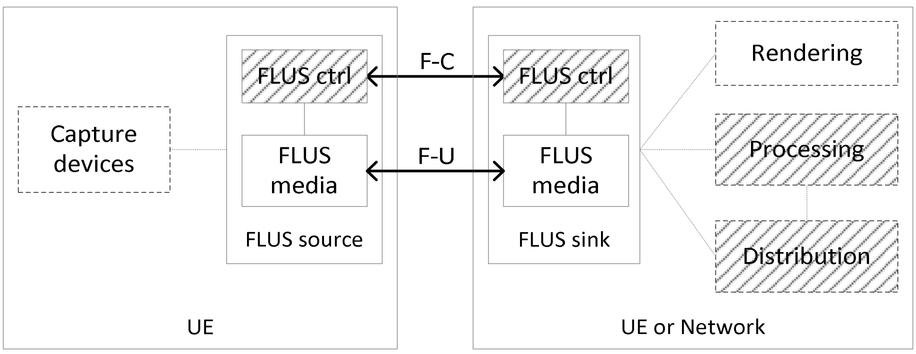


Figure 12.5-1: FLUS-1: key functions of the FLUS Framework

References

[1] TS 26.238, Uplink Streaming
[2] TR 26.939, Guidelines on the Framework for Live Uplink Streaming (FLUS)

12.5.5 Further video enhancements for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750069	Further video enhancements for LTE	LTE_ViLTE_enh2	R2	RP-172726	CMCC

Summary based on the input provided by CMCC in RP-172381 revised in RP-181747.

This work item specifies enhancements for long backhaul latency reduction for video.

In this WI, UE assisted local cache is introduced.

UE assisted local cache is a solution to address long backhaul latency issue. The UE is allowed to transmit assistance information bit to eNB to enable the eNB to identify whether an uplink data needs to be transferred to the local cache entity, which may be co-sited with eNB or has direct connection with eNB, by operator implementation.

UE can report to the network its capability of supporting UE assistance information for local cache. If supported, the UE assisted local cache function can be activated by the eNB. After that, the UE may indicate the assistance information in the uplink PDCP PDU. Whether the UE includes this assistance information is based on for instance the service from the application layer the UE requests that support local cache handling.

References

[1] Last approved WID: RP-172726
[2] Last status report: RP-181745
[3] R2-1813086 TS 36.331 CR to introduce assistance information for local cache CMCC
[4] R2-1808297 TS 36.300 CR to introduce assistance information for local cache CMCC
[5] R2-1808301 TS 36.323 CR to introduce assistance information for local cache CMCC
[6] R2-1808308 TS 36.306 CR to introduce assistance information for local cache CMCC

12.5.6 Speech quality with ambient noise

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780021	Speech quality in the presence of ambient noise for super-wideband and fullband modes	SPAN	S4	SP-170836	HEAD acoustics GmbH

Summary based on the input provided by HEAD acoustics GmbH in SP-180838.

This work item developed speech quality requirements and performance objectives for super-wideband (SWB) and fullband (FB) terminals in the presence of background noise. The quality prediction models for this purpose were already introduced in Rel-14 of the acoustic terminal measurement specifications TS 26.131 [1] and TS 26.132 [2], but limits were only available in a provisional state.

Within this work item [3], multiple UEs equipped with EVS-SWB codec were evaluated in handset and handheld hands-free mode regarding their speech quality performance according to ETSI TS 103 281 [4] in the presence of background noise. Based on this data, numbers for performance requirements and objectives could be derived, resulting in a first change request [5] on initial, but still provisional values in TS 26.131.

After the investigation of the reproducibility of the method regarding different measurement rooms, a change request [6] with final performance requirements and objectives to Rel-15 of TS 26.131 was agreed.

In addition, another change request [7] to TS 26.132 regarding the assessment method was agreed within this work item. In Rel-14 of TS 26.132, the two prediction models (A and B) according to ETSI TS 103 281 were used. Due to a pending commercially available implementation of model B, the measurement procedure was modified to use only model A.

References

[1] TS 26.131, "Terminal acoustic characteristics for telephony; Requirements"

[2] TS 26.132, "Speech and video telephony terminal acoustic test specification"
[3] SP-170836, "New WID on Speech quality in the presence of ambient noise for super-wideband and fullband modes"
[4] ETSI TS 103 281, "Speech quality in the presence of background noise: Objective test methods for super-wideband and fullband terminals", 04/2017
[5] S4-180582, CR "Addition of requirements and objectives for SWB and FB terminals"
[6] S4-180923, CR "Requirements and objectives for SWB and FB terminals"
[7] S4-180921, CR "Modification of speech quality assessment method"

12.6 Active Antenna System (AAS)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
710074	Enhancements of Base Station (BS) RF and EMC requirements for Active Antenna System (AAS)	AASenh_BS_LTE_UTRA	R4	RP-161668	Huawei
770034	Self-Organizing Networks (SON) for Active Antenna System (AAS) deployment management	OAM_SON_AAS	S5	SP-170658	Nokia (Weixing Wang)

Summary based on the input provided by Huawei in RP -172345 (long version), revised in RP-182112 (shorter version, more in line with the rest of this present document).

The WI added a full set of OTA requirements to the AAS BS specification for MSR, single RAT UTRA and single RAT E-UTRA AAS BS with no conducted interface.

The OTA AAS BS is a system which contains multiple transceiver (i.e. ≥8 for E-UTRA and MSR, or ≥4 for UTRA) units and a composite antenna. Since a single OTA AAS BS is comparable to a non-AAS BS with multiple transceivers, the eAAS requirements aim to ensure that the same protection and performance is provided as a non-AAS BS with 8 transceivers for E-UTRA and MSR and with 4 transceivers for UTRA.

The previous AAS WI produced an AAS BS specification for an AAS BS which provided access to a conducted interface. Requirements were applied at both the conducted interface (the Transceiver Array Boundary) and the radiated interface. An AAS BS conforming to the release 13/14 AAS BS requirements is now referred to as a hybrid AAS BS in the release 15 specification. To enable AAS BS with larger number of transceiver units and higher frequencies, where maintaining a conducted interface may limit implementation, all OTA requirements have been developed enabling the OTA AAS BS to be treated as a black box that is tested externally using radiated test signals.

12.6.1 Architecture and interfaces

The OTA AAS BS architecture is similar to the hybrid AAS BS architecture with the removal of the conducted interface (the transceiver array boundary).

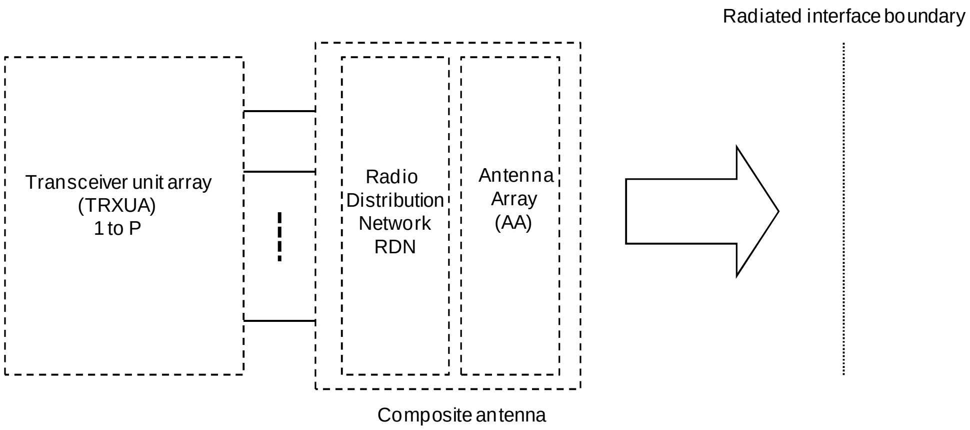


Figure 12.6.1-1: Radiated points of reference of *OTA AAS BS*

The Radiated Interface Boundary (RIB) is an interface at which the OTA requirements can be specified. As an OTA AAS BS is expected to have a large number of transceiver units, the minimum number of transceiver units is restricted to 8 for E-UTRA and MSR and to transceiver 4 for UTRA.

12.6.2 OTA requirements

Transmitter requirements

Transmitter requirements can be classified into 3 types:

1. Directional requirements

   Directional requirements are specified over the OTA peak directions set (for power accuracy requirement) or the OTA coverage range (for signal quality requirements). Multiple OTA peak directions sets may be declared by the BS manufacturer for the widest and narrowest possible beam widths along with the associated EIRP values. There is only a single OTA coverage range declared, all the OTA peak directional sets have to be within the OTA coverage range.

   Examples of the directional requirements are: EIRP accuracy, power dynamics, control signal power accuracy, signal quality (EVM, frequency accuracy, TAE).

2. TRP emissions

   Emissions limits are specified as TRP as in the dynamic cellular environment where UE's can be considered as randomly located it is the Total Radiated Power (TRP) which dominated the average level of interference to adjacent networks rather than the instantaneous peak power.

   Examples of the TRP requirements are: Wanted signal power, unwanted emissions (ACLR, UEM, SEM) and Tx spurious emissions.

3. Co-location requirements

   Co-location requirements are a new type of OTA requirements introduced in Rel-15 RAN4 BS specifications, which specify performance in co-location scenarios. OTA co-location requirements define the BS co-location scenario and specify power levels into and out of a Co-location Reference Antenna (CRA) placed next to the AAS BS.

   Examples of co-location requirements are: Tx OFF power, protection of RX, co-location emissions, TX IMD.

Receiver requirements

With the exception of the receiver spurious emissions (which is TRP like the transmitter spurious emissions) all the receiver requirements are based on receiving a wanted signal at a specified power level, either on its own or in the presence of an interferer.

The OTA receiver requirements have 2 types of OTA sensitivity defined:

1. OTA sensitivity - highest gain assumed hence lowest EIS.

   The Rel-13/14 specification included OTA sensitivity requirement which was based on a declared range of angle of arrivals (RoAoA) for the UL signal. The OTA sensitivity requirement is by BS manufacturer declaration and was intended to capture the effects of the antenna (such as scan loss). Multiple declarations can be made with different EIS values and RoAoA's. One of the declarations will be based on the maximum antenna gain and hence will represent the best case EIS, this value is defined as OTA minimum sensitivity.

2. OTA reference sensitivity - lowest gain assumed hence highest interferer levels.

   The OTA reference sensitivity is the minimum level of sensitivity to be achieved over the OTA REFSEN RoAoA which is defined as the RoAoA determined by the contour defined by the points at which the achieved EIS is 3dB higher than the achieved EIS in the reference direction. It is equivalent to the sensitivity a passive system would achieve over the same RoAoA. The level is also used to specify the maximum interferers to be seen by each receiver unit input.

Each of the interference requirements are specified with respect to:

- the OTA sensitivity, or
- the OTA reference sensitivity, or
- Both, depending on the nature of the requirement.

For in-band interference requirements (i.e. dynamic range, ACS ICS, in-band blocking, RX IMD) wanted and interferer signal are specified as having the same angle of arrival. The relative difference between the wanted signal and the interferer is the same as the conducted requirement in all cases.

Out of band blocking requirement is specified as field strength (in V/m) and is the same for all frequencies. The wanted signal is an offset from $EIS_{minSENS}$.

For co-location blocking tests a radiated wanted signal, based on an offset from $EIS_{minSENS}$, is specified in the same way as the other interference requirements. The interferer is applied via CRA, the level of the interferer is specified at the conducted input to the CRA.

EMC requirements

EMC radiated emission requirements are already OTA and are hence merged into the RF radiated spurious emission requirements. As the RF requirements are dominant, the OTA emissions are captured in the BS RF specification and this is referenced from the RAN4 BS EMC specification.

The EMC radiated immunity requirements generate much higher interferer levels than the RF blocking requirements and hence the two aspects have to be separated. As the OTA AAS BS has an intentional radiator and its wanted performance is specified by the declared RoAoA, these 2 types of RAN4 requirements are separated by a spatial mask (i.e. so called spatial exclusion) with radiated immunity requirement only specified outside the declared RoAoA.

References

[1] RP-171745 WID -Enhancements of Base Station (BS) RF and EMC requirements for Active Antenna System (AAS)
[2] RP-172344 eAAS Status Report to TSG (RAN#78)
[3] TR 37.840 Study of Radio Frequency (RF) and Electromagnetic Compatibility (EMC) requirements for Active Antenna Array System (AAS) base station
[4] TR 37.842 Evolved Universal Terrestrial Radio Access (E-UTRA) and Universal Terrestrial Radio Access (UTRA) Radio Frequency (RF) requirement background for Active Antenna System (AAS) Base Station (BS)
[5] TR 37.843 E-UTRA and UTRA Radio Frequency (RF) requirement background for Active Antenna System (AAS) Base Station (BS) radiated requirements
[6] TS 37.105 Technical Specification Group Radio Access Network; Active Antenna System (AAS) Base Station (BS) transmission and reception
[7] R4-1714387 CR to TS 37.105: eAAS technical specification v.15.0.0
[8] TS 37.114 Active Antenna System (AAS) Base Station (BS) Electromagnetic Compatibility (EMC)
[9] R4-1714386 Big CR to TS 37.114: eAAS EMC specification, v15.0.0

12.7 OAM improvements

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760055	Control and monitoring of Power, Energy and Environmental (PEE) parameters in Radio Access Networks (RAN)	PEE_CMON	S5	SP-170479	Jean-Michel CORNILY, ORANGE

Summary based on the input provided by Orange at SA#83 (no SA tdoc number at the time this input is incorporated here).

This WI specifies how OA&M supports the control and monitoring of Power, Energy and Environmental (PEE) parameters in pre-5G Radio Access Networks (RAN). It specifies an OA&M architecture and interfaces to support such capabilities. It relies on Energy Efficiency (EE) KPIs for Radio Access Networks, as well as their measurement methods, as they have been defined jointly by ETSI TC EE and ITU-T SG5. Collected parameters serve as input for calculating the Energy Efficiency KPI of live base stations, defined by ETSI TC EE as follows:

$$EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$$

where DV is the Data Volume, expressed in bit, transported across a network element, and EC is the Energy Consumption, expressed in Joule, of the same network element.

This work item:

- Specifies requirements on the interface between the Remote Management Server (RMS) (cf. ETSI ES 202 336-12), located at the NM layer, and either the 3GPP Domain Manager (DM), or a Power, Energy and Environmental (PEE) XCU/DGU (XML enabled CU / Data Gathering Unit) (cf. ETSI ES 202 336-12), or a Vendor-Specific Remote Management Server (VS-RMS), so as to enable the control and monitoring of PEE parameters of 2G, 3G and LTE base stations having either built-in PEE sensors or external PEE sensors;
- Specifies the protocol-independent information model;
- Produces a solution set based on (HTTP-based) REST / JSON.

References

[1] TS 28.304: "Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Requirements".
[2] TS 28.305: "Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Information Service (IS)".
[3] TS 28.306: "Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Solution Set (SS) definitions".
[4] TR 32.856: "Study on Operations, Administration and Maintenance (OAM) support for assessment of energy efficiency in mobile access networks".
[5] ETSI ES 202 336-12 (V1.1.1) (2015-06): "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".
[6] ETSI ES 202 336-1 (V1.1.2) (2008-09): " Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks) Part 1: Generic Interface".
[7] ETSI ES 203 228 V1.1.7 (2016-11): "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760057	Charging for enhancement to Flexible Mobile Service Steering (eFMSS)	eFMSS_CH	S5	SP-170949	Long,Biao, China Telecom

Summary based on the input provided by China Telecom in SP-190045.

This work introduces the charging enhancement for eFMSS, which specifies how the core network can collect accounting information to distinguish the traffic steering to third party service enablers in (S)Gi-LAN.

The charging enhancement for eFMSS affects the PS domain, in offline charging for third party traffic differentiation.

The charging enhancement to support eFMSS is specified in TS 32.251 on PS charging. The related parameters to support eFMSS are updated for Charging Data Record (CDR) encoding rules in TS 32.298 and the related AVPs to support eFMSS are updated for Diameter charging applications in TS 32.299.

References

[1] TS 32.251: Packet Switched (PS) domain charging
[2] TS 32.298: Charging Data Record (CDR) encoding rules description
[3] TS 32.299: Diameter charging applications

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur

780032	REST Solution Sets	REST_SS	S5	SP-170950	

Summary based on the input provided by Nokia, Nokia Shanghai Bell in SP-xxx.

Design rules for REpresentational State Transfer (REST) Solution Sets (SS) are defined. These rules are applied when specifying REST Solution Sets (a.k.a. stage 3 definitions of Management Services or protocol definitions).

A new Solution Set (SS) called REpresentational State Transfer (REST) Solution Set (SS) is introduced in Rel-15. It is based on REST principles and uses HTTP [3], [4] as transport protocol. The request and response message bodies are encoded using JSON Schema. TS 32.158 [2] defines guidelines to be used when specifying REST Solution Sets.

The guidelines define how managed object instances are represented as HTTP resources. They specify also how the basic create, read and write (CRUD) operations have to be realized using HTTP methods. Advanced design patterns for scoping and filtering, attribute selection and partial resource updates are defined as well. A basic structure to be used for resource representation in message bodies is specified.

References

[1] 3GPP TR 32.866: "Study on a RESTful HTTP-based Solution Set (SS)".
[2] 3GPP TS 32.158: "Design rules for REpresentational State Transfer (REST) Solution Sets (SS)".
[3] IETF RFC 7230: "Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing".
[4] IETF RFC 7231: "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content".

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790016	Forward compatibility for 3GPP Diameter Charging Applications	FWDCA	S5	SP-180076	Gardella, Maryse, Nokia

Summary based on the input provided by Nokia Shanghai Bell in SP-181185.

This work introduces the supported feature mechanism for Diameter Charging Applications for new Rel-15 features.

The supported feature mechanism specified in TS 29.229, is introduced for Diameter charging applications in TS 32.299, with a first list of new Rel-15 features in PS charging and ProSe charging.

References

TS 32.299: Diameter charging applications
TS 32.251: Packet Switched (PS) domain charging
TS 32.277: Proximity-based Services (ProSe) charging

12.8 Other enhancements

12.8.1 Simplified HS-SCCH for UMTS

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760082	Simplified HS-SCCH for UMTS	UTRA_simple_HSSCCH	R6	RP-171443	Ericsson

Summary based on the input provided by Ericsson in RP-172306.

The HS-SCCH is a downlink control channel used for scheduling HS-DSCH transmissions as well as for instructing the UE to perform specific actions via HS-SCCH orders. The HS-SCCH is monitored by the UE at all path-loss conditions within the cell, and according to current observations the HS-SCCH can become limiting and costly in bad radio conditions since the power invested in the HS-SCCH limits the available power for the HS-PDSCH.

The decoding of the HS-SCCH is performed by testing against all the codewords that can be carried over the HS-SCCH, since any of those codewords could have been transmitted in downlink. Nonetheless under bad radio conditions only a small subset of those codewords can occur in practice. In addition, the detection/decoding of the HS-SCCH part I (slot 0) needs to succeed before proceeding to decode the HS-SCCH part II (slot 1 & 2), meaning that the detection and decoding of slot 0 is a key aspect of the performance of the HS-SCCH.

Accounting for the above technical aspects, and the investigations performed during the study item phase, it was concluded that the simplification on the HS-SCCH type 1 should consist of making "known in advance" the bits corresponding to the "Modulation Scheme" and the "Number of codes" (code group indicator bits).

The simplification of the HS-SCCH type 1 brings benefits in terms of BLER, an improved false detection, an improved miss detection, power savings in downlink (could be translated to coverage improvements), and backward compatibility.

The Simplified HS-SCCH type 1 operation enables the UE to determine when to expect HS-SCCH type 1 transmissions indicating one HS-PDSCH code and QPSK modulation scheme.

The legacy CQI reports are used as triggering mechanism when low CQI values (from 1 to 6) are reported from the UE to the network. In addition to the CQI based triggering mechanism, HS-SCCH orders can be used to create an interval where the HS-SCCH type 1 is received carrying one HS-PDSCH code and QPSK modulation scheme to extend the usage of the simplified HS-SCCH type 1 transmission independently of the radio conditions.

For both triggering mechanisms, once the UE has transmitted a CQI report over the HS-DPCCH, the UE may expect a HS-SCCH type 1 transmission carrying control information corresponding to one HS-PDSCH code and QPSK modulation scheme in the first available HS-SCCH subframe, once four sub-frames have passed after the end of the sub-frame where the HS-DPCCH was transmitted.

When the network has transmitted a HS-SCCH order for stopping the transmission interval created by the HS-SCCH orders, a fall back to the CQI based triggering mechanism occurs.

The Simplified HS-SCCH type 1 operation is applicable for Cell_DCH state.

The UE indicates its capability support for Simplified HS-SCCH type 1 operation to the network. The network signals its support in RRC messages to the UE.

References

[1] RP-171443, New Work Item proposal: on a Simplified HS-SCCH for UMTS, RAN #76

[2] RP-171211, Status Report to TSG: Work Item on a simplified HS-SCCH for UMTS, RAN #77

[3] TR-25709, Study on a simplified HS-SCCH for UMTS,

RAN6#5

[4] R6-170350, "Introduction of Simplified HS-SCCH type 1 operation for UMTS," Ericsson.

[5] R6-170420, Revision of R6-170350.

[6] R6-170352, "Introduction of Simplified HS-SCCH type 1 operation for UMTS, " Ericsson.

[7] R6-170419, Revision of R6-170352.

[8] R6-170353, "Introduction of Simplified HS-SCCH type 1 operation for UMTS," Ericsson.

[9] R6-170354, "On the simplified HS-SCCH type 1 operation," Ericsson.

[10] R6-170355, "On the triggering mechanism for the simplified HS-SCCH based on legacy CQI reports," Ericsson.

[11] R6-170356, "Introduction of the triggering mechanism for the simplified HS-SCCH type 1 operation," Ericsson.

[12] R6-170407, Revision of R6-170356.

[13] R6-170436, Revision of R6-170407.

[14] R6-170357, "On the triggering mechanism for the simplified HS-SCCH based on HS-SCCH orders, " Ericsson.

[15] R6-170358, "Work plan for the WI on a simplified HS-SCCH for UMTS," Ericsson.

[16] R6-170406, Revision of R6-170358.

[17] R6-170363, "Impacts on layer 2 and 3 specifications," Ericsson.

[18] R6-170418, Revision of R6-170363.

[19] R6-170364, "Introduction of Simplified HS-SCCH type 1 operation for UMTS, " Ericsson.

[20] R6-170421, Revision of R6-170364.

[21] R6-170424, "LS on the WI of a simplified HS-SCCH for UMTS," TSG RAN WG6.

[22] R6-170409, "Introduction of the HS-SCCH orders for the additional triggering mechanism based on HS-SCCH orders," TSG RAN WG6.

RAN6#6

[23] R6-170477, CR on "Simplified HS-SCCH type 1 operation using HSDPA code offset reservation," Nokia, Nokia Shanghai Bell.

[24] R6-170476, CR on "Simplified HS-SCCH type 1 operation with HSDPACH code offset reservation," Nokia, Nokia Shanghai Bell.

[25] R6-170475, CR on "Simplified HS-SCCH type 1 operation with HSDPA code offset reservation," Nokia, Nokia Shanghai Bell.

[26] R6-170474, CR on "Simplified HS-SCCH type 1 operation with HSDPA code offset reservation," Nokia.

[27] R6-170473, "Simplified HS-SCCH type 1 operation using HSDPA code offset reservation, " Nokia, Nokia Shanghai Bell.TSG RAN WG3

RAN3#97 No TU.

RAN3#97bis

[28] R3-173988, "RAN3 Impact: Work Item on a simplified HS-SCCH for UMTS," Ericsson.

[29] R3-173989, "Support on a simplified HS-SCCH for UMTS," Ericsson.

[30] R3-173990, "Support on a simplified HS-SCCH for UMTS," Ericsson.

RAN3#98

[31] R3-174820 RAN3 Impact: Enhancement proposal to UMTS WI simplified HS-SCCH type 1 operation, Nokia Solutions & Networks (I).

[32] R3-174824 Support on a simplified HS-SCCH for UMTS, Ericsson

[33] R3-174825 Support on a simplified HS-SCCH for UMTS, Ericsson.

12.8.2 Increased number of E-UTRAN data bearers

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780070	Increased number of E-UTRAN data bearers	INOBEARRAN	R2	RP-180569	Samsung

Summary based on the input provided by Samsung in RP-181619.

The maximum number of LTE / EPS data bearers has been limited to 8 in LTE Rel-8. Even though the radio access and the core network signalling in principle supports up to 11 bearers, the UE capability was limited only to 8 data bearers. Since LTE Rel-8 operators have launched a number of new services, and it has become more and more evident that more than 8 radio bearers will be needed to support simultaneously all the services. Without this extension there can be risk of inconsistent end user service behaviour that will ultimately prevent adding further QoS based services for a UE. It also worth noting that LTE Rel-8 has a restriction of having 8 AM bearers or 5AM+3 UM data bearers, which limits further availability for emerging differentiated data services. As an example, there can be user cases and scenarios where up to 4 RLC AM might be needed.

In response to the aforementioned limitations, TSG RAN agreed to instantiate a new LTE Rel-15 WI aiming to remove those restrictions by increasing the number of supported data radio bearers.

LTE Rel-8 functionality is limited to 8 data radio bearers, which was never revised in later releases. And even though radio access and the core network signalling supports in principle up to 11 data bearers, MAC header design has logical channel ID space only for 8 bearers.

RAN WG2 decided to extend the MAC header logical channel ID space from 32 to 64 code points, which allows for not only extending the number of supported data radio bearers, but also introduces a possibility to add more MAC control elements in the future. After extensive discussions between RAN and SA WGs, it was concluded to extend the number of supported data radio bearers to 15 to minimize impact to the existing information elements on the NAS and CN signalling. It is also worth noting that extended number of LTE data radio bearers is also aligned with the 5G/NR technology, in which the minimum UE requirement is to support 16 data radio bearers.

As for RAN WG3, it has been concluded that radio access interfaces already can support up to 15 data radio bearers. In addition it, there also exist procedures to handle various error cases when e.g. one eNB does not support as many bearers as has been configured by the source eNB. As a summary, no changes were introduced in RAN WG3.

Finally, it bears mentioning that even though this WI aimed at increasing the number of data radio bearers for LTE connected to EPC, same enhancements can be supported by a UE supporting LTE connected to 5GC, i.e. architecture options 5 and 7. In those deployment cases when both LTE and NR are connected to the same 5GC, it allows operator to deploy and use same services irrespective of the radio access technology that a UE is configured with.

12.8.3 Increasing the number of EPS bearers

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790035	Increasing the number of EPS bearers	INOBEAR	S2	SP-171044	Andy.Bennett, Samsung

Summary based on the input provided by Samsung R&D Institute UK in SP-181196.

This Work Item, in conjunction with the changes made for INOBEARRAN, allows for 8 or 15 bearers when attached to WB-E_UTRAN access. (This applies also for dual connectivity using E-UTRAN access.)

As mentioned in the summary for INOBEARRAN, the maximum number of EPS bearers has previously been limited to 8 since Rel-8 but it has become apparent that more than 8 radio bearers are needed to simultaneously support all the services that operators have been introducing. TSG SA agreed to work on a Rel-15 Work Item [1], which is a counterpart of INOBEARRAN, to ensure that 15 EPS bearers can be supported by the core network.

E-UTRAN idle mode mobility and handover procedures are updated to support the additional EPS bearers. In networks that are only partly upgraded, mobility procedures to target nodes that do not support 15 EPS bearers result in bearers being released based on existing error handling procedures. Bearers will also be released if a UE that supports 15 bearers moves to UTRAN or GERAN, as GPRS core network and Radio Access networks do not support 15 PDP contexts.

To minimize the impact of releasing bearers as a result of mobility to non-supporting target nodes the MME should be able to allocate EPS bearer IDs in such way that the bearers with higher operator preference will be preserved in case of mobility involving legacy target nodes.

It is necessary for all PDN GWs in a PLMN to support 15 EPS bearers, and MME's can be configured to take into account whether the HPLMN supports 15 EPS bearers when selecting a PDN GW for a supporting UE. Inter-PLMN handover is also based on MME configuration.

12.8.4 Enhancement of background data transfer

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750001	Enhancement of background data transfer	eBT	S1	SP-170161	Atsushi Minokuchi, NTT DOCOMO

Summary based on the input provided by NTT DOCOMO in SP-180858.

Requirements for background data transfer were enhanced in order to avoid "bill shock" in the 3rd party and to handle the dynamic change of transfer policies.

An indication from the 3rd party server to the 3GPP system was introduced, so that the 3rd party server can indicate that background data transfer when that happens beyond agreed conditions is to be stopped. A capability was introduced that allows the 3GPP system to respond to the 3rd party server in one coordinated response, which reflects congestion level over a certain geographic area. Stage 1 work only was done. Stage 2 work for EPC was not initiated. Stage 2 work for 5GC is taking into account these requirements; the details are found in TS 23.503.

References

[1] S1-171415, CR Enhancement of the service exposure for background data transfer, SA1#77.

12.8.5 Enhanced VoLTE performance

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780046	Enhanced VoLTE performance	eVoLP	S2	SP-170935	Xiaobo Wu, Huawei

Summary based on the input provided by Huawei in SP-19xxxx.

Voice services over LTE (VoLTE) may require better LTE RSRP (Reference Signal Receiving Power) compared to data service, which means the LTE radio signal may be good enough for pure data session, but may not be good enough for VoLTE. LTE radio network dimensioning is typically optimized for data services. To avoid negative impacts on user experience for VoLTE subscribers in areas with weak LTE coverage, a handover to 2G or 3G is performed sooner, i.e. at a higher RSRP level, for UEs with established voice bearers compared to UEs with only data bearers.

As in the Technical Specification for Multimedia Telephony Service over IMS (MTSI), TS 26.114, which is used as basis for the GSMA IR.92 VoLTE profile, there have been several tools for increased robustness of speech calls with initial selection of Codecs and their Configuration and in-call dynamic rate and mode adaptation and application layer redundancy. EVS (Enhanced Voice Services), especially the EVS Channel Aware mode, demonstrates higher robustness against transmission errors than AMR and AMR-WB codecs.

Based on the above provided background and depending on network dimensioning, which typically targets at data services, the VoLTE coverage may be a function of the selected codec and its configuration, its rate adaptation, and potentially the applied application layer redundancy, as well as the required QoS of the VoLTE bearer. It is adopted that a new QoS parameter Maximum Packet Loss Rate in UL and DL directions is defined and sent from PCRF to eNB. At reception of the IMS service information from the P-CSCF, if configured through policy, the PCRF determines the Maximum Packet Loss Rate for UL and DL based on the IMS service information e.g. codec and sends it to PCEF along with the PCC rule for the voice media. This parameter is transferred to the eNB to support it for handover threshold decision.

Based on the analysis/evaluation of this eVoLP WID, the existing 3GPP 4G specifications TS 23.401, 23.203 and 5G specifications TS 23.501, 23.502, 23.503 have been modified according to it.

References

[1] SP-170935 "New WID for enhanced VoLTE performance" (S2 aspects)
[2] CP-173109 "CT aspects on enhanced VoLTE performance" (CT aspects)

12.8.6 DL interference mitigation for UMTS

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750068	DL interference mitigation for UMTS	UTRA_DL_IM	R2	RP-170703	Qualcomm

Summary based on the input provided by Qualcomm Incorporated in RP-171135.

This feature introduces new RRC (DL) signaling for indicating adjacent channel interference.

The indication, from the network to the UE, about potential DL adjacent channel interference, can be beneficial for optimizing DL performance, e.g. UE could try to filter out the interference signal(s).

The feature is applicable to FDD only, and has been standardized starting from Rel-14.

With the feature DL interference mitigation [2, 3], the UE can receive indication about a possible DL adjacent channel interference level (due to GSM). The new signalling indication is conveyed in existing broadcast messages (SIB 5/6). UEs could use such indication to mitigate the DL interference, e.g. using optimized Rx filtering.

The new RRC/SIB signalling indication is as follows (new IE [1]):

IE name	Presence	Type/Value	Description	Release
Adjacent channel interference level	Optional	Enumerated (MODERATE, HIGH)	Only for FDD. This IE indicates the level of external adjacent channel interference.	REL-14

Below is the stage-3 description of the UE behaviour (RRC SIB5/6 handling), [1].

1> for FDD, if the IE "Adjacent Channel Interference level" is included and UE supports DL interference mitigation:

2> configure the lower layers with the IE "Adjacent Channel Interference level", which may be used to mitigate the DL interference, e.g. to apply an optimized Rx filtering.

Further details are left to implementation.

References

[1] TS 25.331: Radio Resource Control (RRC); Protocol specification
[2] TS 25.300: UTRAN General description - Stage 2:
[3] RP-170703: WID, Qualcomm Incorporated

12.8.7 Enhanced Calling Name Service

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760012	Enhanced Calling Name Service	eCNAM		SP-160548	Hala Mowafy, Ericsson

Summary based on the input provided by Ericsson, sent by e-mail.

TS 22.173 V15.1.0 introduced the service description of Enhanced Calling Name (eCNAM), and subsequently, TS 24.196 V15.0.0 specified the stage three (protocol description) of this terminating service. eCNAM provides the subscriber with the following:

1. An untruncated name (not limited to 15-characters), and
2. Metadata.

Delivery of an untruncated name plus metadata about the originating party assists subscribers in better managing their incoming calls and empowers them to protect themselves against potential scams. The untruncated name and some of the metadata are to be retrieved from authoritative data sources by the terminating service provider.

Description

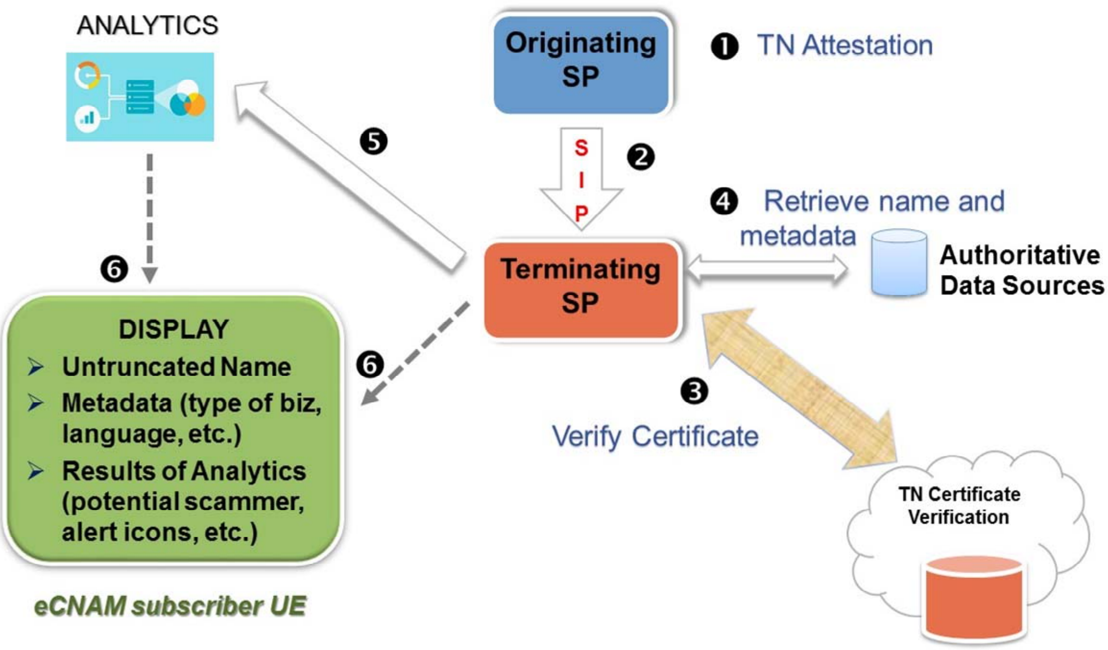


Figure 12.8.7-1: eCNAM Environment and Functionality

eCNAM does not deliver messages from the originator across multiple networks to the terminating user. eCNAM is a service that resides in the terminating service provider's (SP) network, most likely in the Telephony Application Server (TAS). However, it utilizes the identity information received in SIP signalling.

1) STIR/SHAKEN attestation takes place in the originating network.

2) Incoming SIP Invite.

3) Terminating network verifies the STIR certificate.

4) If verification is successful, eCNAM service commences. Name and metadata are retrieved from authoritative sources using an E.164 TN as that searchkey.

5) It is expected that terminating SPs will employ an assessment of the incoming call through analytics. Some of the call information will be used as input to the analytics (analytics is not part of eCNAM)

6) The eCNAM service logic (in the TAS) assembles the data and formats it to be delivered for display on the UE.

The untruncated name is delivered in the "display-name" parameter of the From header field and/or P-Asserted-Identity header field that the terminating Application Server sends to the terminating UE.

The metadata will be delivered in one or more Call-Info header field(s). The eCNAM service logic in the AS assembles and formats several data elements (subject to local policy). eCNAM metadata may include type of call, location of a business, or language of the originator. Furthermore, eCNAM metadata may include the results of robocalling analytics that are used to alert the subscriber of possible scams. Typically, service providers partner with analytics providers that offer risk indicators about incoming calls (e.g., known scammers). The results of such analytics are relayed to the user in the form of text strings and/or icons to be displayed on his/her UE. The eCNAM Call-Info header fields support the delivery of text and icons. Given the changing nature of scams, the results of the analytics are expected to vary. eCNAM provides the advantage of a flexible "envelope" - namely the Call-Info header field(s) - that delivers different types of payload without having to modify existing standards frequently.

References

[1] TS 22.173: "IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services".

[2] TS 24.196: "Technical Specification Group Core Network and Terminals; Enhanced Calling Name (eCNAM)".

12.8.8 PS Data Off Phase 2

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760030	PS Data Off Phase 2	PS_DATA_OFF2		SP-170246	Murhammer, Leopold, Deutsche Telekom AG

Summary based on the input provided by T-Mobile Austria GmbH in SP-180686.

"PS Data Off Services" (PS_DATA_OFF) was a new feature in 3GPP Rel-14 which, when configured by the HPLMN and activated by the user, prevents transport via PDN connections in 3GPP access of all IP packets except IP packets required by 3GPP PS Data Off Exempt Services. In Phase 2, for the new work item "PS_DATA_OFF2", the HPLMN may configure up to two sets of 3GPP PS Data Off Exempt Services for its subscribers: one is used when in HPLMN and another when roaming.

Stage 1 made changes into TS 22.011 to update the requirements and the list of PS Data Off Exempt Services. It is now possible that the HPLMN configures up to two sets of 3GPP PS Data Off Exempt Services for its subscribers (one is used when in HPLMN and one when roaming).

Stage 2 is based on Rel-14 Study Item FS_PS_DATA_OFF approved at SA#72 (June 2016) - TR 23.702, taking into account also the changed requirements from stage 1 in TS 22.011. SA2 has completed the Work Item PS_DATA_OFF2 with CRs to update TS 23.060, TS 23.203, TS 23.221, TS 23.228, and TS 23.401 for the normative work. The scope is to provide architecture enhancements to update 3GPP PS Data Off feature in the stage 2 specifications based on the stage 1 requirements defined in TS 22.011:

- Making the UE aware of the list of services configured to be part of the 3GPP PS Data Off Exempt Services to allow appropriate policy enforcement in the UE for uplink traffic. In Rel-15 up to two lists are possible, one to be used for HPLMN and one to be used when roaming, for all VPLMNs.

Stage 3 is covered by Work Item PS_DATA_OFF2-CT:

- CT1 with CRs to update TS 24.424, TS 24.301, TS 24.229, TS 24.368, TS 24.173, TS 24.275, TS 24.341, TS 24.390, TS 24.391.

- CT3 with CRs to update TS 29.212.
- CT6 with CRs to update TS 31.102.

References

[1] TS 22.011, Service accessibility

13 LTE improvements

13.1 Further enhancements to Coordinated Multi-Point (CoMP) Operation for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750060	Further enhancements to Coordinated Multi-Point (CoMP) Operation for LTE	feCOMP_LTE	R1	RP-171031	Intel

Summary based on the input provided by Intel Corporation, ZTE in RP-180318.

Based on the conclusions from the study item on "further enhancements to Coordinated Multi-Point (CoMP) operation for LTE", captured in TR 36.741 [1], this work item (WI) aims for providing specification support for non-coherent joint transmission scheme [2], where the transmission of the multiple MIMO layers is performed from two transmission points (TPs) without adaptive precoding across the TPs.

The following new functionalities have been specified as part of the work item:

- Support of a new quasi co-location assumption for DM-RS antenna ports at the UE:
  - New quasi co-location (QCL) assumption of Type C was specified for the UE supporting transmission mode 10 (TM10). The new QCL assumption allows network implementation with simultaneous transmission of two DM-RS antenna port groups and associated two sets of MIMO layers from two TPs without joint precoding across the TPs.
- Support of control signalling enhancements to assist QCL and PDSCH REs mapping:
  - For non-coherent joint transmission, due to difference in the propagation environment or practical impairments, the received MIMO layers at the UE from different TPs may have different time and frequency offset characteristics. To facilitate proper time and frequency offset tracking and consistent channel estimation at the UE for the MIMO layer(s) transmitted by different TPs, the control signalling has been enhanced to support indication of up to two reference signals set (one per each set of MIMO layers) that can be used by the UE to obtain the correct reference for synchronization. Similarly, due to different reference signals configurations (e.g. CRS) at the TPs, physical downlink shared channel (PDSCH) resources may not be the same for two sets of MIMO layers. The control signalling enhancement also specifies mechanism to indicate for the UE up to two sets of physical resource elements for PDSCH reception (one per each set of MIMO layers).
- Support of CSI feedback enhancement:
  - To facilitate accurate link adaption in non-coherent joint transmission, enhancement to channel state information (CSI) reporting was introduced. The CSI enhancement facilitates reporting information on the preferred number of the MIMO layers, precoding information and channel quality information per each TPs under assumption of non-coherent joint transmission. The CSI enhancement for NC-JT also supports fall back CSI reporting assuming conventional transmission of PDSCH from a single TP.

References

[1] TR 36.741, "Study on further enhancements to Coordinated Multi-Point (CoMP) operation for LTE", v14.0.0.

[2] RP-180478, "Revised WID: Further enhancements to Coordinated Multi-Point (CoMP) Operation for LTE", Intel, TSG RAN Meeting #79, Chennai, India, March 19-22, 2018.

13.2 Enhancements for high capacity stationary wireless link and introduction of 1024 QAM for LTE DL

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750064	Enhancements for high capacity stationary wireless link and introduction of 1024 QAM for LTE DL	LTE_1024QAM_DL	R1	RP-171067	Huawei

Summary based on the input provided by Huawei, HiSilicon in RP-180854.

In many scenarios with high capacity wireless connections, the distinctive wireless channel characteristics can be utilized to improve network efficiency. One scenario is a small cell setting with higher SINR, where LTE eNB communicate with stationary laptop or docked smartphone. Another scenario is that LTE eNB communicate with an outdoor above-rooftop or indoor customer premises equipment (CPE) which then delivers traffic to indoor users via other links.

This work item [1] specifies enhancements for unicast physical channels and related procedures and signalling to exploit the characteristics of stationary wireless links, specifically the support of 1024QAM and DMRS overhead reduction [2]. In addition, new UE categories are also specified supporting DL 1024QAM.

1024QAM for DL channels.

To further improve spectral efficiency, 1024QAM can be configured for PDSCH to DL 1024QAM capable UEs. The constellation mapping is extended as following for bits$\{b_i, \ldots, b_{i+9}\}$.

$$x = \frac{1}{\sqrt{682}}(1-2b_i)\left[16-(1-2b_{i+2})\left[8-(1-2b_{i+4})[4-(1-2b_{i+6})[2-(1-2b_{i+8})]]\right]\right]$$

$$+j\frac{1}{\sqrt{682}}(1-2b_{i+1})\left[16-(1-2b_{i+3})\left[8-(1-2b_{i+5})[4-(1-2b_{i+7})[2-(1-2b_{i+9})]]\right]\right]$$

New TBS indexes 34A, 35, 36, 37 and 37A and new MCS table corresponding to 1024QAM have been specified. When configured, the UE will monitor DL DCI assignments with CRC scrambled by C-RNTI or SPS-C-RNTI of DCI formats other than 1A and 1C to use the newly introduced MCS table and TBS indexes to support 1024QAM. New CQI table has also been introduced with entries supporting 1024QAM. This allows configured UEs to feedback CQI with spectral efficiency supported by 1024QAM. In addition, UE capability for support of 1024QAM is reported per band/band combination.

RF EVM for DL 1024QAM

To achieve the benefits of high order modulation, the EVM requirement needs to be fulfilled at eNB side. EVM (Error Vector Magnitude) is a measure of the difference between the ideal symbols and the transmitted symbols after equalization, which is critical to the performance of data channels. The required EVM at LTE eNB is 2.5% for 1024QAM.

DMRS overhead reduction

The DMRS overhead for TM9/10 is reduced by using OCC4 for DL SU-MIMO rank 3 or 4. With the introduced DMRS overhead reduction, the DMRS overhead is reduced by a half and the spectral efficiency is increased. New entries are added to the DMRS table (the table for Antenna port(s), scrambling identity and number of layers indication) to support the scheduling of PDSCH with reduced DMRS.

Rel-15 UE DL Categories

DL UE category 20 is updated to support DL 1024QAM. New DL UE categories have been specified with support of 1024QAM as below:

- DL Category 22 with peak data rate 2.3-2.5Gbps
- DL Category 23 with peak data rate 2.7-2.8Gbps
- DL Category 24 with peak data rate 2.9-3Gbps

- DL Category 25 with peak data rate 3.1-3.3Gbps
- DL Category 26 with peak data rate 3.4-3.5Gbps

References

[1] RP-171738, "Revised WID: Enhancements for high capacity stationary wireless link and introduction of 1024 QAM for LTE DL", Huawei, HiSilicon, Qualcomm Incorporated, China Telecom, RAN#77, Sapporo, Japan, September 2017.

[2] RP-180852, "Status report for WI: Enhancements for high capacity stationary wireless link and introduction of 1024 QAM for LTE DL", Huawei, HiSilicon, RAN#80.

13.3 UE requirements for network-based CRS interference mitigation for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
761001	UE requirements for network-based CRS interference mitigation for LTE	LTE_NW_CRS_IM	R4	RP-171408	Ericsson

Summary based on the input provided by LTE Ericsson LM in RP-181864.

This Work Item implements the E-UTRA network and UE operation with reduced CRS bandwidth in LTE whenever UEs do not perform any DL or UL operation requiring CRS, and allows to achieve in practice the gains with CRS reduction which were suggested by, e.g., the Rel-12 Study Item on Small Cell Enhancements for E-UTRA and E-UTRAN - Physical-layer aspects and the Rel-13 Work Item on Licensed-Assisted Access using LTE which enabled the operation in CRS free DL SCells in unlicensed spectrum.

Right from the start in Rel-8, LTE has been designed to rely on Cell-specific Reference Signals (CRS), which are transmitted over full system bandwidth and in all DL subframes of an LTE radio frame and used by UE for many important purposes, e.g., cell search/mobility, time/frequency synchronization, channel estimation, and radio resource management.

The Work Item on UE requirements for network-based CRS interference enabled a cell to transmit over a reduced bandwidth (6 centre PRBs) when there is no need for its CRS or the network load is not high, which allows to adapt the CRS bandwidth in cells, e.g., to:

- reduce the interference floor in LTE networks,
- facilitate using higher-order modulation schemes (e.g., 256QAM or above) over larger parts of the radio network coverage,
- save energy in BS,
- save energy in UE capable of network-based CRS interference mitigation which can optimize their DRX operation according to the scenarios specified in TS 36.133, Clause 3.6.1.1.

If network-based CRS interference mitigation is enabled in a cell, then the UE capable of network-based CRS interference mitigation can assume that:

- CRS is transmitted over full bandwidth of the cell during active time periods (T1), during which the UE is performing a DL or UL requiring full-bandwidth CRS, and over at least 6 central resource blocks of the cell during the inactive time periods (T2) when the full-bandwidth CRS is not required, and
- CRS is transmitted over full bandwidth of the cell during at least N1 number of non-MBSFN DL subframes immediately before the T1 time period, and
- CRS is transmitted over full bandwidth of the cell during at least N2 number of DL subframes after the T1 time period when UE receives the downlink physical channel during the T1 time period.

The feature concept is illustrated in Figure 1 below for a single UE configured with DRX cycles and performing a DL operation requiring full-bandwidth CRS during periods T1, each of which is preceded with N1 warm-up subframes (e.g., for channel estimation or time tracking) and succeeded by N2 cool-down subframes (e.g., for channel estimation) associated with this DL operation.

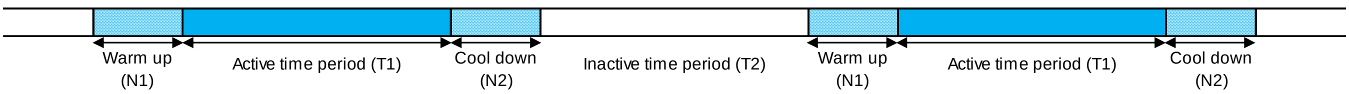


Figure 13.3-1: A UE assumes full-bandwidth CRS in T1, N1, and N2 periods, and reduced CRS during T2 time periods.

References

[1] RP-181315, WID for LTE Work Item on UE requirements for network-based CRS mitigation, June 2018.
[2] R4-1707709, Time plan for network-based CRS interference mitigation WI, Ericsson, Aug. 2018.
[3] R4-1709102, WF on network-based CRS interference mitigation, Ericsson, Nokia, Aug. 2018.
[4] R4-1708732, WF for performance part for network-based CRS-IM, Ericsson, Aug. 2018.
[5] R4-1714498, Way Forward on RRM with network-based CRS interference mitigation, Ericsson, Nov. 2018.
[6] R4-1714495, Way forward for CRS-IM related advanced receiver impact analysis for network-based CRS-IM, Ericsson, Nov. 2018.
[7] R4-1803172, WF on UE demodulation for network-based CRS interference mitigation, Ericsson, Feb. 2018.
[8] R4-1805558, LS on network-based CRS interference mitigation, Ericsson, April 2018.
[9] R4-1806016, WF on network-based CRS interference mitigation, Ericsson, April 2018.
[10] R4-1808479, RAN4 LS to RAN2, LS on UE capability for network-based CRS-IM, May 2018.
[11] R4-1808528, CR to TS 36.133, Introduction of network-based CRS interference mitigation, Ericsson, May 2018.
[12] R4-1811735, CR to TS 36.133, Applicability requirement for network-based CRS-IM, Qualcomm, Aug. 2018.
[13] R4-1811864, WF for demodulation performance requirements for network-based CRS interference mitigation, Ericsson, Aug. 2018.

13.4 Bluetooth®/WLAN measurement collection in LTE Minimization of Drive Tests (MDT)

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780068	Bluetooth®/WLAN measurement collection in LTE Minimization of Drive Tests (MDT)	LTE_MDT_BT_WLAN	R2	RP-180306	CMCC

Summary based on the input provided by CMCC in RP-180867 revised in RP-181744.

This work item specifies Bluetooth® (BT) and WLAN measurement collection in MDT to monitor and assess coverage performance of BT and WLAN network and also to provide location information for the associated other MDT measurements. Bluetooth® is a registered trade mark from the Bluetooth SIG.

In this WI, both logged MDT and immediate MDT functionality facilitating BT and WLAN measurements collection is introduced.

For WLAN measurement logging and Bluetooth® measurement logging, the UE shall perform WLAN and Bluetooth® measurements, respectively, only when indicated in the corresponding configuration. The measurement logging is performed only for logging intervals for which WLAN and Bluetooth® measurements are available, respectively.

The measurement quantities for WLAN measurement logging are fixed and consist of BSSID, SSID, HESSID of WLAN APs. If configured by the network, optionally available RSSI and RTT can be included. The measurement quantity for Bluetooth® measurement logging is fixed and consists of MAC address of Bluetooth® beacons. If configured by the network, optionally available RSSI can be included.

References

[1] Last status report: RP-181742

13.5 UL data compression in LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770067	UL data compression in LTE	LTE_UDC	R2	RP-172076	CATT

Summary based on the input provided by CATT in RP -180912 revised in RP-181769.

This work item specifies Uplink Data Compression (UDC) in LTE, i.e. uplink data can be compressed at the UE and can be decompressed at the eNB.

In this WI, DEFLATE based UDC solution is introduced.

DEFLATE based UDC solution could achieve high compression efficiency which would save more uplink resources and reduce the transmission latency. The eNB can configure the UE to use UDC or not. If UDC is configured for a DRB, ROHC is not used for that DRB. One byte UDC header is introduced to indicate whether the PDCP PDU is compressed by UDC or not, whether the compression buffer is reset or not, and 4 validation bits of checksum to check whether the compression and decompression buffers are synchronous. For each DRB, at most 8192 bytes compression buffer is used. If there are some errors or failure due to buffer mismatching, the eNB can send an error notification control PDU to the UE, the UE may reset the compression buffer.

To improve compression efficiency of the first few packets, two types of pre-defined dictionary can be used for UDC. One is standard dictionary for SIP and SDP signalling as defined in RFC 3485, and another is operator defined dictionary. The eNB could configure whether or which dictionary is used for a UDC DRB.

UDC related capabilities are also defined in UE capability. There are three capabilities: supporting basic UDC function; supporting standard dictionary and supporting operator defined capability. If the UE supporting operator defined capability, it should also report the version of the dictionary and the associated PLMN ID to assist the eNB to identify the dictionary stored by the UE. The eNB should configure UDC according to UE capabilities.

References

[1] RP-180914 Revised WID on UL data compression in LTE CATT, CMCC
[2] RP-180911 Status Report for WI: UL data compression in LTE CATT
[3] R2-1806964 Introduction of DEFLATE based UDC Solution (36.323 CR) CATT
[4] R2-1813089 Introduction of DEFLATE based UDC Solution (36.331 CR) CATT
[5] R2-1806966 Introduction of DEFLATE based UDC Solution (36.306 CR) CATT
[6] R2-1806963 Introduction of DEFLATE based UDC Solution (36.300 CR) CATT

13.6 UE Positioning Accuracy Enhancements for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750063	UE Positioning Accuracy Enhancements for LTE	LCS_LTE_acc_enh	R2	RP-171508	Nokia

Summary based on the input provided by Nokia in RP-180947.

This work item adds support for signalling of new assistance information (dedicated and broadcast signalling) to enable enhanced GNSS methods (differential GNSS, Network Real Time Kinematic GNSS and Precise Point Positioning) for high accuracy positioning. It also enhances the sensor based location information reporting to report motion information detected by Inertial Measurement Unit sensor. The enhancements in this WID makes possible new commercial use cases and new revenue generation potential for the operators (high accuracy positioning as a subscribed service) and the ability to improve OTDOA positioning performance by utilizing the IMU sensor reported information. This WID enhances the existing LTE positioning protocol, LTE positioning protocol A, and Radio Resource Control protocol.

Key functionalities introduced by this work item includes:

- UE support for measuring and reporting of GNSS carrier phase measurement (36.214)
- Support for signalling of many new assistance information from E-SMLC to UE to enable new high accuracy GNSS positioning methods (single base RTK service, Non-Physical Reference Station Network RTK service, MAC Network RTK service, FKP Network RTK service, 'SSR PPP' Precise Point Positioning service) (36.305)
    - dedicated signalling of GNSS positioning assistance information using LPP protocol (36.355)

  - broadcast signalling (system information message) of GNSS positioning assistance information using RRC protocol (36.331)
  - Support for E-SMLC initiated and UE initiated/requested periodic assistance data delivery of new assistance information
- Introduction of broadcasting of GNSS and OTDOA positioning assistance information (36.355, 36.331, 36.455)
- Support for transfer of assistance information from E-SMLC to eNB to enable eNB to broadcast existing and new GNSS assistance information (36.455)
- E-SMLC support for segmentation of broadcast positioning assistance information (36.355)
- E-SMLC support for end-to-end encryption of broadcast positioning assistance information (36.355)
- Support for distribution of encryption keys from E-SMLC to UE (36.355, 36.331)
- UE support for reporting of motion information detected by IMU sensor corresponding to the time when a OTDOA signal measurement is made. Motion information is reported to E-SMCL along with OTDOA signal measurement information (36.355)

References

[1] RP-172313, "WI UE Positioning Accuracy Enhancements for LTE (LCS_LTE_acc_enh)"
[2] RP-180944, "Status Report for WI UE Positioning Accuracy Enhancements for LTE"
[3] R2-1808058, "RTK Stage 2 CR for 36.305", CR Rel-15 36.305
[4] R2-1808061, "Addition of RTK and PPP support", CR Rel-15 36.355
[5] R2-1808890, "Addition of broadcast of positioning assistance data", CR Rel-15 36.335
[5] R2-1808889, "Addition of broadcast of positioning assistance data", CR Rel-15 36.331
[6] R2-1808896, "Introduction of IMU support for OTDOA", CR Rel-15 36.355
[7] R3-183437, "Assistance Information Broadcasting", CR Rel-15 36.455
[8] TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer - Measurements"
[9] TS 36.305: "Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN"
[10] TS 36.355: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP)"
[11] TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC)"
[12] TS 36.455: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa)"

13.7 UE requirements for LTE DL 8Rx antenna ports

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780072	UE requirements for LTE DL 8Rx antenna ports	LTE_8Rx_AP_DL	R4	RP-172842	Huawei

Summary based on the input provided by Huawei, HiSilicon in RP-180959.

In 8Rx WI, operating bands and CA combinations are introduced to support 8Rx antennas, and to define the UE requirement for single carrier and CA scenario. This enables utilization of 8 layers on a single carrier to increase the spectrum efficiency, or enhance the coverage for the cell edge users.

8Rx WI introduce Band41, Band42 and Band43 to support 8Rx antennas considering implementation feasibility and the market requirement. CA_41A-42A is introduced as the band combination to support 8Rx feature, B41 and B42 can support 8Rx at the same time.

Since UE category 18 and 19 which needs 8 layers on a single carrier in DL is introduced from Rel-13, 8Rx is applied with release independent manner to start from Rel-13.

The REFSENS exceptions for 2Rx and 4Rx is reused for 8Rx, when no exception is allowed, the 8Rx REFSENS is tightened with the same value as single carrier.

References

[1] last approved WID:
RP-172842, New WID: UE requirements for LTE DL 8Rx antenna ports, Huawei, HiSilicon
[2] last state report:

RP-180133, Status report for WI: UE requirements for LTE DL 8Rx antenna ports, Huawei, HiSilicon

[3] CRs:

CR info Tdoc No Tdoc title Company Note

CR to TS 36.101 R4-1803450 CR on UE RF requirement for 8Rx Huawei, HiSilicon Agreed at RAN4#86

CR to TS 36.101 R4-1805721 CR for 36.101: 8Rx CA RF requirement Huawei, HiSilicon Agreed at RAN4#86bis

CR to TS 36.307 R4-1805615 TS 36.307 big CR for introduction new band support for 8Rx antenna ports R13 Huawei, HiSilicon Agreed at RAN4#86bis

CR to TS 36.307 R4-1805719 TS 36.307 big CR for introduction new band support for 8Rx antenna ports R14 Huawei, HiSilicon Agreed at RAN4#86bis

CR to TS 36.307 R4-1805720 TS 36.307 big CR for introduction new band support for 8Rx antenna ports R15 Huawei, HiSilicon Agreed at RAN4#86bis

13.8 Shortened TTI and processing time for LTE

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
720091	Shortened TTI and processing time for LTE	LTE_sTTIandPT		RP-161299	Ericsson

Summary based on the input provided by Ericsson in RP-181008 revised to RP-181870.

The transmission time interval (TTI) in LTE has since the first release of the specifications been 1 ms for the transport channels associated with PDSCH, PDCCH, PUSCH and PUCCH.

Also, the minimum timing from DL assignment to HARQ feedback and UL grant to UL transmission has been fixed occurring three subframes later than where the control information was sent in the DL.

These are the two main aspects that have been improved by this work item, i.e.:

- A reduced processing time for 1 ms TTI operation
- A shortening of the 1 ms TTI operation combined with a reduced processing time

13.8.1 Short processing time for 1 ms TTI

With a reduced processing time for 1 ms TTI, the processing time from DL assignment to HARQ feedback and UL grant to UL transmission is reduced from the currently assumed n+4 timing (meaning three subframe processing time) to n+3.

The reduction in the specifications are referred to short processing time and applies to all frame structure types, i.e. FS1, FS2 and FS3.

The short processing time is illustrated in Figure 13.8-1 for FS1.

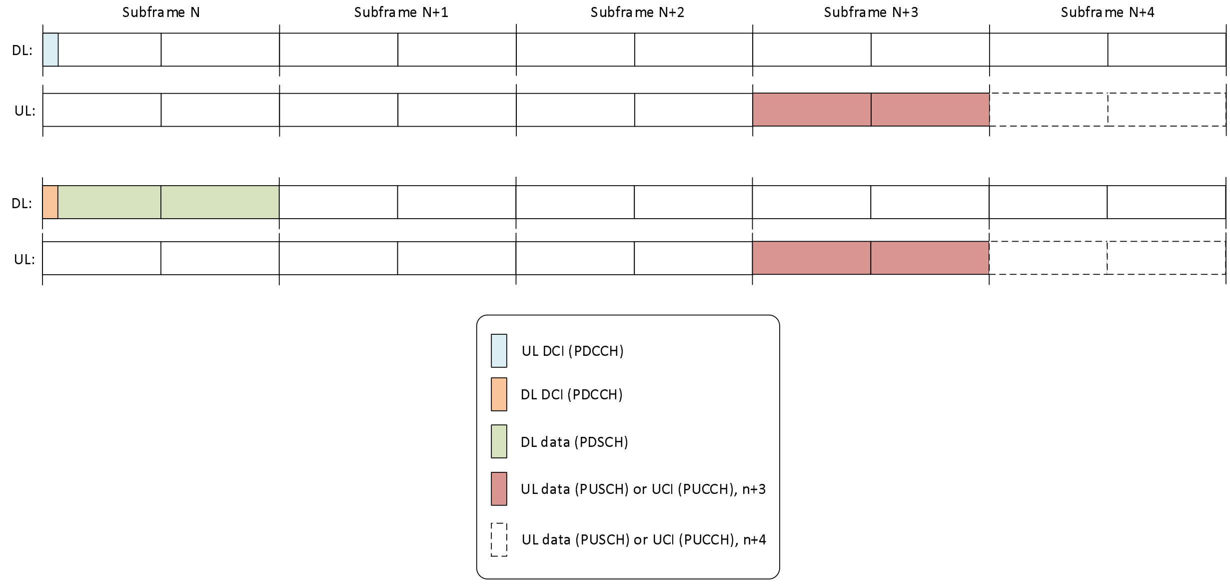


Figure 13.8-1: Short processing time for FS1

Also for FS2, the minimum processing time is reduced, although restrictions on the DL/UL configuration limits the processing time reduction achievable.

For scheduling, only PDCCH based scheduling is supported, i.e. SPS is not supported with n+3 timing for UL and DL. A fallback operation to the legacy timing of n+4 is still supported by scheduling from the common search space (CSS), while the short processing time is applicable when scheduling from the user-specific search space (USS). The fallback results in possible collision between n+4 and n+3 timing in different/same DL subframe and/or same/different UL subframe. For example, the use of fallback results in possible uplink collision in the PUCCH format 1/1a/1b resource usage for the same UE when the two DL subframes have been scheduled targeting HARQ feedback in the same UL subframe. Collision handling has been specified to ensure a consistent UE behaviour.

Short processing time is configured per component carrier (CC) by RRC and applies to both DL assignment to HARQ feedback and UL grant to UL transmission.

Short processing time is associated with asynchronous HARQ operation on the UL, and hence PHICH is no longer considered for HARQ feedback of n+3 based scheduling (PHICH is still used for synchronous n+4 based scheduling). HARQ processes on DL are shared between n+4 and n+3 based scheduling, while there is no sharing of HARQ processes between synchronous (n+4) and asynchronous (n+3) HARQ on the UL. The HARQ content for a given UL subframe m can consist of HARQ bits for n+3 carriers as well as HARQ bits for n+4 carriers at the same time.

Similar to HARQ, shortened processing time also applies to CSI, so that a UE configured with shortened processing time for 1ms TTI will measure CSI on a reference resource no less than 3 subframes away (nCQI_ref greater or equal to 3) from the CSI report. For TM10, the legacy value of the delay between the CSI reference and the CSI report is reduced by 1 subframe (nCQI_ref = legacy value -1).

SRS timing for UE configured with Short processing time is such that for a trigger received in subframe n, aperiodic SRS is transmitted in the first available subframe n+3 or later, subject to the given UL subframe being configured for SRS transmission.

When the processing time is shortened, the timing advance takes up a proportionally larger part of the overall processing time available to the UE. A consequence of this is that the maximum timing advance for a CC configured with short processing time is reduced from 667 us to 200 us.

13.8.2 Short TTI

In addition to reducing the processing time, the WI also included the work to reduce the TTI from 1 ms to what is referred to as either a subslot, or slot transmission, also referred to as short TTI, sTTI. A slot transmission is simply a shortening of the current subframe transmission in half, while a subslot transmission consist of either a 2-symbol or a 3-symbol transmission duration.

The subslot division in a subframe is fixed in the UL while it varies depending on the first potential symbol for PDSCH in the DL, as shown in Figure 13.8-2. Each subframe is divided into up to 6 subslots. Subslot operation is not defined for $l_{DataStart}$=4.

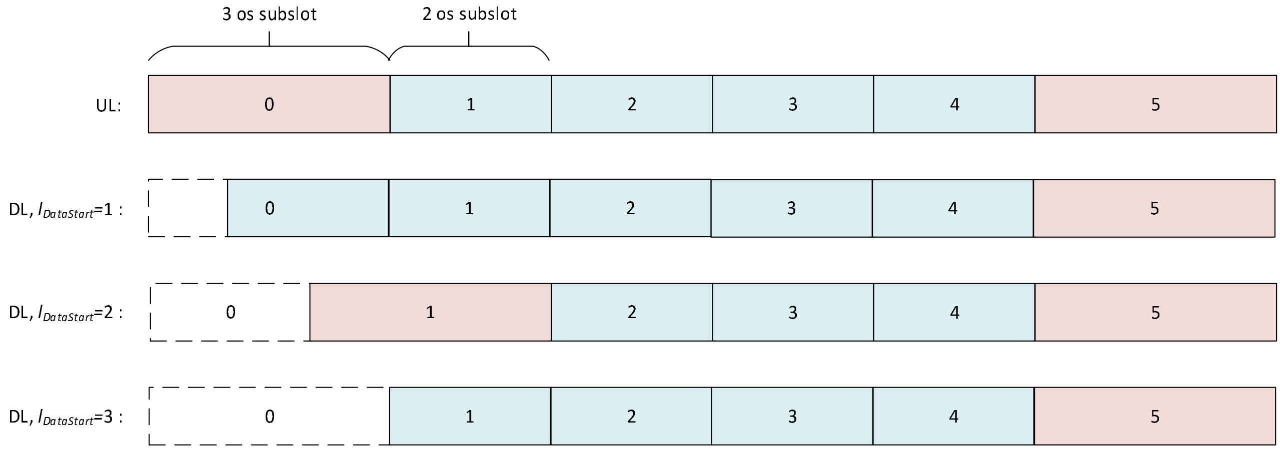


Figure 13.8-2: DL and UL subslot subframe division (subslot number 0,..,5)

The slot operation is defined for both FS1 and FS2, while subslot operation is only defined for FS1. FS3 is not supported.

The combinations of slot and subslot operation on DL and UL are shown in Table 1. The asymmetric operation of subslot in DL and slot in UL is primarily allowed to improve coverage for the UL control channel.

In a carrier aggregation setting, an sTTI DL/UL combination is configured per component carrier (CC). A CA PUCCH group should have the same UL/DL sTTI configuration for the sTTI-configured SCells and the cell carrying PUCCH. However Different DL/UL sTTI lengths can be configured for the serving cells across different PUCCH groups. sTTI operation can also be configured in a DL only Scell. The maximum number of supported UL and DL sTTI carriers is the same as in 1 ms TTI operation. Cross-carrier scheduling is not supported for sTTI.

Table 13.8-2: DL/UL combinations of subslot/slot operation

FS	DL	UL
1 or 2	Slot	Slot
1	Subslot	Subslot
1	Subslot	Slot

The physical channels for subslot and slot operation are given in Table 13.8-3.

Table 13.8-3: Physical channels for slot and subslot operation

SPDCCH
PDSCH
SPUCCH
PUSCH

As can be seen, although the transmission duration of the data channels (PDSCH/PUSCH) also follows the slot and subslot transmission duration, they are not defined as new physical channels. Except for some changes on the transport block size (TBS), resource allocation scheme and DL/UL UE-specific reference signal pattern, the main characteristics of the 1 ms data channels have been maintained. Both UL and DL control channels, on the other hand, have been significantly re-designed motivating to treat them as separate physical channels in the specification. SPUCCH follows subslot and slot duration (including also SR with a periodicity down to 1 subslot), while SPDCCH has either 1 os, 2 os or 3 os duration, transmitted at the start of each subslot/slot, and may span only configured frequency resources as illustrated in Figure 13.8-3.

A fallback mode to 1 ms transmission is also supported for subslot and slot operation, the fallback is dynamic and can occur on a subframe to subframe basis. The UE needs to monitor both 1 ms and subslot/slot based control. Collision handling in case of simultaneous subslot/slot and subframe transmission in UL on the same CC has been specified to ensure a consistent UE behaviour.

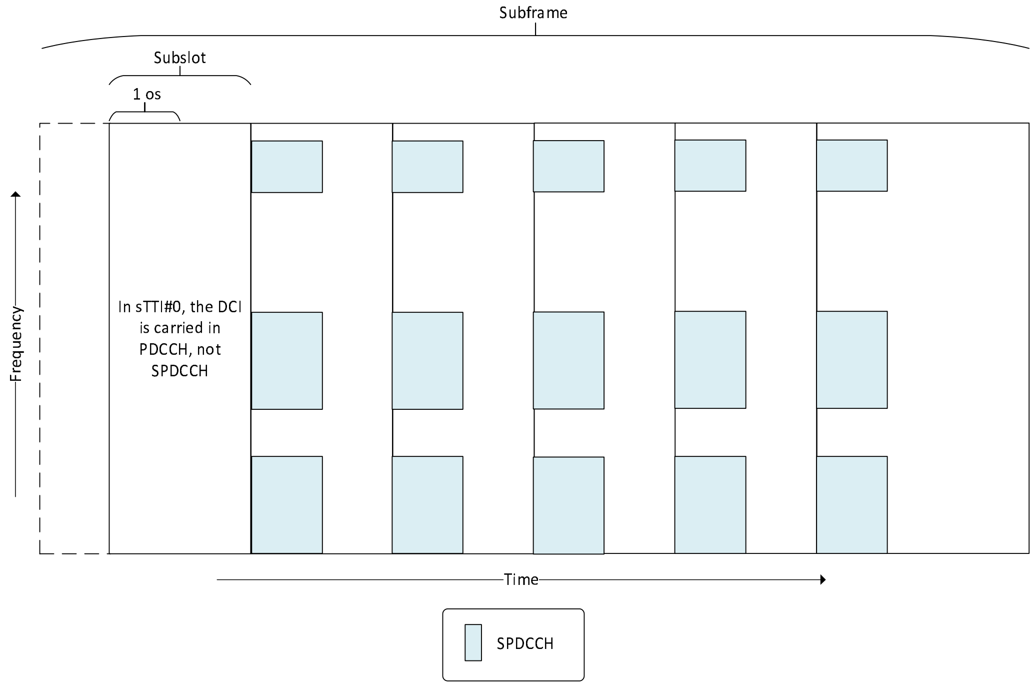


Figure 13.8-3: 1 os SPDCCH illustration for subslot operation

Both CRS-based and DMRS-based demodulation is supported for SPDCCH and in case of CRS-based SPDCCH, the mapping of the SPDCCH can be configured to be either over 1 or 2 symbols in time (1 symbol illustrated above in Figure 3). In case of DMRS-based SPDCCH, the control is always mapped over 2 symbols for slot-based SPDCCH, while for subslot it aligns with the subslot duration (2 or 3 symbols).

To efficiently make use of the control resources not used in a subslot/slot, a re-use mechanism is specified to re-use the control region for data, illustrated in Figure 4. Both a semi-static and dynamic mechanism is specified. The efficiency of the re-use depends on the configuration (ideal re-use assumed in Figure 13.8-4).

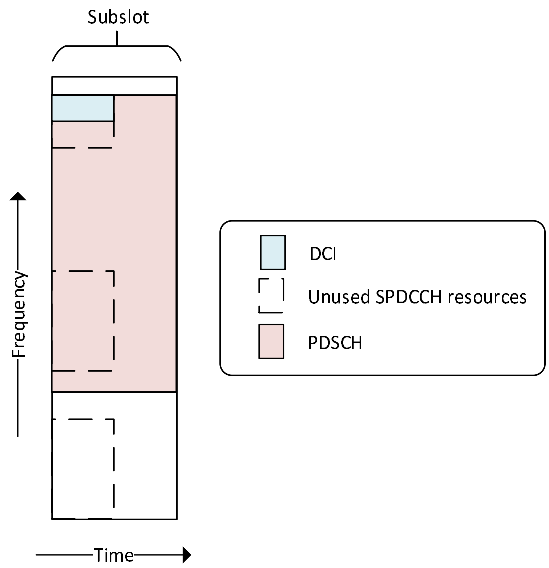


Figure 13.8-4: SPDCCH re-use for PDSCH

To further minimize overhead, the DL DMRS can be shared between two consecutive subslots within a slot . The presence of the DL DMRS for PDSCH in subslot operation is indicated in the DL DCI (present or not). In UL the DMRS can be shared between all three subslots of a slot. The UL DMRS presence and position is indicated in the UL DCI. A possible configuration of the UL DMRS in a subframe that minimizes DMRS overhead is illustrated in Figure 13.8-5.

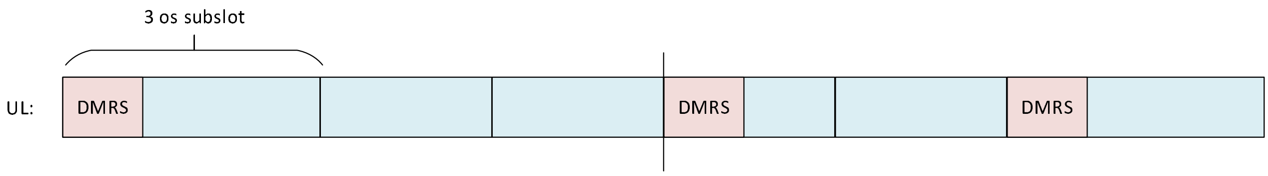


Figure 13.8-5: UL sharing of DMRS

The specification also allows for DMRSs symbols to be shared between UEs in the UL, also referred to as DMRS multiplexing. In this case, an IFDMA based DMRS is typically used which allows users of different resource allocation to share the DMRS symbol by the use of different IFDMA combs, maintaining orthogonality between UEs.

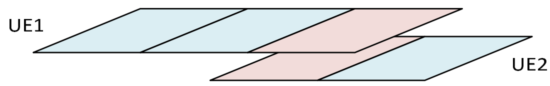


Figure 13.8-6: UL multiplexing of DMRS

As with short processing time for 1 ms, subslot/slot transmissions are associated with asynchronous HARQ operation on the UL. The processing time compared to regular 1 ms operation and the maximum timing advance are also reduced for both slot and subslot operation. In case of subslot operation, the UE can in its capability indicate the support of different processing timeline sets with associated maximum timing advance depending on the DL control channel configuration (DMRS-based SPDCCH, 1os CRS-based SPDCCH or 2os CRS-based SPDCCH). The processing timelines and associated maximum timing advance is summarized in Table 13.8-4. As can be seen, for each processing timeline set, there are two possible processing timelines (for example n+4 and n+6 for Set 1). Which one to use is under network control and configured by RRC (depending on the timing advance assigned to the UE).

Table 13.8-4: Processing timelines for slot and subslot operation with associated maximum timing advance

(s)TTI length	Max TA	Processing time line [(s)TTI lengths]	Comment
Slot	310 us	N+4	
Subslot	67 us (1) 67 us + 4os (2)	N+4 N+6	Set 1 see note
	167 us (1) 167 us + 4os (2)	N+6 N+8	Set 2 see note
NOTE: If Set 1 or Set 2 is supported is a UE capability. The processing timeline between (1) and (2) is configured by RRC. Capability can be indicated separately for 1os and 2os CRS based control, and DMRS based control.			

The number of HARQ processes has been increased to 16 for slot/subslot operation and the HARQ processes can be shared between subslot/slot and 1 ms operation (with the restriction that the TBS and number of codewords limitations of subslot/slot need to be respected in case of initial transmission on 1 ms with a later retransmission on subslot/slot).

A new set of DCI formats, named DCI format 7.x is associated with sTTI for slot and subslots scheduling. Among the specific features of these DCI formats, resource allocation has been modified to reflect the shorter TTI and therefore the granularity in RB allocation is increased.

Additional functionality also specified in the feature is sTTI specific aperiodic CSI reporting which includes measuring on a slot/subslot CSI reference resource as well as faster triggering and faster processing time for the CSI to be reported. Periodic CSI reporting is not supported.

Also, semi-persistent scheduling is specified for sTTI with similar functionality as in legacy operation. A contention based SPS operation is allowed where different UEs can be assigned different cyclic shifts and IFDMA combs for the DMRS, but fully/partially overlapping resource allocation.

References

[1] RP-171468, Revised WI on shortened TTI and processing time for LTE, source Ericsson. RAN#76
[2] RP-172247, Status report of WI Shortened TTI and processing time for LTE; rapporteur: Ericsson. RAN#78
[3] RAN1 CR pack
[4] RAN2 CR pack
[5] RAN4 CR pack

13.9 Enhanced LTE Support for Aerial Vehicles

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780069	Enhanced LTE Support for Aerial Vehicles	LTE_Aerial	R2	RP-172826	Ericsson

Summary based on the input provided by Ericsson in RP-181045 revised in RP-181644.

Enhancements according to those identified in TR 36.777 [1] to support aerial UE functions in LTE were introduced in this WI [2].

An aerial UE which is flying has a higher likelihood of having line-of-sight to eNBs which terrestrial UEs normally do not have line-of-sight to. This could result in interference and issues with mobility. This WI aimed to address such issues. Below is a description of the enhancements introduced as part of this WI.

TS 36.331 was extended with two reporting events H1 and H2. With these two new events, the UE triggers a height report when the UE's altitude is above(H1) or below(H2) of an eNB-configured threshold. Further, the RRM measurement framework was extended such that the UE can be configured to trigger a measurement report if an event condition is met for a configurable number of cells. Events applicable for this enhancement are A3, A4 and A5. These enhancements help the eNB to determine that a UE is flying and/or allow to detect that the UE may be causing or experiencing interference.

To improve mobility performance, RRC signalling was added to allow the UE to indicate to the eNB the planned flight path. More specifically, the UE can indicate where the UE is planned to be in the future which could be taken into account by the eNB for mobility purposes, e.g. the eNB may be able to use this information to know in advance which cell would be suitable for the UE to be handed over to and if a new X2 connection is beneficial to be established.

In some countries it may not be allowed to fly drones which are connected to LTE network without authorization. In order for the network to know if the user of the UE has a suitable subscription, a signalling from the CN to the eNB was introduced with information about whether the subscription supports Aerial UE function. How the eNB uses this information was left for implementation.

To reduce possible uplink interference, UL power control enhancements were specified allowing for UE-specific fractional pathloss compensation factor, and the range of the UE specific P0 parameter was also extended.

For more details please refer to the status report [3] and associated CRs [4-5].

References

[1] TR 36.777 Study on Enhanced LTE Support for Aerial Vehicles
[2] RP-172826 New WID on Enhanced LTE Support for Aerial Vehicles
[3] RP-181643 Status report for Enhanced LTE Support for Aerial Vehicles
[4] R2-1813412 Introduction of Release-15 Aerial functionality
[5] R2-1813487 Introduction of capabilities for Rel-15 Aerial WI

13.10 Enhancing LTE CA Utilization

Unique_ID	Name	Acronym	WG	WID	Rapporteur
750071	**Enhancing LTE CA Utilization**	LTE_euCA	R2	RP-170805	Nokia

Summary based on the input provided by Nokia in RP-181596.

The LTE work item on enhancing CA utilization specifies enhancements to reduce delays in SCell set-up, including shorter Scell configuration delay after UE moves from idle to connected. This is addressed by IDLE mode measurements for CA, allowing SCell state configuration by RRC, allowing separate CQI reporting configuration, introducing a dormant Scell state for faster Scell state transitions and allowing common Scell configuration to reduce signalling overhead. Changes triggered by the work item are captured into TS 36-series specifications in [3][4][5][6]

The key functionalities introduced in this work item include the following:

- UE measurements during IDLE mode: the eNB may assign UE to do measurements during IDLE that the network can use for when the UE enters CONNECTED mode.
  - This may include limitations on which cells are measured, how long the measurements are done and in which cells the measurements are applicable.
  - UE indicates the availability of the measurements at connection setup, and network decides whether to query them via RRC reporting.
- Dormant Scell state: A new Scell state called dormant state is introduced. While in dormant state, UE measures and reports CQI/RRM measurements but doesn't decode PDCCH.
  - New MAC CE is introduced to control the dormant state transitions.
- Direct Scell state configuration: The Scell state may be configured to be activated or dormant via RRC.
  - This means e.g. that the SCell state may be indicated in handover or at reconfiguration, allowing the SCell to be used
- Short CQI reporting: After Scell activation, UE may be configured to have an alternative (short) CQI reporting cycle to allow UEs to indicate faster when Scell is activated.
  - After a fixed period of time, UE switches back to using the regular CQI configuration.
- Common Scell configuration: A common configuration applying to multiple SCells may be provided to UE to allow signalling optimizations.
  - This is done via SCell configuration groups that allow to define common Scell parameters specific to all Scells belonging to the group. SCell dedicated configuration can be used to override the common parameters in the group configuration to allow changing some parameters only to some SCells.

References

[1] RP-180561, Revised WID on Enhancing CA Utilization, Nokia, RAN#79
[2] R2-1809245, UE capability definitions for euCA, Nokia, RAN2#102
[3] R2-1809246, Stage-2 description of euCA, Nokia, RAN2#102
[4] R2-1809269, MAC functionality for euCA, Nokia, RAN2#102
[5] R2-1813087, RRC signalling for euCA, Nokia, RAN2#103

14 OAM improvements

14.1 Other 5G System Charging aspects

14.1.1 Service Based Interface for 5G Charging

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780034	**Service Based Interface for 5G Charging**	5GS_Ph1-SBI_CH	S5	SP-170951	Chen, Shan, Huawei

Summary based on the input provided by Huawei Technologies France in SP-181159.

The 5G Phase 1 architecture specifies the CHF as "Charging Function". The main purpose of the CHF is to provide the Service based Interface "Nchf". This Work Item specifies the Nchf_ConvergedCharging services, operations and procedures.

The service aspects are defined in TS 32.290 while the Service API Definition and Open API are defined in TS 32.291.

TS 32.290 also defines the charging scenario (converged event based charging and converged session-based charging), charging functionalities and the Message format of the Common Data structure of Charging Data (Request and Response). TS 32.291also defines the bindings of CDR field, Information Element and Resource Attribute.

14.1.2 Charging for IMS over 5G System Architecture Phase 1

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
800040	**Charging for IMS over 5G System Architecture Phase 1**	5GS_Ph1_IMSCH	S5	SP-180391	Nokia Shanghai Bell

Summary based on the input provided by Nokia Shanghai Bell in SP-181183.

This work introduces the IMS charging extensions for IMS on top of 5G Core. In this context, the IMS charging (relying on existing Diameter based Ro/Rf charging architecture) is enhanced by extension of existing parameters:

- The "Access network charging identifier" associated to the SDP media component of the IMS session and specified for correlation purpose, contains the 5GS Charging Id (i.e. PDU session Charging Id).
- The "Access Network Information" associated to the SIP P-Access-Network-Info header, includes the User location for NR access (TAI and NCI).

These parameters apply for both online and offline charging, including information captured in IMS CDRs.

This is defined in TS 32.260 (IMS charging); TS 32.299 (Diameter charging applications) and TS 32.298 (CDR parameter description).

14.1.3 SMS Charging in 5G System Architecture Phase 1

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
810028	**SMS Charging in 5G System Architecture Phase 1**	5GS_Ph1-SMSCH	S5	SP-180900	Nokia Shanghai Bell

Summary based on the input provided by Nokia Shanghai Bell in SP-181184.

This work introduces the SMS Charging in 5G System Architecture Phase 1.

For "SMS over NAS" in 5G Core, SMS charging is specified from SMSF in the service-based charging architecture with CHF, for SMO and SMT via SMSF:

- Using the "Event-based" charging mode achieved under a variant of Nchf_ConvergedCharging service Create Operation
- dedicated "SMS Charging information" appended to the converged charging information across Nchf with the corresponding data types and API stage 3 extensions.
- SMS charging CHF CDR definition.

For SMS via IMS, SMS Diameter-based Rf offline charging is introduced from IP-SM-GW with new ISM-SMO and ISM-SMT CDRs and includes 5GS RAT Type and User Location.

SMS Diameter-based Rf offline charging from SMS-SC and SC-SMO/SC-SMT CDRs are extended with 5GS RAT Type and User Location.

SMS Diameter-based Ro online charging from both IP-SM-GW and SMS-SC are extended with 5GS RAT Type and User Location.

References

[1] TS 32.274: Short Message Service (SMS) charging
[2] TS 32.290: 5G system; Services, operations and procedures of charging using Service Based Interface (SBI)
[3] TS 32.291: 5G system, charging service; Stage 3
[4] TS 32.299: Diameter charging applications
[5] TS 32.298: Charging Data Record (CDR) parameter description

14.2 Management and virtualization aspects of 5G networks and network slicing

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760066	Management and orchestration of 5G networks and network slicing	NETSLICE	S5	SP-170960	Jan Groenendijk, Ericsson

Summary based on the input provided by Ericsson, ZTE, Intel, Huawei, Nokia in SP-xxx.

This set of Work Items enhances the Management Services (MnS) specifications to support the 5G network in addition to the pre-5G network supported in previous Releases. These WIs are shown in the table below.

Structure of the "Management and orchestration of 5G networks and network slicing" Feature

Unique ID	Title	WID
760066	Management and orchestration of 5G networks and network slicing	SP-180816
760065	Provisioning of 5G networks and network slicing	SP-180818
780041	Fault Supervision for 5G networks and network slicing	SP-180817
780038	Assurance data and Performance Management for 5G networks and network slicing	SP-180814
780037	Network Resource Model (NRM) for 5G networks and network slicing	SP-180812
780040	5G Trace management	SP-170958
780039	Management and virtualization aspects of 5G networks	SP-170958

Management and orchestration of 5G networks and network slicing

The basic concepts for Management Services (defined in TS 28.533) are:

- A management service combines elements of management service component type A, B and C. Where
- component type A is a group of management operations and/or notifications agnostic of managed entities.
- component type B is the management information represented by information model of managed entities (e.g. NRM).
- component type C is performance information of the managed entity and fault information of the managed entity.
- A management service offers management capabilities. These management capabilities are accessed by management service consumers via standardized service interface composed of individually specified management service components.
- The management services can be consumed by another entity, which may in turn produce (expose) the service to other entities.
- Interactions between management service producer and management service consumer use following paradigms:
- "Request-response": A management service producer is requested by a management service consumer to invoke an operation, which either performs an action or provides information or both. The management service producer provides response based on the request by management service consumer.
- "Subscribe-notify": A management service consumer requests a management service producer to establish a subscription to receive network events via notifications, under the filter constraint specified in this operation.

The generic management services concept, defined in TS 28.530, follows the management service concepts as defined in TS 28.533. The specification includes the following information:

- Generic provisioning management service (operations and notifications),
- Generic fault supervision management service (operations and notifications).
- Generic performance assurance management service (operations and notifications),

- RESTful HTTP-based solution set of provisioning.
- RESTful HTTP-based solution set of fault supervision.

Provisioning of 5G networks and network slicing

The following functionalities related to provisioning are defined in TS 28.531, TS 28.532 and TS 28.541:

- Provisioning procedures for networks and network slicing.
- Protocol-independent information model of network slice and network slice subnet.
- Management services for provisioning of networks and network slicing.
- RESTful HTTP-based solution set of provisioning.
- The stage 3 NRM solution sets (XML, JSON, YANG) for network slicing.

Fault Supervision for 5G networks and network slicing

Fault Supervision is one of the fundamental functions for the management of a 5G network and its communication services. This work item specifies the following aspects of fault supervision for 5G networks and network slicing:

1) Fault Supervision (FS); Stage 1, which includes:

    - The definitions of fault supervision related management services
    - The use cases and requirements for fault supervision of 5G networks and network slicing.

2) Fault Supervision (FS); Stage 2 and stage 3, which includes:

    - The definition of interfaces of the fault supervision related management services; (Stage 2)
    - The definition of notifications; (Stage 2)
    - The definition of alarm related information models (e.g. alarmInformation, alarmList, etc.); (Stage 2)
    - The definition of solution set(s) (e.g. RESTful HTTP-based solution set for Fault Supervision); (Stage 3)

The stage 1 part is documented in TS 28.545 [13] and the stage 2 and stage 3 parts are documented in clause 6 and clause 9 of TS 28.532 [10].

Performance assurance for 5G networks including network slicing

The performance assurance of 5G networks and network slicing relies on a set of management services with the relevant management data (e.g. performance measurements and KPIs).

The management services in terms of performance assurance include the measurement job control service, performance data file reporting service, performance data streaming service, and management data analytics service (MDAS). The performance data includes performance measurements and KPIs for NFs, NSSIs and NSIs. The performance data of NSSI are generated based on the aggregation and calculation of performance data of NFs, and the performance data of NSIs are produced based on the aggregation and calculation of performance of data of NSSIs and NFs.

The performance assurance related management services are defined in TS 28.550 [14].

The performance measurements and KPIs for 5G networks are defined in TS 28.552 [15] and TS 28.554 [16] respectively.

Network Resource Model (NRM) for 5G networks and network slicing

To support management and orchestration of 5G network and network slicing, several Network Resource Model (NRM) related specifications were added or enhanced including TS 28.540 [17], TS 28.541 [18], TS 28.622 [19], TS 28.623 [20], TS 28.626 [21] and TS 28.658 [22]. The specifications include the following information:

- 5G Network Resource Model use cases and requirements
- Generic NRM information service and solution set
- 5G RAN NRM information service and solution set
- 5G Core NRM information service and solution set
- Network Slice NRM information service and solution set

5G Trace management

The work item introduced 5G system (including both NG-RAN and 5GC) Trace in following aspects:

- 5G Trace use case and requirements in TS 32.421 [23].

- 5G Trace session activation and deactivation mechanism (including both management based and signalling based Trace activation and deactivation) in TS 32.422 [24].

- 5G Trace control and configuration parameter definitions in TS 32.422 [24].

- 5G Trace record data definitions in TS 32.423 [25].

The objective of this WI is to enhance the interactions between 3GPP management system and supporting external management systems (e.g., ETSI NFV MANO) to support the management of 5GC and NG-RAN where a gNB is split into a CU (Centralized Unit) that can be implemented as VNF, and a DU (Distributed Unit) that can be implemented as PNF, with the F1 interface between CU and DU.

References

TS 28.530: "Management and orchestration; Concepts, use cases and requirements"
TS 28.532: "Management and orchestration; Generic management services"
TS 28.533: "Management and orchestration; Architecture framework"
TS 28.531: "Management and orchestration; Provisioning"
TS 28.545: "Management and orchestration; Fault supervision"
TS 28.550: "Management and orchestration; Performance assurance"
TS 28.552: "Management and orchestration; 5G performance measurements and assurance data"
TS 28.554: "Management and orchestration; 5G end to end Key Performance Indicators (KPI)"
TS 28.540: "Management and orchestration; 5G Network Resource Model (NRM); Stage 1"
TS 28.541: "Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3"
TS 28.623: "Telecommunication management; Generic Network Resource Model (NRM) Integration Reference Point (IRP); Solution Set (SS) definitions"
TS 28.622: "Telecommunication management; Generic Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)"
TS 28.626: "Telecommunication management; State management data definition Integration Reference Point (IRP); Solution Set (SS) definitions"
TS 28.658: "Telecommunication management; Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)"
TS 32.421: "Telecommunication management; Subscriber and equipment trace; Trace concepts and requirements"
TS 32.422: "Telecommunication management; Subscriber and equipment trace; Trace control and configuration management"
TS 32.423: "Telecommunication management; Subscriber and equipment trace; Trace data definition and management"

15 Work Items for which no summary is needed

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
770007	Protocol enhancements for Mission Critical Services	MCProtoc15	C1	CP-172145	Jörgen Axell

This work item is for small improvements for mission critical services that are not included in any of the dedicated work items.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
750005	HPLMN Radio Access Technology deployment Optimisation in Network Selection	HORNS	S1	SP-170277	Eddy Hall, Qualcomm Incorporated

No normative work resulted from this study.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790039	Policy and Charging for Volume Based Charging	PC_VBC	C3	CP-180051	Huang, Zhenning, China Mobile

No input claimed nor received.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
780019	Remote UE access via relay UE	REAR	S1	SP-160511	Huawei, Laurence Meriau

There is no normative work for this feature in Stage2/3 for Rel-15 (seems also nothing in Rel-16).

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
800041	**UE Conformance Test Aspects - CT6 aspects of 5G System**	5GS_Ph1_UEConTest	C6	CP-181176	Azem, Dania (COMPRION GmbH)

Testing only.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760050	MC Communication Interworking between LTE and non-LTE Systems	MCCI	S6	SP-170578	Monnes, Peter, Harris Corporation

There is no Stage 3 normative work for this feature in Rel15 (the Stage 3 has been moved to Rel16), so this Feature is not implementable in this Release.

SP-180993, from Harris Corporation, summarises Stages 1 and 2 of this Work Item, remembering that these Stages are, by definition, not implementable: it intended to specify Mission Critical (MC) communication interworking with Land Mobile Radio (LMR) systems, as to enable calls to be carried on between the participants in both systems. This would have enabled an LMR system for: affiliation; group calls; private calls; broadcast calls; etc.

The Stages 1 and 2 defined the architecture, identities, procedures and information flows to enable an MC system to interwork with an LMR system. The Stage2 is available in TS 23.283.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
760049	MC system migration and interconnection	MCSMI	S6	SP-170577	Chater-Lea, David; Motorola Solutions

There was no stage 3 work carried out for MCSMI in Rel-15.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
790019	Usage of CAPIF for xMB API	CAPIF4xMB	S4	SP-180031	Thorsten Lohmar, Ericsson LM

This was moved to Rel-16.

Unique_ID	Name	Acronym	WG	WID	WI Rapporteur
720075	Security Assurance Specification for PGW network product class	SCAS_PGW	S3	SP-160481	Peng Jin, China Mobile

No change for R15.

Annex A: Structure of 5GS Rel-15 3GPP work

The table below provides the overall view of all the 5G-related work items in Rel-15, including their hierarchical structure and where they are summarised in the present document:

Unique ID	Name	Acronym	Lead	WID	Summary
740005	**5G System - Phase 1**	5GS_Ph1		SP-160958	Y
750019	**Study on Charging Aspects of 5G System Architecture Phase 1**	FS_5GS_Ph1_CH	S5	SP-170953	N
720005	**(Stage 1 of 5G) New Services and Markets Technology Enablers**	SMARTER	S1	SP-160364	Y
740061	**Stage 2 of 5G System - Phase 1**	5GS_Ph1	S2	SP-160958	Y
750025	**CT aspects of 5G System - Phase 1**	5GS_Ph1-CT	ct	CP-181081	Y
750026	Studies on CT1 aspects of 5G System - Phase 1	5GS_Ph1-CT		CP-181081	N
770042	Study on 5G Network selection	5GS_Ph1-CT	C1	CP-181081	N
770043	Study on 5G Mobility management	5GS_Ph1-CT	C1	CP-181081	N
770044	Study on 5G Session management	5GS_Ph1-CT	C1	CP-181081	N
770045	Study on 5G Non-3GPP access networks	5GS_Ph1-CT	C1	CP-181081	N
770046	Study on 5G Interworking with EPC	5GS_Ph1-CT	C1	CP-181081	N
770047	Study on 5G System core network impact on services, network functions and capabilities	5GS_Ph1-CT	C1	CP-181081	N
770048	Study on 5G Network slicing	5GS_Ph1-CT	C1	CP-181081	N
780008	CT1 aspects of 5G System - Phase 1 (normative work)	5GS_Ph1-CT	C1	CP-181081	Y
780009	5G Network selection	5GS_Ph1-CT	C1	CP-181081	Y
780010	5G Mobility management	5GS_Ph1-CT	C1	CP-181081	Y
780011	5G Session management	5GS_Ph1-CT	C1	CP-181081	Y
780012	5G Non-3GPP access networks	5GS_Ph1-CT	C1	CP-181081	Y
780013	5G Interworking with EPC	5GS_Ph1-CT	C1	CP-181081	Y
780014	5G System core network impact on services, network functions and capabilities	5GS_Ph1-CT	C1	CP-181081	Y
780015	5G Network slicing	5GS_Ph1-CT	C1	CP-181081	Y
750027	Study on CT3 aspects of 5G System - Phase 1	5GS_Ph1-CT	C3	CP-181081	N
790044	CT3 aspects of 5G System - Phase 1	5GS_Ph1-CT	C3	CP-181081	Y
750028	CT4 aspects of 5G System - Phase 1	5GS_Ph1-CT	C4	CP-181081	Y
750029	Study on CT6 aspects of 5G System - Phase 1	5GS_Ph1-CT	C6	CP-181081	N
790043	CT6 aspects of 5G System - Phase 1	5GS_Ph1-CT	C6	CP-181081	N
760029	**IMS impact due to 5GS IP-CAN**	5GS_Ph1-IMSo5G	ct	CP-180094	Y
770017	CT1 aspects of IMSo5G	5GS_Ph1-IMSo5G	C1	CP-180094	Y
770018	CT3 aspects of IMSo5G	5GS_Ph1-IMSo5G	C3	CP-180094	Y
770019	CT4 aspects of IMSo5G	5GS_Ph1-IMSo5G	C4	CP-180094	Y
780034	**Service Based Interface for 5G Charging**	5GS_Ph1-SBI_CH	S5	SP-170951	Y
780035	**Data Charging in 5G System Architecture Phase 1**	5GS_Ph1-DCH	S5	SP-170952	Y
750016	**Security aspects of 5G System - Phase 1**	5GS_Ph1-SEC	S3	SP-170881	Y
800041	**UE Conformance Test Aspects - CT6 aspects of 5G System**	5GS_Ph1_UEConTest	C6	CP-181176	N
750035	**EPC enhancements to support 5G New Radio via Dual Connectivity**	EDCE5		SP-170583	Y
750012	**SA2 aspects of EDCE5**	EDCE5	S2	SP-170583	Y
750036	**SA3 aspects of EDCE5**	EDCE5	S3	SP-170233	Y
760001	**CT aspects of EDCE5**	EDCE5-CT	ct	CP-173038	Y
760068	CT1 aspects of EDCE5	EDCE5-CT	C1	CP-173038	Y
760069	CT3 aspects of EDCE5	EDCE5-CT	C3	CP-173038	Y
760070	CT4 aspects of EDCE5	EDCE5-CT	C4	CP-173038	Y
760062	**Charging aspects of EDCE5: PS Charging enhancements to support 5G New Radio via Dual Connectivity**	EDCE5-CH	S5	SP-170487	Y
750067	**New Radio Access Technology**	NR_newRAT	R1	RP-171485	Y
750167	**Core part: New Radio Access Technology**	NR_newRAT	R1	RP-180536	Y
750267	**Perf. part: New Radio Access Technology**	NR_newRAT	R4	RP-180536	Y
750072	**LTE connectivity to 5G-CN**	LTE_5GCN_connect	R2	RP-171432	Y
750172	**Core part: LTE connectivity to 5G-CN**	LTE_5GCN_connect	R2	RP-180064	Y
760087	**UE Conformance Test Aspects - 5G system with NR and LTE**	5GS_NR_LTE-UEConTest	R5	RP-180418	N

Annex B: Process to get further information

B.1 General

Since the present document is limited to provide an overview of each Feature, this chapter explains how to get additional information, in particular how to retrieve all the Specifications (TSs) and Reports (TRs) as well as all the CRs which relate to a given Work Item.

The Unique Identifier (UID) is the key to get additional information on a given Work Item. It can be found in the table located just below the clause's header. The table has the following format:

Table B-1: table format

Unique Identifier (UID)	Name	Acronym	Outline Level (1=Feature, 2=Building Block, 3=Work Task)	Responsible Working Group	Work Item Description

For readability reasons, the table headers are omitted in the continuation of the present document.

For instance, for the "Mission Critical Push to Talk over LTE Realignment", the table has to be understood as:

Table B-2: Example of table at the introduction of each Feature

Unique Identifier (UID)	**Name**	**Acronym**	**Outline Level**	**Responsible Working Group**	**Work Item Description**
700029	**Mission Critical Push to Talk over LTE Realignment**	MCImp-MCPTTR	2	S1	SP-150821

Thus, the UID for this Work Item is 700029.

Two methods are now possible to retrieve more information on a given feature: the "Step by step method" and the "Direct method". The "direct method" is faster but implies to know the hierarchical structure of the Work Items. The "step by step method" is slower but is easier to use, in particular when the hierarchical structure is unknown.

For instance, for retrieving all the CRs that relate to "Enhancements for Mission Critical Push To Talk", the search has to be done on UID 740022 but also potentially on its children Work Items (UID 720056, 740023 and 740024).

Table B-3: Example of a hierarchical structure and its consequences on the search procedure

740022	**Enhancements for Mission Critical Push To Talk**	MCImp-eMCPTT		SP-160490
720056	Stage 2 of Enhancements for Mission Critical Push To Talk	MCImp-eMCPTT	S6	SP-160490
740023	Stage 3 of Enhancements for Mission Critical Push To Talk	MCImp-eMCPTT-CT	CT	CP-160824
740024	CT1 aspects of Enhancements for Mission Critical Push To Talk	MCImp-eMCPTT-CT	C1	CP-160824

These two methods are described in the following clauses.

B.2 Direct method

The links below lead to the pages containing respectively all the Specifications and all the Change Requests (CRs) linked to a given Feature:

https://portal.3gpp.org/Specifications.aspx?q=1&WiUid=[UID]

https://portal.3gpp.org/ChangeRequests.aspx?q=1&workitem=[UID]

where "[UID]" has to be preplaced by the UID value.

Using the example provided in the table 4.1-3, the specification linked to "Stage 2 of Enhancements for Mission Critical Push To Talk" can be found in:

https://portal.3gpp.org/Specifications.aspx?q=1&WiUid=720056

And all the related Change Requests are listed in:

https://portal.3gpp.org/ChangeRequests.aspx?q=1&workitem=720056

B.3 Step by step method

This method is to be used when the hierarchical structure is not known or when the "direct method" above does not show the expected results.

In this case, the 3GPP Ultimate web site has to be used:

https://portal.3gpp.org

As a preliminary step, it is essential that the "Customized Selection" is set to "All TSGs" (otherwise, a filter would be applied).

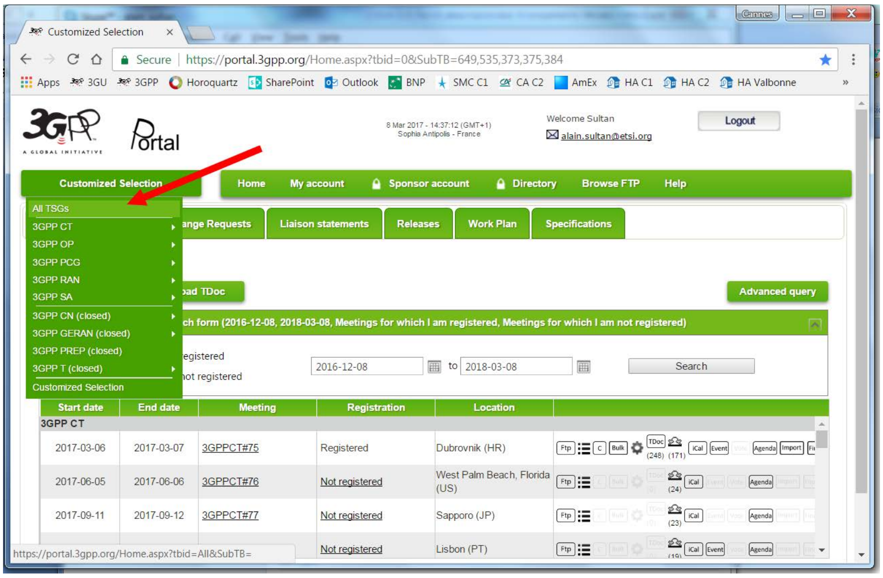


Figure B.3-1: Selecting "All TSGs" in "Customized Selection" as to remove any potential filter on the Search

Then select the "Work Plan" tab (upper red arrow in the figure below).

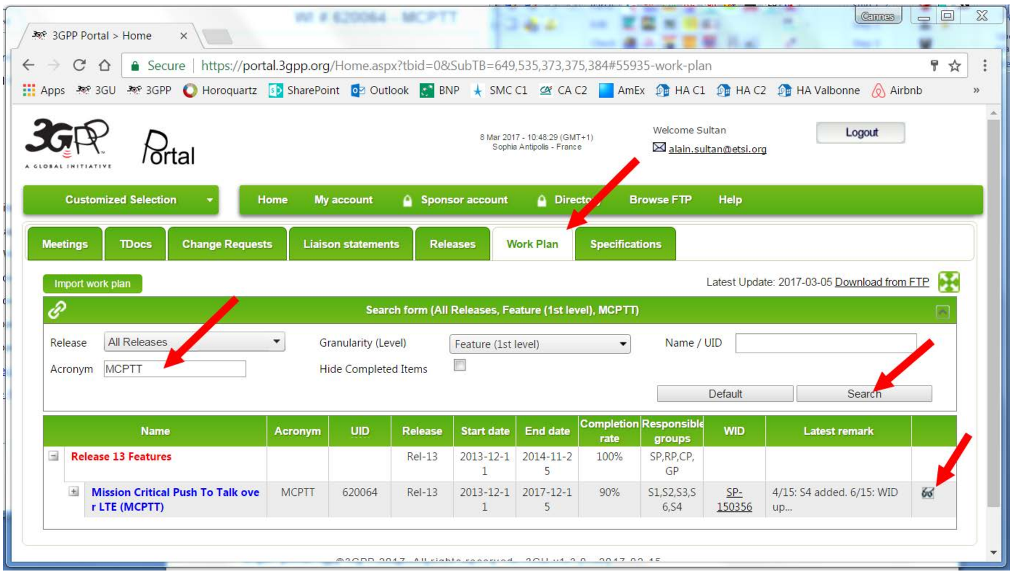


Figure B.3-2: Using the 3GU Portal to retrieve more information on a given Feature

Then the search might be performed by either typing the Acronym (as shown by the left red arrow on the figure above, using the example "MCPTT"), or by the name or UID (right box) then by clicking on the "Search" button. Watch the "Granularity (Level)" field, which is a filter to return only the Items which level is specified here.

In the results, the icon depicting some binoculars has to be hit (lower right red arrow on the figure above).

This will lead to the page shown in the figure below:

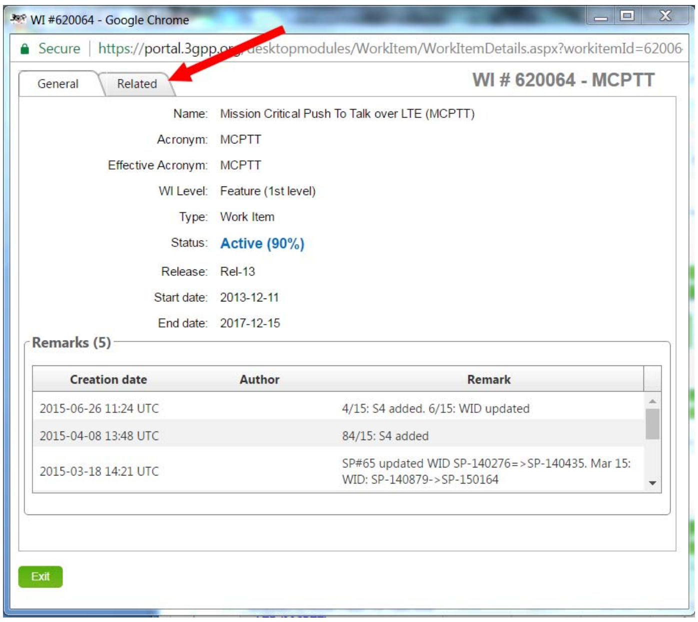


Figure B.3-3: Window resulting from a "Search"

On this window, the "Related" tab has to be clicked, as pointed by the red arrow in the figure above. This will lead to the window depicted in the figure below.

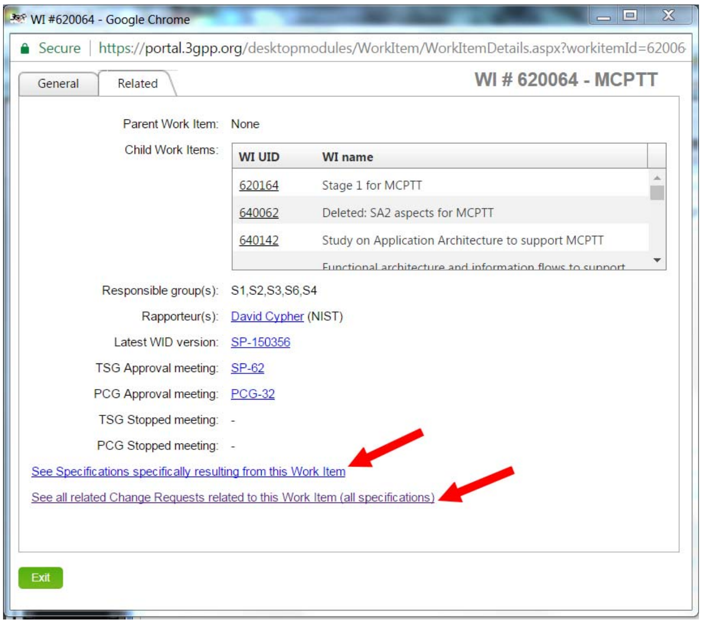


Figure B.3-4: "Related" tab in a Work Item search, with links to all related Specifications and Change Requests

The two links pointed by the red arrows in the figure above lead to the pages containing respectively all the Specifications and all the Change Requests (CRs) linked to this Feature.

Annex C: Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2018-03	SA#79	SP-180182				Initial draft	0.0.1
2018-06	TSG#80	CP-181179/ RP-181286/ SP-180553				Draft presented at TSG#80 for consolidated list of expected input	0.1.0
2018-09 to 2019-03	TSG#81 to 83					Incorporation of summaries as they were received	0.2.0 to 0.8.0
2019-03	TSG#83					MCC renumbering of clauses and editorial clean up One missing summary.	1.0.0
2019-03	TSG#83					All summaries provided.	1.1.0
2019-09	TSG#85					Deep editorial clean-up. Several sections re-written. Final clean-up performed	1.2.0
2019-09	TSG#85					Raised to v.2.0.0 for presentation for approval by TSG#85	2.0.0
2019-09	TSG#85					Approved by TSG#85	15.0.0

History

Document history		
V15.0.0	October 2019	Publication