EXECUTIVE SUMMARY

INSIDE 3GPP RELEASE 13

Understanding the Standards for LTE-Advanced Enhancements

2016 Update

FOREWORD

For nearly 15 years, 5G Americas (and 3G Americas and 4G Americas) has published white papers that condense and explain the standards work by 3GPP on the GSM-UMTS-LTE family of technologies. In June 2015, a working group of member company experts prepared a detailed report, ***Mobile Broadband Evolution Towards 5G: 3GPP Release 12 & Release 13 and Beyond*** to help in understanding the future of wireless broadband and how new requirements and technological goals will be achieved. An ***Executive Summary – Inside 3GPP Release 13: Understanding the Standards for HSPA+ and LTE-Advanced Enhancements*** was published in August 2015. With the completion of Release 13 standards in March 2016, the Executive Summary on Release 13 is being updated to reflect any changes since June 2015 in this current publication.

INTRODUCTION

EXECUTIVE SUMMARY
Inside 3GPP Release 13: Understanding the Standards for LTE-Advanced Enhancements
2016 Update

There are more than 7.2 billion wireless connections[1] using the 3rd Generation Partnership Project (3GPP) standards, including 1.45 billion LTE connections, and increasingly those connections are interoperating with other wireless technologies including Wi-Fi. 3GPP Release 13 (Rel-13) will further advance LTE toward the wireless broadband foundation for the fifth generation (5G) or IMT-2020. 5G mobile technology will need to face unprecedented challenges: accommodating skyrocketing traffic growth amid a spectrum shortage, escalation of the Internet of Things (IoT) and a vision for network transformation that will create an all-IP environment. All of that will not be alleviated until the next decade or further as IMT-2020 or 5G technology begins to take shape.

However, the 3GPP standards have many innovations remaining for both LTE and HSPA+ to create a foundation for 5G. Rel-12, which was finalized in December 2014, contains a vast array of features for both LTE and HSPA+ that brings greater efficiency for networks and devices, as well as enables newer services. As in previous releases, and given the large number of features first introduced in Rel-12, many were extended into Rel-13. Rel-13 continues to build on these while adding many rich new features of its own. Rel-13 was functionally frozen in December 2015, and completed in March 2016 (with an exception to complete the NB-IoT feature by June 2016).

In this executive summary, a concise overview of the main Rel-13 features is provided. More detailed explanations of 3GPP Rel-13 are provided in the 4G Americas white paper, ***Mobile Broadband Evolution Towards 5G: Rel-12 & Rel-13 and Beyond*** and will be further explained in a future paper on Releases 13 to 15 toward the later part of 2016.

For LTE-Advanced, Rel-13 supports Active Antenna Systems (AAS), including beamforming, Multi-Input Multi-Output (MIMO) and Self-Organizing Network (SON) aspects, enhanced signaling to support inter-site Coordinated Multi-Point Transmission and Reception (CoMP), Carrier Aggregation (CA) enhancements to support up to 32 component carriers and Dual Connectivity (DC) enhancements to better support multi-vendor deployments with improved traffic steering. Improvements in Radio Access Network (RAN) sharing

1 Ovum, WCIS+. June 2016. [Data does not include M2M]

have also being worked on as part of Rel-13. Work on enhancements to Machine Type Communication (MTC) and Proximity Services (ProSe) continued from Rel-12.

Further features addressed in Rel-13 are: Licensed Assisted Access for LTE (LAA), in which LTE can be deployed in unlicensed spectrum, LTE Wireless Local Area Network (WLAN) Aggregation (LWA) where Wi-Fi can now be supported by a radio bearer and aggregated with an LTE radio bearer, Narrowband IoT (NB-IoT) where lower power wider coverage LTE carriers have been designed to support IoT applications, and Downlink (DL) Multi-User Superposition Transmission (MUST) which is a new concept for transmitting more than one data layer to multiple users without time, frequency or spatial separation.

For HSPA+, the main Rel-13 items are enhancements for reducing control channel overhead and support for dual band Uplink (UL) Carrier Aggregation.

With respect to network-related services, Rel-13 introduces Wi-Fi integration enhancements to support Network-Based IP Flow Mobility (NBIFOM) enhancements to harmonize the support of voice and video services over Wi-Fi and enhancements to support Mission Critical Push-to-Talk (MCPTT) over LTE for public safety. Rel-13 continues work from Rel-12 in optimizing performance for MTC services by defining a Dedicated Core (DECOR) and Monitoring Enhancement (MONTE) for MTC services, as well as enhancements to MBMS, ProSe and group communications.

Additional features in network-related services include the User Plane Congestion Management (UPCON) feature which enables the identification of cells and users in congested situations so that policy decisions can be used to mitigate congestion, and the Application Specific Congestion Control for Data Communication (ACDC) can manage access attempts on a per application basis. Architecture Enhancements for Service Capability Exposure (AESE) was added in Rel-13 to expose valuable information to third party application providers.

As 3GPP Rel-13 was being completed to further develop the standards for HSPA+ and LTE/LTE-Advanced, simultaneous discussion on future network requirements and recommendations for the next generation of 5G technologies was also underway. Groups such as 5G Americas are contributing to the discussion and are liaising with other organizations such as NGMN Alliance, 5G PPP, ATIS, ITU, Small Cell Forum and others. 5G Americas has published several white papers on 5G topics including spectrum and technology recommendations. Discussions in the 3GPP working groups have turned to 5G standardization in Rel-14 and Rel-15.

The summary following is an overview of some of the key features in Rel-13.

3GPP RELEASE 13: HSPA+ AND LTE-ADVANCED

1. E-UTRAN/LTE-ADVANCED ENHANCEMENTS

1.1 ACTIVE ANTENNA SYSTEMS (AAS)

Active Antenna Systems (AAS) introduces advanced antenna systems, usually comprised of radiating elements and transceiver units, to Base Stations (BS) installations as shown in Figure 1. In TR 37.842 3GPP[2] defines an active antenna system base station as a base station which combines an antenna array with a transceiver unit array, and optionally a radio distribution network covering single- and multi- radio access technologies and coverage scenarios from local- to wide-area.

Rel-13 identified the RF requirements that may be needed for an AAS BS specification and the necessary conformance testing derived from those RF requirements.

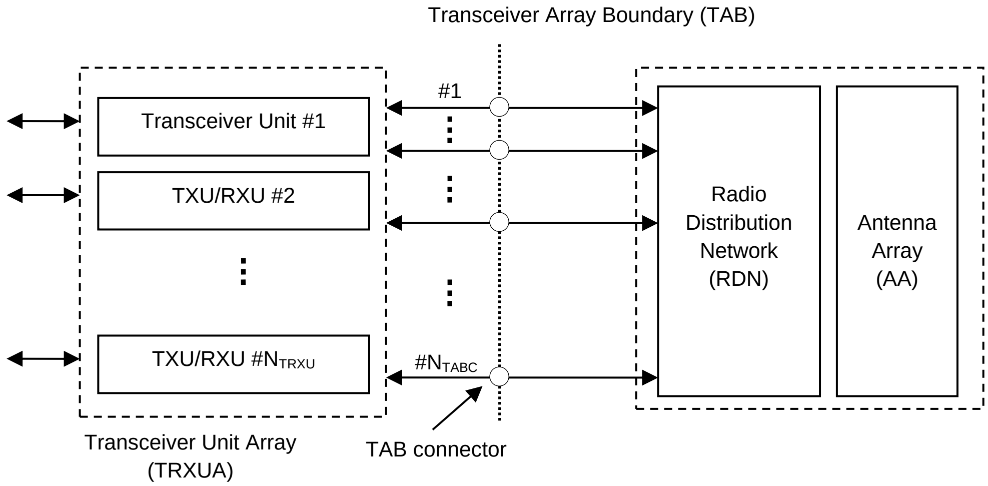

Figure 1. General Active Antenna System Base Station Architecture.

1.2 SELF-OPTIMIZING NETWORKS (SON) FOR ACTIVE ANTENNA SYSTEM (AAS) DEPLOYMENTS

Active Antenna Systems (AAS) allow the creation of multiple vertical and horizontal (or combination) beams making the cell deployment dynamic. This enables dynamic cell splitting/merging to handle changing load conditions in the cell. Rel-13 focused on ensuring the connection continuity and adapting the existing SON/MRO principles (from earlier releases) during the dynamic deployment changes due to AAS-based

[2] 3GPP TR 37.842 V1.12.0 (2016-08) Radio Frequency (RF) requirement background for Active Antenna System (AAS) Base Station (BS) (Release 13).

deployments without impacting the RRM mechanism. This was achieved by synchronous handling between OAM based configuration and X2 signaling.

1.3 ELEVATION BEAMFORMING (EBF) AND FULL DIMENSION (FD) MULTI-INPUT MULTI-OUTPUT (MIMO)

After extensive study of EBF-FD MIMO[3] [, 3GPP has concluded and decided to support several enhancement techniques in Rel-13 including non-precoded CSI-RS transmission schemes, beamformed CSI-RS transmission schemes, SRS enhancement for TDD, DMRS enhancement for higher order multiuser transmission and CSI measurement restriction.

For non-precoded CSI-RS transmission schemes based on Class A CSI reporting, a number of new codebooks have been designed for 1D and 2D antenna arrays based on CSI measurement over non-precoded CSI-RS ports. Another category of CSI measurement and feedback supported in Rel-13 is based on beamformed CSI-RS transmission with Class B CSI reporting. In general, Class B CSI reporting can be categorized as techniques of CSI dimensionality reduction compared to Class A CSI reporting. SRS transmission is further enhanced in Rel-13 because of the implementation of AAS and channel reciprocity-based MIMO operation. From downlink perspective, DMRS ports 7, 8 and 11 and 13 with OCC4 can be used for multiuse transmission because of increased likelihood of high order MU pairing. Therefore with the combination of four orthogonal DMRS ports using OCC and two non-orthogonal DMRS ports using scrambling identities, up to 8 multi-user layers can be supported from Rel-13. Last but not least, Rel-13 can support CSI measurement restriction, with either channel measurement restriction, or interference measurement restriction, or both. With channel measurement restriction, the mechanism of beam probing can be supported at the time domain UE-transparently.

1.4 ENHANCED SIGNALING FOR INTER-ENB COORDINATED MULTI-POINT (CoMP)

The goal of this work item is to introduce a coordination mechanism to reduce interference between two eNBs. It is believed that Inter-eNB CoMP can provide better performance by improving the coverage of high data rates, cell-edge throughput and overall system throughput coordinated scheduling. Such a centralized (master/slave) approach, where slave eNBs operating in a cluster provide coordination information to a Centralized Coordination Function (CCF), is shown in Figure 2.

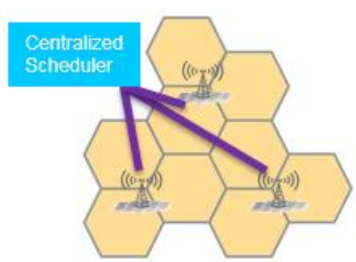

Figure 2. Centralized Approach with CCF.

[3] TR 36.897 Study on Elevation Beamforming/Full-Dimension (FD) MIMO for LTE.

Figure 3 summarizes the enhancements to inter-eNB CoMP as part of Rel-13.

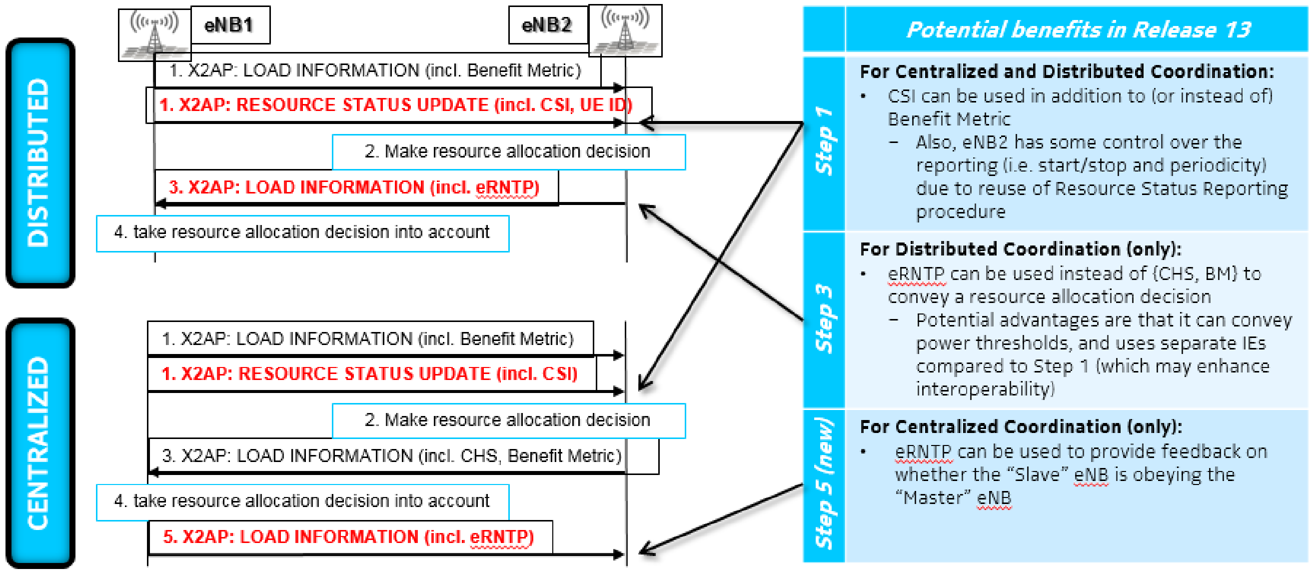

Figure 3. Enhancements to Inter-eNB CoMP as part of Rel-13.

1.5 FURTHER LTE PHYSICAL LAYER ENHANCEMENTS FOR MACHINE TYPE COMMUNICATION (MTC)

The general aim is to specify a new UE for MTC operation in LTE that also allows for enhanced coverage compared to existing LTE networks and low power consumption. The main target areas are as follows.

Introduction of a new Rel-13 low complexity UE category/type for MTC operation: to be applied in any LTE duplex mode (full duplex FDD, half duplex FDD, TDD), based on the Rel-12 low complexity UE category/type supporting the following additional capabilities:

- Reduced UE bandwidth of 1.4 MHz in downlink and uplink
- Reduced maximum transmit power
- Reduced support for downlink transmission modes
- Further UE processing relaxations can also be considered

1.6 INDOOR POSITIONING ENHANCEMENTS

The Indoor Positioning Study Item was initiated in September of 2014 to analyse potential enhancements that would improve positioning both indoors and in other challenging environments. This was driven by the observation that mobile devices are used increasingly indoors. In the U.S., the FCC in January of 2015 issued the Fourth Report and Order on Wireless E911 Location Accuracy Requirements[4]. This order

[4] FCC Fourth Report and Order in the Matter of Wireless E911 Location Accuracy Requirements, PS Docket No. 07-114.

requires that wireless providers provide either a dispatchable location or an x/y location within 50 meters for 80 percent of all wireless 911 calls within six years. Within eight years, wireless providers must deploy dispatchable location or z-axis technology that meets yet undetermined z-axis accuracy metric. Further, there are several interim benchmarks that must be met before the final six and eight year requirements. The current Study focuses on methods that provide x/y/z-axis and not dispatchable location.

After the indoor positioning study item was completed [TR 37.857], 3GPP initiated a Rel-13 indoor positioning work item. This work item, completed in December 2015, resulted in the introduction of the following new positioning methods targeted to address the indoor positioning needs [TS 36.305 v13.0.0]:

- Barometric sensor method
- WLAN method
- Bluetooth method
- Terrestrial Beacon System method

1.7 LICENSED ASSISTED ACCESS (LAA) USING LTE

Licensed-assisted access (LAA) is a 3GPP enhancement of Long-Term Evolution (LTE) in the unlicensed spectrum, which has been standardized in LTE Release 13. Under LAA, licensed carriers are aggregated with unlicensed carriers in order to opportunistically enhance downlink user throughput while still offering seamless mobility support. In order to coexist with Wi-Fi in the unlicensed spectrum, enhancements include a mechanism for channel sensing based on listen-before-talk (LBT), discontinuous transmission on a carrier with limited maximum transmission duration, dynamic frequency selection (DFS) for radar avoidance in certain bands, and multicarrier transmission across multiple unlicensed channels. The DTX and LBT functionalities will have a major impact on various aspects of LTE ranging from downlink physical channel design, channel state information (CSI) estimation and reporting, hybrid ARQ (HARQ) operation, to radio resource management (RRM) as shown in Figure 4.

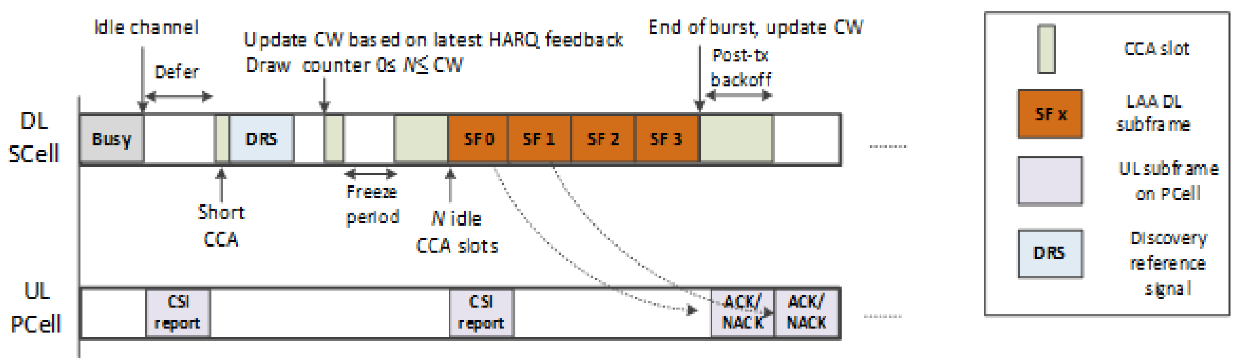

Figure 4. LAA DL Transmissions with LBT CW Updates Based on HARQ ACK/NACK Feedback.

1.8 CARRIER AGGREGATION (CA) ENHANCEMENTS

Carrier aggregation was first introduced in Rel-10, allowing operators to use their spectrum assets more efficiently, to boost user throughputs, and increase capacity. Through Rel-12, aggregation of up to five carriers and bandwidths up to 100MHz are supported.

In Rel-13, the carrier aggregation framework was extended to support up to 32 carriers, targeting carriers in unlicensed spectrum to be used in conjunction with LAA. With Rel-13 CA enhancements, in principle, LTE terminals will be able to handle bandwidths up to 640 MHz, most of which will be located in unlicensed spectrum, hence allowing UEs to achieve tremendous data rates.

1.9 DOWNLINK MULTI-USER SUPERPOSITION TRANSMISSION (MUST)

A new Study Item was initiated in March 2015[5] to investigate the benefits of downlink Multi-user Supposition Transmissions (MUST), a concept of joint optimization of multi-user operation from both the transmitter and receiver's perspective. The objective of this study is to investigate the potential gain of schemes enabling simultaneous transmissions of more than one layer of data for more than one UE within one cell without time, frequency and spatial layer separation. This concept may have a potential to further improve multi-user system capacity while orthogonal beams and layers from a cell are limited, so that more than one layer of data transmission in a beam using superposition coding becomes beneficial. The details of superposition coding are for further study, but an advanced receiver with successive interference cancellation capability is commonly assumed.

1.10 RADIO ACCESS NETWORK (RAN) ASPECTS OF RAN SHARING ENHANCEMENTS

RAN Sharing allows multiple participating operators to share the resources of a single RAN according to agreed allocation schemes. The Shared RAN is provided by a Hosting RAN Operator (a provider of a Hosting RAN) which can be one of the participating operators (operator that uses allocated shared RAN resources provided by a Hosting RAN Provider under agreement). With the growing deployment of the shared network, operators anticipate the scenarios where CN and/or RAN overload can result in a situation where an overloaded PLMN's users can starve another PLMN's users, thus leading to unfairness.

Current mechanisms of EUTRAN sharing do not allow a hosting provider to calculate and enforce policing of DL and UL data volumes used by a participating operator (per PLMN). Hence, new functions were added in Rel-13 to enable aggregated DL and UL data volume collection per PLMN and per QoS profile parameters. Depending on Sharing Operators agreement, a QoS profile may be limited to a subset of standard parameters (e.g., QCI).

1.11 ENHANCED LTE DEVICE-TO-DEVICE (D2D) PROXIMITY SERVICES (ProSe)

The Rel-13 work on D2D ProSe covers enhancements to LTE device-to-device communications and discovery, meeting public safety requirements for in-network coverage (intra-cell and inter-cell), partial network coverage and outside network coverage scenarios. For non-public safety discovery, the work item

5 RP-150496: Downlink Multiuser Superposition Transmission for LTE.

covers in-network coverage (intra-cell and inter-cell) only. In particular, the work will cover enhancements to D2D discovery, enhancements to D2D communication, and enhancements and specs in support of ProSe related MCPTT requirements identified by SA groups (e.g., performance of call-set-up), the study of additional co-existence issues with adjacent carrier frequencies that may arise due to the new mechanisms being defined, and the Definition (if needed) of additional Tx/Rx RF and RRM core requirements for the UE. The proposed solutions should enable D2D services on the same or on different carrier(s) than that used for LTE WAN communication by the UE.

1.12 DUAL CONNECTIVITY ENHANCEMENTS

Dual Connectivity in Rel-13 builds on the capabilities provided in Rel-12, including addressing uplink bearer split. In Rel-13 a UE reporting method to determine the time difference between PCell and PSCell has been added. The UE uses the SFN and Sub-Frame number of both the PCell and PSCell to calculate the timing difference between MeNBs and SeNBs which is deemed important for multi-vendor deployments. Traffic steering during DC operation is also supported in Rel-13. It is believed that the increase in demand for higher data requiring more small cells deployed for coverage could increase the traffic load at the core network significantly. DC can benefit from offloading certain services to minimize core network congestion and hence more flexible traffic steering techniques are necessary for DC. To offload operator network in DC scenario, local breakout is important as it provides the operator with the means for efficient backhaul usage and reduces the load on the core network. Two existing mechanisms for traffic redirection are Local IP Access (LIPA) and Selective IP Traffic Offload (SIPTO) already defined in 3GPP. LIPA is used for HeNB only, whereas SIPTO is used for both HeNB as well as Macro eNBs.

1.13 LTE-WIRELESS LOCAL AREA NETWORK (WLAN) RADIO LEVEL INTEGRATION AND INTERWORKING ENHANCEMENTS

The Rel-13 standard work on LTE-WLAN Radio Level Integration and Interworking Enhancements includes three main components/features:

- LTE-WLAN Aggregation (LWA), which builds upon 3GPP Rel-12 Dual Connectivity split-bearer architecture with aggregation of data links at PDCP layer, and allows utilization of radio resources on both LTE and WLAN simultaneously for a data bearer
- LTE-WLAN Radio Level Integration with IPsec Tunnel (LWIP) integrates 3GPP RAN with WLAN network above the PDCP layer using IPsec tunnelling without requiring any modifications to the WLAN network, and allows use of WLAN radio resources for LTE traffic in both uplink and downlink
- RAN Controlled LTE WLAN Interworking (RCLWI), which builds upon 3GPP Rel-12 RAN Assisted WLAN Interworking by allowing eNB to send a steering command to the UE for WLAN offload, in part based on UE measurements for WLAN

The main goal of LWA is to allow offloading of data from cellular more efficiently than earlier solutions for WLAN deployments either by a mobile network operator and/or its partners. In all previous WLAN solutions developed by 3GPP, the anchor point for the traffic was Core Network and in particular S-GW and the decision to offload is done by the UE (with some assistance information in Rel-12 solution). LWA uses eNB as the anchor point and decision making node, which allows more dynamic and granular offloading decisions. LWIP was introduced in Rel-13 to address the operator needs to leverage the capacity available from the large incumbent WLAN network base where modifications to WLAN, as required by LWA would not be feasible because of hardware, architectural or operational constraints. The use of WLAN resources in downlink and uplink is controlled by the eNB, and completely bypasses the LTE user plane protocol stack. LWIP allows use of combined LTE and WLAN capacity for a user by allowing either inter-bearer distribution or intra-bearer per IP flow distribution across the LTE and WLAN radio links. RCLWI still uses CN-based offloading but the eNB can make the decision to steer traffic between LTE and WLAN which can provide better performance compared to previous CN based solutions. 3GPP WLAN offloading solutions always allow the user preferences to have higher priority over standardized mechanisms offered by the network. The same principle also applies to LWA and RCLWI.

1.14 RADIO ACCESS NETWORK (RAN) ENHANCEMENTS FOR EXTENDED DISCONTINUOUS RECEPTION (DRX) IN LTE

As already identified by earlier 3GPP releases, reducing significantly UE power consumption can be very valuable for certain UEs (e.g., for MTC/IOT sensors that run on small batteries may be a major cost to exchange/charge batteries; otherwise the battery duration may simply determine the device's lifetime). In Rel-12, 3GPP adopted a NAS layer solution-defined Power Saving Mode (PSM), allowing a very low UE power consumption in certain use cases (e.g., Mobile Originated (MO)-only or scheduled Mobile Terminated (MT) data). However, the PSM has limited applicability for unscheduled MT data with a certain requirement on delay tolerance. If the maximum allowable delay tolerance is less than the order of many hours, the PSM solution may not be so efficient, due to more frequent periodic registrations. Another approach to provide better UE power consumption in those scenarios (partly studied in Rel-12[6] [7]), is to extend current DRX operation.

In Rel-13, 3GPP standardized a RAN-based solution for extended DRX[8] to address the previously described shortcomings:

- Extend idle mode DRX cycles up to approximately 45 minutes (for non-NB-IoT) or 3 hours for NB-IoT
- Extend connected mode DRX cycles up to 10 seconds

1.15 RAN ASPECTS OF CELLULAR INTERNET OF THINGS (CIOT) AND NARROWBAND INTERNET OF THINGS (NB-IOT)

CIOT & NB-IOT are adopted by 3GPP in order to compete with LPWA arena for providing connectivity in the exponentially growing market of the Internet of Things services.

The requirements that lead their development are based on TR45.820, which mainly focuses on:

- Reduced UE complexity
- Improved power efficiency
- Improved indoor coverage
- Support of massive number of low throughput devices

[6] TR 23.887: Study on Machine-Type Communications (MTC) and other mobile data applications communications enhancements.
7 TR 37.869: Study on Enhancements to Machine-Type Communications (MTC) and other Mobile Data Applications; Radio Access Network (RAN) aspects.
8 RP-150493: RAN enhancements for extended DRX in LTE.

With these requirements in mind, the main design goal is not backwards compatibility, but rather enabling new IoT technologies with minimal impact to existing 3GPP RAN nodes. CIOT focuses on GSM/GPRS technology and NB-IOT focuses on LTE.

CIOT was designed to share radio resources with existing GSM/GPRS systems, and therefore using the 200 kHz channelization present in this RAT. The main characteristics of this technology are shown in Table 1.

Table 1. Characteristics of Cellular Internet of Things GSM/GPRS Systems.

Deployment	In-Band GSM
MCL (Coverage)	164 dB (33dBm power class UE) 154 dB (23dBm power class UE)
Downlink	TDMA/FDMA GMSK and 8PSK (optional), 1Rx
Uplink	TDMA/FDMA GMSK and 8PSK (optional)
Bandwidth	200KHz channelization. Typical system requirement 1.4MHz (600kHZ under study)
Peak data rate	70 kbps with GMSK and 240 kbps with 8PSK
Duplex	HD FDD (in order to achieve reduced cost UE with a single RF chain)
Power saving	PSM and ext I-DRX (in order to improve power efficiency)
Power class	23 dBm and 33 dBm

NB-IOT has been designed to be integrated in LTE eNBs, with three type of deployments envisaged for this technology:

- In-band, integrated as part of the resource regularly used for the eNB communication
- Guard band, using 180 kHz of the unused frequency band between the last Physical Resource Block (PRB) used and the channelization edge
- Standalone system in any assigned band, such as a re-farmed channel from a previous GSM/GPRS system owned by the operator

The main characteristics of NB-IOT are summarized in Table 2.

Table 2. Characteristics of Narrowband Internet of Things Using LTE.

Deployment	In-Band LTE, Guard band LTE, Standalone
MCL (Coverage)	164 dB
Dowlink	OFDMA (15 KHz subcarrier spacing), 1 Rx, 1 or 2 TX antenna
Uplink	SC-FDMA (15 KHz subcarrier spacing) Turbo Code or Single Tone (15kHz and 3,5 kHz spacing)

Bandwidth	180 kHz (1 PRBs) inside eNB assigned BW
Peak data rate	250 kbps (20 kbps for UL single tone)
Duplex	HD FDD, TDD
Power saving	PSM, ext I-DRX, C-DRX
Power class	23 dBm

2 UTRAN/HSPA+ ENHANCEMENTS

2.1 DOWNLINK (DL) ENHANCEMENTS

The DL enhancements for UTRAN/HSPA+ in Rel-13 focused on:

- Algorithm 3 (allows to slow down the inner loop power control by applying decimation on the TPC commands transmitted in downlink)
- URA_PCH with seamless transmission (by introducing unique URA-wide identities, the UE can keep them while in URA_PCH and can avoid Cell Update procedures when it has data to send)
- Improved Synchronization RRC Procedures (faster activation by RNC sending an indication in the RRC reconfiguration message that the UE and the Node B agree on an activation time)
- Retrievable Configurations (an indication is included in the RRC reconfiguration message telling to the UE to store the values of a defined set of parameters together with an identity)
- Enhanced State Transition (allows UEs to transition to a pre-configured state after finalized data transmission)

2.2 SMALL DATA TRANSMISSION ENHANCEMENTS

This feature targets very long battery life (e.g. up to few years) for MTC/IoT type devices by extending the Idle mode UTRA DRX cycle. The extended Idle mode DRX (eDRX) ranges from 10.24 seconds up to ~44 minutes (for the PS domain). Legacy Idle DRX could go up to 5.12 seconds. In essence, the Idle eDRX behavior is still based on Paging Occasions (PO) as determined by the CN (PS) domain-specific DRX cycle length coefficient that is broadcast by the network. However, the UE is not required to monitor every PO, but only the POs that belong to a certain Paging Transmission Window (PTW). This is illustrated in Figure 5.

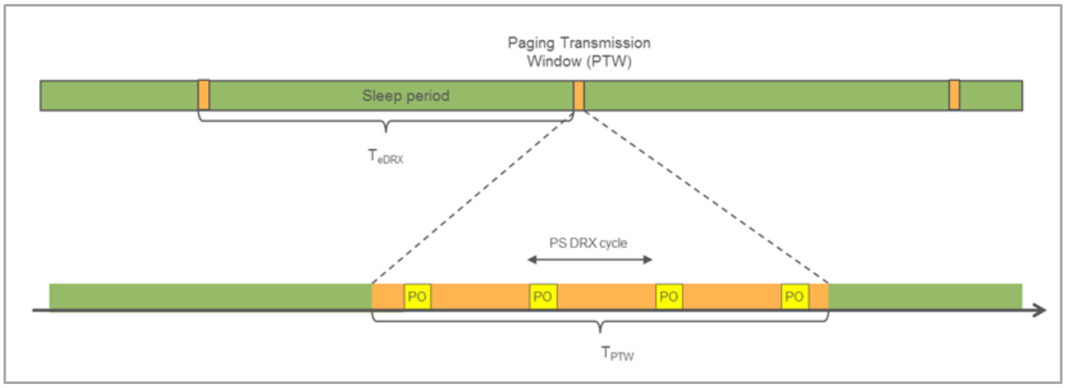

Figure 5. Extended DRX in Idle Mode.

2.3 DUAL BAND UPLINK (UL) CARRIER AGGREGATION (CA)

Leveraging from existing HSPA multi-carrier data aggregation features, such as Dual Band Dual Cell ((DB)DC)/4C-HSDPA (DL) and DC-HSUPA (UL), this new functionality extends UL multi-carrier operation by aggregating two UL carriers across bands.

An example of target dual-band deployment scenario is shown in Figure 6.

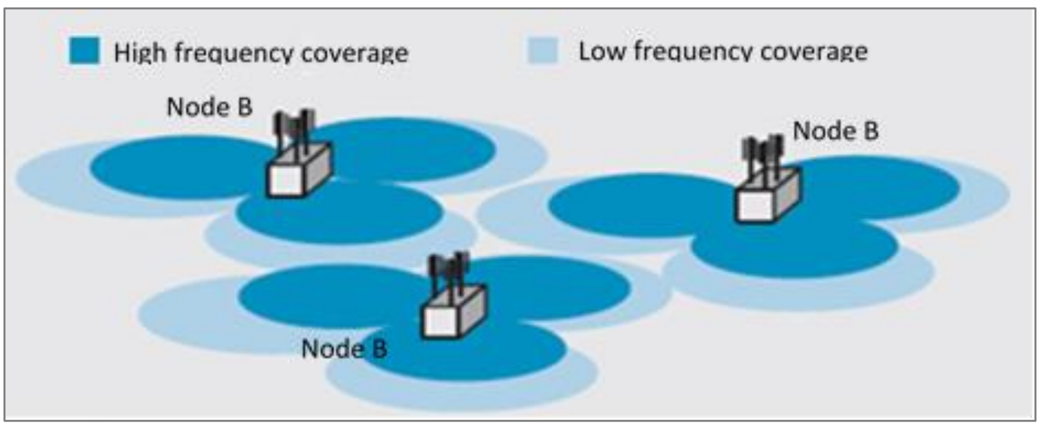

Figure 6. Example of (Co-Located) Dual-Band Deployment.

3. NETWORK SERVICES RELATED ENHANCEMENTS

3.1 IP FLOW MOBILITY SUPPORT FOR S2A AND S2B INTERFACES

Prior to Rel-13, mechanisms have been defined for simultaneous connectivity over Wi-Fi and 3GPP-based technologies for different PDN connections. The NBIFOM feature standardized in Rel-13 added the IFOM functionality for the PMIP and GTP-based mobility protocols for both trusted (S2a based) and untrusted (S2b based) WLAN access, as shown in Figure 7.

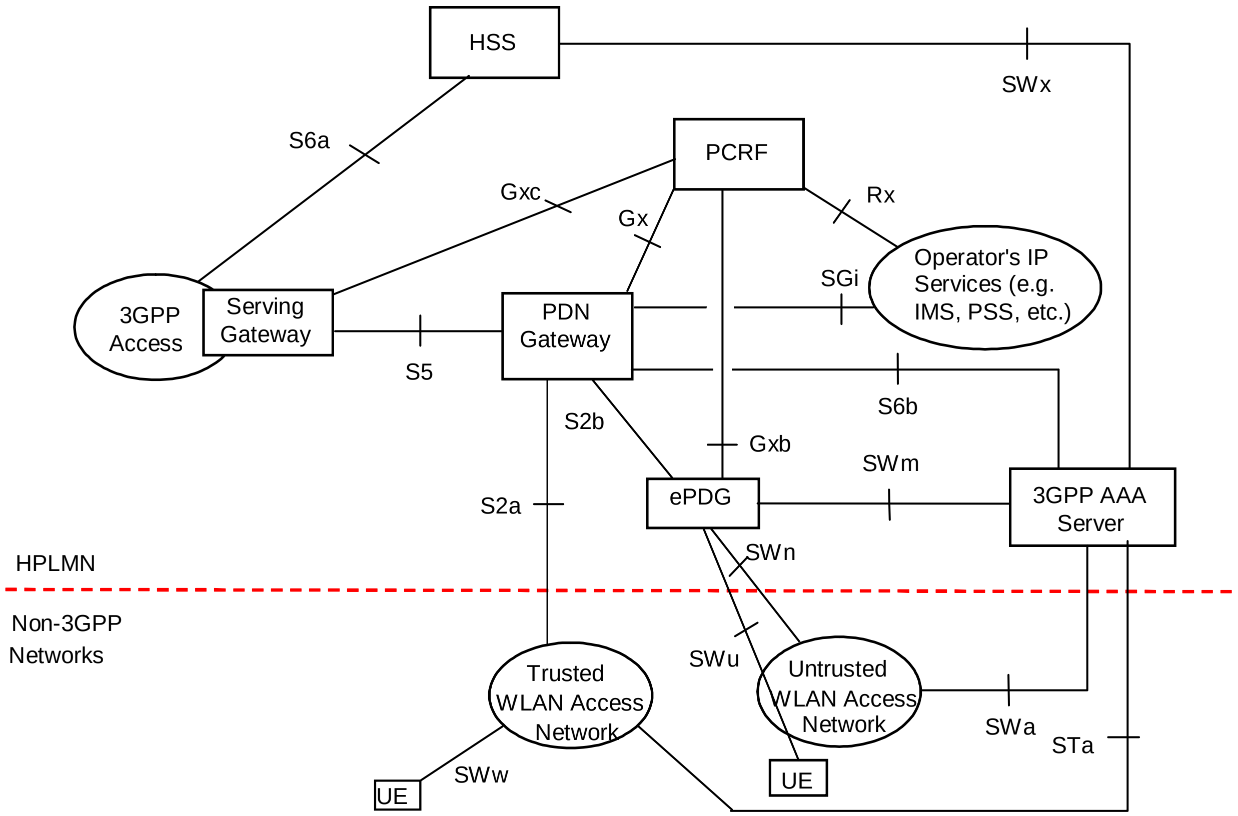

Figure 7. Non-Roaming Architecture within EPS Using S5, S2a and S2b.[9]

3.2 USER PLANE CONGESTION MANAGEMENT (UPCON)

The User-Plane Congestion (UPCON) Work Item aims at detecting and mitigating situations where the offered load exceeds the capacity of the RAN to transfer user data for a few seconds or longer (short bursts in offered load are not in scope). 3GPP Working Group (WG) SA1 defined related requirements (see TS 22.101) not only address detection of congestion ("The network shall be able to detect RAN user plane congestion onset and abatement"), but also to specify the foreseen mitigation measures. As depicted in Figure 8, a new architectural entity (RAN Congestion Awareness Function (RCAF)) has been added to 3GPP specifications. The RCAF performs three key tasks:

1. Determines whether a cell is congested
2. If a cell is congested, determines the UEs that are served by the congested cell, and
3. Informs the PCRF about the UEs which are currently served by a congested cell (and the related congestion level)

Based on receiving congestion indications from the RCAF, the PCRF can subsequently apply different policies to mitigate the congestion.

[9] TR23.861 "Network Based IP Flow Mobility"

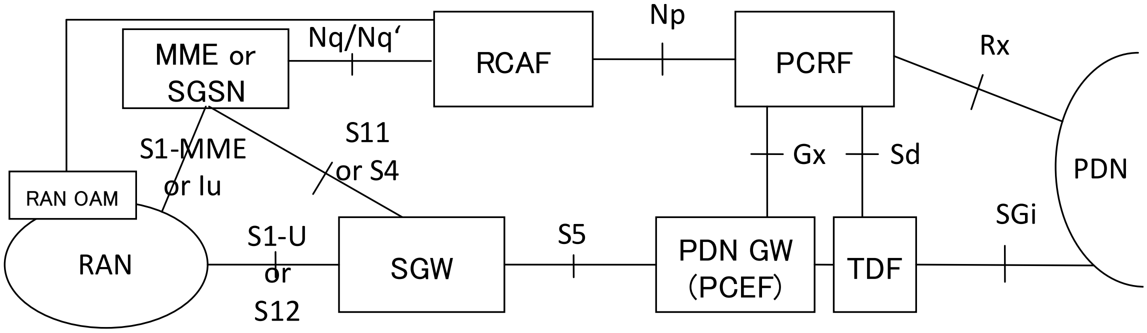

Figure 8. Rel-13 UPCON Solution Architecture.[10]

3.3 PUBLIC SAFETY

There is an acknowledged need for expansion of public safety radio systems to take advantage of broadband technologies, particularly LTE. The advantage to the police, fire and emergency medical personnel of having voice, video and high speed data capabilities integrated into their communications devices is significant and widely sought around the world. This need has led to the beginning of work in 3GPP to create such capabilities over the LTE radio interface.

3.3.1 MISSION CRITICAL PUSH-TO-TALK OVER LTE (MCPTT)

The goal of the MCPTT work in 3GPP Rel-13 was to create specifications for mission critical voice over LTE (VoLTE). Support for video and data for public safety users is not in the scope of the Rel-13 work. Group calls will take advantage of both unicast and broadcast (eMBMS) bearers to distribute voice content to members of the group.

Interworking of MCPTT over LTE with existing Land Mobile Radio (LMR) systems such as P25 and Terrestrial Trunked Radio (TETRA) will be required to provide a migration path to countries and jurisdictions from LMR systems to LTE-based public safety communications. An aspect of MCPTT is the use of 3GPP Proximity Services (ProSe) to allow two public safety devices to communicate directly with each other both in and out of regular LTE network coverage. The MCPTT capabilities, based on the requirements in 3GPP TS 22.179, will include group calls, person-to-person calls, prioritization of calls and of individuals, group management, user management, configuration management, security, operation in relay-to-network mode, operation in off-network mode and a number of other related features.

3.3.2 ENHANCEMENTS TO PROXIMITY BASED SERVICES

In Rel-13, further enhancements to Proximity-based Services (ProSe) are being studied in SA2 in order to support the Public Safety and non-Public Safety use cases that could not be completed in Rel-12 and to fulfill the requirements of Mission Critical Push to Talk (MCPTT). Specifically, Rel-13 focused on enhancements to Direct Discovery (including Restricted Discovery and Request/Response Discovery) and Enhancements to Direct Communication (One-to-one communication, Support for ProSe UE-Network

[10] 3GPP TR 23.705, “Study on system enhancements for user plane congestion management”.

Relays, Support for ProSe UE-UE Relays, Support for service continuity when moving from “on network” to “off network” and vice versa, and Support for Group priority and QoS).

3.3.3 MBMS ENHANCEMENTS

MBMS access was made available to applications in Rel-12 by the creation of the MB2 interface. This work was primarily done to support MCPTT, but also supports any application implementing the MB2 interface. Two areas in MBMS that were found to need improvement in Rel-13 are service continuity and greater independence of the application from knowing the service areas defined in the network.

3.4 MACHINE TYPE COMMUNICATION (MTC) ENHANCEMENTS

In this section, the enhancements considered relevant and applicable towards Machine Type Communications are described. These enhancements are Architecture Enhancements for Services capability exposer (AESE), optimizations to support high latency communication (HLCom), Group Based Enhancements (GROUPE), Extended DRX Cycle optimization and Monitoring Enhancements (MONTE).

3.4.1 DEDICATED CORE NETWORKS (DÉCOR)

This work studies and defines architectural enhancements required to support dedicated core networks for specific type(s) of subscribers. The use of Dedicated Core Network (DCN) can be to provide specific characteristics and/or functions or isolate specific UEs or subscribers (e.g., M2M subscribers, subscribers belonging to a specific enterprise or separate administrative domain, etc.). The main architecture enhancements are to route and maintain UEs in their respective dedicated core network (for UEs with assigned DCN).

A dedicated core network is comprised of one or more MMEs/SGSNs and it may be comprised of one or more SGWs/PGWs/PCRFs. A DCN may be deployed to support one RAT only, multiple RATs or all RATs. The dedicated MME/SGSN which serves the UE selects the dedicated S-GW and P-GW based on UE Usage Type.

A new optional subscription information parameter ("UE Usage Type") is defined for the HSS subscriber profile and is used by the serving network to select which of its CNs shall serve the UE. For the MME, the MME Group Identity (MMEGI)(s) identifies a DCN within the PLMN. For SGSNs, a group identifier(s) identifies a DCN within the PLMN. That is, the group of SGSNs that belong to a DCN within a PLMN. This identifier can have the same format as a Network Resource Identifier (NRI) value that does not identify a specific SGSN node in the serving area, or; “SGSN Group ID” provided by an SGSN to the RAN which triggers the NAS Node Selection Function (NNSF) procedure to select an SGSN from the group of SGSNs corresponding to the Null-NRI/SGSN Group ID.

3.4.2 ARCHITECTURE ENHANCEMENTS FOR SERVICES CAPABILITY EXPOSURE (AESE)

The 3GPP system has unique core assets, denoted as 3GPP service capabilities, such as Communications, Context, Subscription and Control that may be valuable to application providers. 3GPP Mobile Network Operators (MNOs) can offer value added services by exposing these 3GPP service capabilities to external application providers, businesses and partners using web-based APIs. In addition, 3GPP MNOs can combine other internal or external services with their network capabilities to provide richer, composite API services to their partners. This Rel-13 project studies and evaluates architecture enhancements for a service capability exposure framework wherein the 3GPP system-provided service capabilities are exposed via one or more standardized APIs, e.g., the OMA-API(s).

3.4.3 OPTIMIZATIONS TO SUPPORT HIGH LATENCY COMMUNICATION (HLCOM)

This Work Item studies system enhancements to support the scenario where applications communicate: 1) with temporarily unreachable devices (could be for a long period) over the 3GPP IP connectivity; and 2) with large numbers of such devices in the system; and in both without negatively affecting the system performance. The specific scenario is the downlink access for devices that are not reachable for a long period, e.g., due to the UE being in Power Saving Mode (PSM) and the problems associated with such devices such as packet discard when the UE sleeps, frequent retransmissions, load on the CN network, waste of radio resources and UE power when the network unnecessarily conveys retransmit packets, etc.

To solve or minimize the above problems, multiple solutions are agreed:

- For cases where the expected temporary unavailability for DL data reachability is compatible with the delay tolerance of the application layer and transport protocols, the DL data can be buffered in the SGW/Gn-SGSN so that when the UE is available again, the data can be immediately delivered
- For coordinating with the AS/SCS when downlink data can be sent to a UE that uses PSM or eDRX, 2 solutions are agreed to allow AS registering with network nodes for UE availability notice:
    - The AS registers with the SCEF
    - The AS registers with the HSS via the SCEF
- For coordination of maximum latency between the application and the network, two solutions are agreed:
    - Through use of coordination between the UE and the application for setting of PSM maximum response time (with which the application is tolerant for the initial IP packet transmission)
    - Through the parameter setting on Maximum latency in monitoring event configuration from the SCS/AS to the SCEF, as defined in MONTE for the UE Reachability event

The HLcom study result is captured in TR 23.709.

3.4.4 GROUP BASED ENHANCEMENT (GROUPE)

Based on the requirements in TS 22.368 sec 7.2.14, to optimize handling of groups of MTC devices in the network, this work studies and evaluates architectural enhancements required for Group-based features. In Rel-13, the following key issues have been studied and concluded:

1. Message Delivery to a Group of Devices
Group-based messaging can be used to efficiently distribute the same message (e.g., a trigger request) to those members of an MTC group that are located in a particular geographical area on request of the SCS (Service Capability Server). Figure 9 shows the group message delivery architecture.

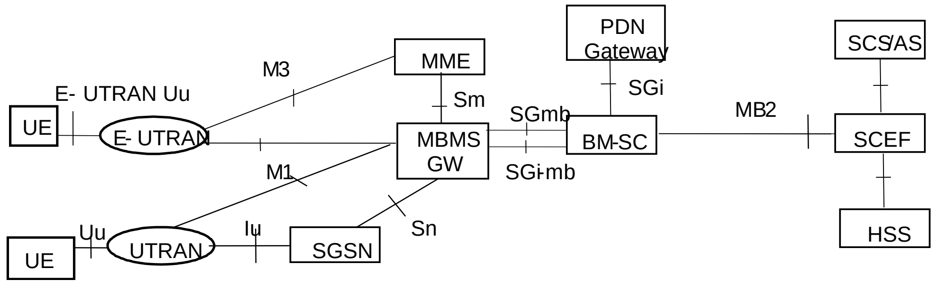

Figure 9. MBMS Based Group Messaging Architecture.[11]

2. Group Based NAS Level Congestion Control

Devices that belong to a predefined group may overload the MME by generating a large amount of NAS signaling. The key issue is how the network determines that UEs belonging to a specific group are causing NAS signaling overload/congestion, in order to provide a mechanism for the MME/SGSN to distinguish attach requests originating from this group of devices. The group needs to be identified by the proposed group identifier in order to apply existing NAS level mobility management congestion control schemes. A 3GPP internal group identifier "internal-group-id" is used to identify the group to which the UE belongs. It is part of the subscriber data in the HSS and is sent by the HSS to the MME/SGSN as part of normal EPS signalling.

3. Group Based Addressing and Identifiers

Group based addressing and identifiers are essential to support group based features such as: delivery of group messaging and group policing; to determine if a subscription is a member of a specific group; or to address the individual devices within a group. A group membership can involve 100s or 1000s of group members. Different types of groups exist, including those that have a relatively static membership and those that have more dynamic memberships.

The proposed solution provides two building blocks that other SCEF services can use:

- the ability to determine the Internal-Group-ID and the Internal-IDs of group members based on an External-Group-ID and optional External-IDs provided by the SCS/AS, and
- the ability to request that the HSS add or remove an Internal-ID from a group that the HSS maintains

3.4.5 EXTENDED DRX CYCLE FOR POWER CONSUMPTION OPTIMIZATION

In Rel-13 a work item for extended DRX cycle for UE power consumption optimization provided the means to substantially extend the normal DRX cycle. This work was initiated as part of Rel-12 work on MTC Power Consumption Optimization. Both extended DRX for idle mode and connected mode are addressed. The SA2 and CT1 work focuses on the implications in the core network and the 3GPP system in general, considering both WB-E-UTRAN and NB-IoT access. For detailed RAN aspects, see clauses 3.1.14 and 3.2.2.

[11] TR23.769: Group based Enhancements.

3.4.6 MONITORING ENHANCEMENTS (MONTE)

As part of Rel-13 Machine Type Communications (MTC) projects, this work item studies, in particular, the ability to monitor various aspects of device operation. A primary mechanism was defined that allows an application (e.g., an SCS/AS as defined by oneM2M) to be able to access the set of capabilities required for monitoring via different 3GPP interfaces/nodes (e.g., HSS via Sh (with enhancements)), or PCRF via Rx (with enhancements), or MME/SGSN via the new interface T6a/T6b to SCEF.

3.5 PAGING POLICY DIFFERENTIATION FOR INTERNET PROTOCOL MULTIMEDIA SUBSYSTEM (IMS) VOICE OVER E-UTRAN

Packet core signaling in the early deployments of large-scale LTE networks is significantly higher than in existing 2G/3G core networks. The paging traffic in particular, generated by MMEs to UEs in idle state to support a network service request, appears to be significant and to represent a substantial part of the total signaling load on the MME (e.g., in dense metropolitan areas). This is partly due to the flatter IP architecture of LTE where the macro and metro cells are directly connected to the MME, and to the increase of the paging load caused by M2M or other applications installed on smart phones.

Voice over E-UTRAN calls typically require a more aggressive paging strategy (e.g., due to the user awareness of the call setup time) than other non-voice services. A more aggressive paging scheme maximizes the probability of success on first page attempt. Applying the same aggressive paging strategy for all services using the IMS signaling bearer, regardless of whether these services correspond to IMS voice or not, causes an undesirable increase of the paging load for non-voice over E-UTRAN services. When termination attempts for non-voice over E-UTRAN services occurs at a rate of 2 to 3 times that of termination attempts for voice over E-UTRAN services, a significant savings of radio and MME resources can be achieved by using a less aggressive paging strategy for the non-voice services.

Paging Policy Differentiation for IMS Voice over E-UTRAN is a new optional feature specified in Rel-13, which allows the MME, based on operator configuration, to apply different paging strategies in LTE access for VoLTE versus other services carried over the IMS signaling bearer.

3.6 ENHANCEMENTS TO WEBRTC INTEROPERABILITY (eWebRTCi)

Continued from Rel-12 WebRTC work, this work item studied the use case that WebRTC clients' IMS subscription correspond to the third party managed users, e.g., corporate users or the users of a web service such as a game, where a range-IMPU corresponds to a set of IMPU (called "individual IP Multimedia Public Identity (IMPU)") that share the same IMS services. The characteristics of this scenario can be:

- The number of the third party managed users may scale from a small number to a huge number
- The assignment for Public User ID (PSI) for the third party managed users is left to a 3rd party (Corporate/Web service). This supports flexibility for the 3rd party to manage their services and users. For example, such range-IMPU may be defined in the format of "!.*!@my-game.company.com"

After studying 3 potential solutions, the architecture working group concluded that using HSS to support IMS subscriptions corresponding to users managed by third parties was the best solution. The study result is captured in TR 23.706, and no specification change is needed.

3.7 SUPPORT OF ENHANCED VOICE SERVICES (EVS) IN 3G CIRCUIT SWITCHED NETWORKS

The Enhanced Voice Service (EVS) codec was introduced in 3GPP Rel-12 to improve IMS VoIP (or MTSI: Multimedia Telephony Service for IMS), mainly for VoLTE. Rel- 13 has extended the support of the EVS codec to 3G CS voice (over UMTS CS networks), providing higher radio capacity (e.g. at low codec rates) and/or better voice quality for 3G users.

One more general benefit of supporting EVS (also) over UMTS is the seamless / consistent user experience and voice quality between VoLTE and 3G CS, e.g. Transcoding-less operation between a VoLTE user and a 3G user (if both using EVS), as well as no codec-switch during mobility between VoLTE and 3G CS.

Figure 10 illustrates some improved user experience examples. Assuming all UEs are EVS capable, e.g. UE1 (VoLTE) can talk seamlessly to UE3 over 3G CS; UE3 can move between LTE and UMTS without codec change/transcoding (likewise for the other end UE, e.g. UE1 or UE2).

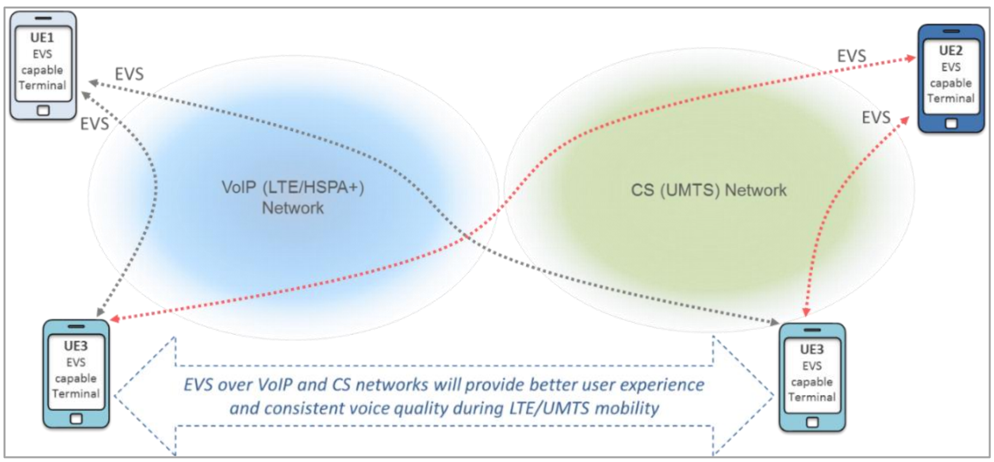

Figure 10. Seamless EVS User Experience between/across LTE and 3G Networks.

3.8 ENHANCED DYNAMIC ADAPTIVE STREAMING OVER HTTP (DASH) IN 3GPP

Following the outcomes of a previous study on Improved Support for DASH[12], 3GPP started to work on Rel-13 enhancements for DASH-based services, targeting normative aspects and operational guidelines as per relevant gaps identified during the study.

3.9 APPLICATION SPECIFIC CONGESTION CONTROL FOR DATA COMMUNICATION (ACDC)

ACDC is an access control mechanism allowing the operator to prioritize/restrict access attempts from specific applications, so as to mitigate overload of the access network and/or the core network. This mechanism is:

[12] SP-140485: New WID on Support of EVS in 3G Circuit-Switched Networks.

- optional at both the network side and the UE side
- applicable to UTRAN (PS Domain only) and E-UTRAN access technologies
- applicable to UEs in idle mode and not applicable to UEs in connected mode
- not applicable to high priority UEs (UEs that are a member of one or more Access Classes 11 to 15)
- not applicable to MMTEL voice, MMTEL video and SMS over IMS (SMS over IP) applications

3.10 CIOT & NB-IOT

In order to enhance 3GPP systems for the provision of IoT E2E communication, between IoT-UEs and service provider platforms, architecture modifications have been introduced on 3GPP system. The targets are to adapt current 3GPP systems to the new IoT requirements (low energy consumption with small and infrequent packets transmissions) and also include new services as subscriber management, security, control plane device triggering, etc.

Figure 11 (from TS 23.682) shows the current architecture for 3GPP systems for IOT service provision, and connectivity to external Application Servers.

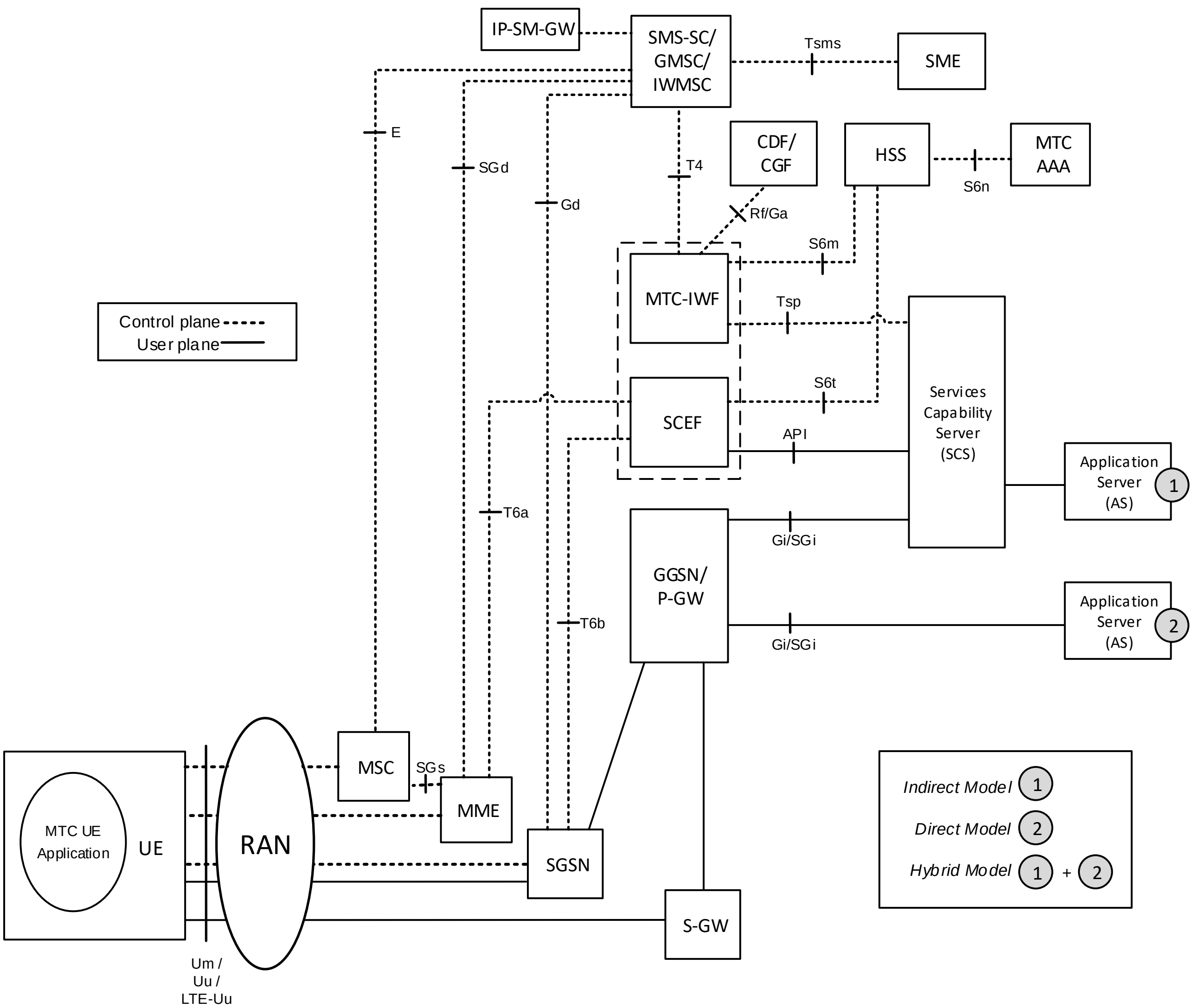

Figure 11. 3GPP Architecture for IoT Service Provision and External Applications.

3.4 RELEASE INDEPENDENT FEATURES

Some 3GPP features are considered release independent. Implementation of a release independent feature in the UE and network is not strictly constrained to the release that first introduces the feature itself, or the releases afterward; its implementation is allowed to go back to earlier releases. One important release independent category is spectrum-related features, including frequency bands and carrier aggregation (CA) combinations.

This section provides information for Rel-13 frequency bands and CA combinations.

3.4.1 FREQUENCY BANDS

During the Rel-13 time frame, 3GPP defined six new E-UTRA bands, four FDD bands and two TDD bands as shown in Table 3.

Table 3. Rel-13 New E-UTRA Operating Bands.

Frequency Band Description	E-UTRA/ UTRA	Band Number	FDD/ TDD	WID
1447-1467MHz Band for TD-LTE in China	E-UTRA	45	TDD	RP-151037
Licensed-Assisted Access to Unlicensed Spectrum	E-UTRA	46	TDD	RP-151045
2 GHz LTE Band for Region 1	E-UTRA	65	FDD	RP-141710
AWS Extension Band	E-UTRA	66	FDD	RP-150428
European 700 Supplemental Downlink band (738-758 MHz) in E-UTRA	E-UTRA	67	FDD	RP-150861
700MHz E-UTRA FDD Band for Arab Region	E-UTRA	68	FDD	RP-151042

3.4.2 LTE CARRIER AGGREGATION COMBINATIONS

During Rel-13, there were a total of 96 new CA band combinations added; the new bands are grouped in Tables 4 and further explained in Tables 5 - 9.

Table 4. Rel-13 CA Band Categories.

CA category	CA band combination counts
Intra-band contiguous CA	3
Inter-band CA (two bands)	43
Inter-band CA (three bands)	35
Inter-band CA (four bands)	12
Intra-band non-contiguous CA (with two sub-blocks)	3
Total	96

Table 5. Rel-13 Intra-band Contiguous CA Operating Bands

E-UTRA CA Band	E-UTRA Band
CA_5	5
CA_8	8
CA_66	66

Table 6. Rel-13 Inter-band CA Operating Bands (two bands).

E-UTRA CA Band	E-UTRA Band
CA_1-3-3	1, 3
CA_1-40	1, 40
CA_1-46	1, 46
CA_2-7	2, 7
CA_2-2-12	2, 12
CA_2-28	2, 28
CA_2-46	2, 46
CA_3-3-5	3, 5
CA_3-3-8	3, 8
CA_3-31	3, 31
CA_3-38	3, 38
CA_3-40	3, 40
CA_3-41	3, 41
CA_3-46	3, 46
CA_4-28	4, 28
CA_4-4-29	4, 29
CA_4-4-30	4, 30
CA_4-46	4, 46
CA_5-29	5, 29
CA_5-38	5, 38
CA_5-40	5, 40
CA_7-22	7, 22
CA_7-40	7, 40
CA_7-42	7, 42
CA_7-42-42	7, 42
CA_7-46	7, 46
CA_8-41	8, 41
CA_8-42	8, 42
CA_19-28	19, 28
CA_20-31	20, 31
CA_20-38	20, 38
CA_20-40	20, 40
CA_20-42	20, 42
CA_20-42-42	20, 42
CA_20-67	20, 67
CA_21-42	21, 42
CA_25-26	25, 26
CA_28-40	28, 40
CA_28-41	28, 41
CA_28-42	28, 42
CA_38-40	38, 40
CA_41-46	41, 46
CA_42-46	42, 46

Table 7. Inter-band CA operating bands (three bands).

E-UTRA CA Band	E-UTRA Band
CA_1-3-7	1, 3, 7
CA_1-3-28	1, 3, 28
CA_1-3-40	1, 3, 40
CA_1-3-42	1, 3, 42
CA_1-5-40	1, 5, 40
CA_1-7-8	1, 7, 8
CA_1-7-28	1, 7, 28
CA_1-8-11	1, 8, 11
CA_1-8-40	1, 8, 40
CA_1-11-18	1, 11, 18
CA_1-19-28	1, 19, 28
CA_1-19-42	1, 19, 42
CA_1-21-42	1, 21, 42
CA_2-2-4-5	2, 4, 5
CA_2-4-4-5	2, 4, 5
CA_2-4-7	2, 4, 7
CA_2-4-30	2, 4, 30
CA_2-2-5-12	2, 5, 12
CA_2-5-29	2, 5, 29
CA_2-7-12	2, 7, 12
CA_3-5-40	3, 5, 40
CA_3-7-8	3, 7, 8
CA_3-7-28	3, 7, 28
CA_3-8-40	3, 19, 40
CA_3-19-42	3, 19, 42
CA_3-7-38	3, 7, 38
CA_3-28-40	3, 28, 40
CA_3-41-42	3, 41, 42
CA_4-4-5-12	4, 5, 12
CA_4-5-29	4, 5, 29
CA_4-4-5-30	4, 5, 30
CA_4-4-12-30	4, 12, 30
CA_4-4-29-30	4, 29, 30
CA_7-20-38	7, 20, 38
CA_19-21-42	19, 21, 42

Table 8. Inter-band CA Operating Bands (four bands).

E-UTRA CA Band	E-UTRA Band
CA_1-3-5-40	1, 3, 5, 40
CA_1-3-7-8	1, 3, 7, 8
CA_1-3-7-28	1, 3, 7, 28
CA_1-3-8-40	1, 3, 8, 40
CA_1-3-19-42	1, 3,19, 42
CA_1-19-21-42	1, 19, 21, 42
CA_2-4-5-12	2, 4, 5, 12
CA_2-4-5-29	2, 4, 29
CA_2-4-5-30	2, 4, 5, 30
CA_2-4-7-12	2, 4, 7, 12
CA_2-4-12-30	2, 4, 12, 30
CA_2-4-29-30	2, 4, 29, 30

Table 9. Intra-band Non-Contiguous CA Operating Bands (with two sub-blocks).

E-UTRA CA Band	E-UTRA Band
CA_5-5	5
CA_40-40	40
CA_66-66	66

3.4.3 HSPA CARRIER AGGREGATION COMBINATIONS

For HSPA, the only Release-independent band combinations standardized as part of Rel-13 are those related to dual band UL carrier aggregation. In particular, the following configurations have been introduced.

Table 10. Dual-Band DL/UL Release Independent Combinations.

UL Bands	Number of UL carriers in Band A/B	DL Band A	Number of DL carriers in Band A	DL Band B	Number of DL carriers in Band B
I and VIII	1	I	1	VIII	1
I and VIII	1	I	2	VIII	1
I and VIII	1	I	2	VIII	2
I and VIII	1	I	1	VIII	2
I and VIII	1	I	3	VIII	1
I and V	1	I	1	V	1
I and V	1	I	1	V	2
I and V	1	I	2	V	1
I and V	1	I	2	V	2
II and V	1	II	1	V	1
II and V	1	II	1	V	2

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