**3GPP TSG RAN Meeting #88e RP-201228**

**Electronic Meeting, June 29 - July 3, 2020**

**Agenda Item:**  **10.3.1**

**Source: Ericsson**

**Title:** **Summary for WI** **Additional MTC enhancements for LTE**

**WI code(s): LTE\_eMTC5**

**Leading WG: RAN1**

**Release: Rel-16**

### 1 Introduction

This work item builds on the LTE features for Machine-Type Communications (MTC) introduced in earlier releases (e.g. low-complexity UE categories M1 and M2, and Coverage Enhancement Modes A and B) by further improving network operation and efficiency in a range of areas. For further background, refer to the documents in the reference list in the end of this document.

### 2 Description

The following sections describe the new MTC features for LTE in Rel-16. 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.

#### 2.1 Improved DL transmission efficiency and UE power consumption

Reduced UE power consumption is achieved through reduced downlink monitoring and reduced signalling, building on features introduced in earlier releases.

* **UE-group wake-up signals (GWUS):** Reduced UE power consumption in idle mode was enabled in Rel-15 by the introduction of the wake-up signal (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. In Rel-16, an enhancement is introduced that allows a WUS to wake up a configurable group of UEs rather than all UEs that happen to monitor the same PO. This helps reduce the power consumption even further. The mapping of GWUS in the time and frequency domains is highly configurable.
* **Mobile-terminated early data transmission (MT-EDT):** For scenarios where the UE only needs to transmit a small amount of data, the early data transmission (EDT) feature in Rel-15 enables the UE to transmit up to (slightly more than) 100 bytes of data already in Msg3 during the random-access procedure, and to receive data already in Msg4. If needed, eNB can order fallback to legacy random-access procedure during the EDT procedure. In Rel-16, an enhancement is introduced that allows not only mobile-originated (MO) EDT access but also mobile-terminated (MT) EDT. When the MME triggers MT-EDT, an indication is included in the paging message, after which the UE triggers random access to resume the connection (in case the UP CIoT EPS optimization is used) or initiate MO-EDT (in case the CP CIoT EPS optimization is used). MT traffic is received in Msg4. MT-EDT is only supported when UE is connected to EPC (not 5GC).
* **Improved DL quality reporting:** Legacy CE mode A supports both periodic and aperiodic CSI reporting which can be used to assist PDSCH link adaptation. In Rel-16, a new type of DL quality reporting is introduced which reflects MPDCCH quality rather than PDSCH quality. The report represents the required number of MPDCCH subframe repetitions for reliable MPDCCH reception. It can be sent in connected mode, but it can also be sent already in Msg3 during the random access procedure, which means that the report can be used for guiding the UE-specific MPDCCH configuration, which helps optimize power consumption, latency, and spectral efficiency.
* **MPDCCH performance improvement:** In legacy LTE-MTC, MPDCCH demodulation is DMRS-based. With this feature, the UE can use a combination of DMRS and CRS for MPDCCH demodulation to improve the MPDCCH performance. The feature takes the configured DMRS-to-CRS power ratio into account. The feature can be used for transmissions in idle mode and/or connected mode. In idle mode, the DMRS-to-CRS mapping is based on precoder cycling, whereas in connected mode, it can be configured to be precoder cycling based, CSI-based, or (in case of TDD) reciprocity-based.

Beside the features listed above, the features described in sections 2.2, 2.3 and 2.6 can also improve UE power consumption and/or transmission efficiency in DL and/or UL.

#### 2.2 Preconfigured uplink resources (PUR)

In Rel-15, signalling overhead and power consumption reductions were introduced by the (mobile-originated) early data transmission (EDT) feature, where data can be transmitted already in Msg3 during the random-access procedure.

In Rel-16, the earlier transmission of UL data payload has been further enhanced by introducing UL transmission using preconfigured uplink resources (PUR). When the feature is configured, both the random-access preamble transmission (Msg1) and the random-access response (Msg2) can be omitted, and the data transmission can be completed in only two messages (i.e., Msg3 and Msg4).

The UE is configured with PUR via dedicated RRC signaling while in connected mode. Configuring a UE with PUR can be triggered by the network or requested by the UE. Before performing a PUR transmission, the UE must evaluate the validity of the timing advance (TA) based on either individual or combined usage of any of the following attributes: a) serving cell change, b) TA timer, c) RSRP change. Additionally, it is possible to configure the TA as always valid within a given cell.

There are two schemes for transmitting using PUR, dedicated PUR and shared PUR, the latter allows up to two users to transmit simultaneously when the number of PUSCH repetitions is greater than or equal to 64 for full-PRB allocation.

#### 2.3 Scheduling of multiple transport blocks

In legacy LTE-MTC operation, each DCI carried by MPDCCH schedules a single PDSCH or PUSCH transport block (TB). In Rel-16, a possibility to schedule multiple TBs using a single is introduced. This can help improve the resource utilization by reducing the number of physical resource blocks (PRBs) spent on MPDCCH transmission and the number of subframes spent on guard time for DL-to-UL and UL-to-DL transition (in half-duplex FDD operation).

* **Unicast multi-TB scheduling:** When the feature is configured, a single DCI can schedule multi TBs for PDSCH or PUSCH (up to 8 TBs in CE mode A, or up to 4 TBs in CE mode B). The number of TBs is dynamically controlled by the DCI. The TBs can be configured to be transmitted consecutively or subframe interleaved (in case of subframe repetition). For PDSCH multi-TB scheduling, HARQ-ACK bundling can optionally be used to improve the resource utilization further for UEs in good coverage. For PUSCH multi-TB scheduling, early termination of the PUSCH transmission is supported through indication of positive HARQ-ACK in the DCI.
* **Multicast multi-TB scheduling:** When the feature is configured a single DCI can schedule up to 8 TBs for PDSCH for a SC-MTCH, with configurable time gaps between the TBs if desired. The number of TBs is dynamically controlled by the DCI.

#### 2.4 CE mode improvements for non-Cat-M UEs

The features in this work item can be supported both by Cat-M UEs and non-Cat-M UEs that support CE mode A or B. In addition, the following features have been specified specifically for non-Cat-M UEs that support CE mode A or B.

* **Enhancements to idle mode mobility:** A possibility is introduced for a non-Cat-M UE in a non-standalone LTE-MTC cell to use enhanced coverage functionality to camp in the cell even if the S-criterion indicates that the UE is in normal coverage. This functionality is enabled/disabled by a configuration provided in SIB1. (This is the default behavior for the standalone LTE-MTC case described in the next section in this document.)
* **CSI feedback based on CSI-RS:** In legacy CE mode A, periodic and aperiodic CSI feedback is based on up to 4 CRS antenna ports. This feature introduces support for periodic CSI feedback based on 8 CSI-RS antenna ports in TM9 for non-Cat-M UEs in CE mode A. The feature can help improve the DL link adaptation and hence the DL performance. As a separate UE capability, the feature can also optionally be supported in combination with codebook subset restriction.
* **ETWS/CMAS in connected mode**: In legacy LTE-MTC, ETWS/CMAS notification indication is supported using DCI format 6-2 in MPDCCH common search space Type-1 in idle mode. This feature introduces ETWS/CMAS notification indication using DCI format 6-1A/B in MPDCCH common search space Type-0 in connected mode for non-Cat-M UEs in CE mode A/B. This means that a UE can be notified without releasing the UE to idle mode.

#### 2.5 Stand-alone deployment

In legacy LTE-MTC operation, the first few OFDM symbols in each DL subframe are unused by LTE-MTC since they are assumed to be occupied by LTE control channels for normal LTE UEs (PCFICH, PDCCH, PHICH). This feature enables transmission of MPDCCH and/or PDSCH to UEs in CE mode A/B in the “LTE control channel region” on carriers that are not used for normal LTE. The feature can be used for transmissions in idle mode and/or connected mode. The potential DL transmission efficiency gain is about 14% (corresponding to 2 out of 14 OFDM symbols) for 1.4 MHz carriers and about 7% (corresponding to 1 out of 14 OFDM symbols) for wider carriers.

#### 2.6 Mobility enhancements

In Rel-15, two new LTE-MTC signals were introduced, the resynchronization signal (RSS) and the wake-up signal (WUS), and in Rel-16 the following mobility enhancements are introduced which make use of the Rel-15 signals.

* **RSS-based measurements**: In Rel-15, support for a resynchronization signal (RSS) was introduced and its configuration is provided by the serving cell. In Rel-16, signaling of RSS configurations for neighbor cells is introduced. Both broadcasted and dedicated signaling can be used to provide the configurations. The primary purpose of RSS is to improved synchronization performance, but with the Rel-16 signaling, the UE may also use RSS for improved measurement performance for intra-frequency RSRP measurements for neighbor cells in both idle and connected mode.
* **RRM measurement relaxation**: The legacy LTE-MTC UE behavior requires the UE to measure on the serving cell and evaluate the cell selection criterion at least every DRX cycle. The wake-up signal (WUS) introduced in Rel-15 would allow the UE to sleep for multiple paging cycles and wake up to receive paging after a configurable time duration, but the UE power saving gain from WUS cannot be fully utilized since the UE is still required to wake up for measurements. Therefore, an RRM measurement relaxation is introduced in Rel-16, which allows the UE meet the requirements using a longer measurement cycle to save power, where the cycle is configurable under certain conditions.

#### 2.7 Performance improvement for NR coexistence

Spectrum sharing with legacy (Rel-13/14/15) LTE-MTC is already supported in Rel-15 NR, and the RF coexistence aspects described in TR 37.823. The following features are introduced in Rel-16 LTE-MTC in order to further improve the performance of the coexistence with NR.

* **DL/UL resource reservation**: Legacy LTE-MTC supports configuration of invalid DL/UL subframes, which can be used in order to avoid mapping LTE-MTC transmissions to subframes that are needed for NR transmissions. Rel-16 takes a step further by introducing finer-granularity LTE-MTC resource reservation in both the time domain (with subframe, slot, or symbol level granularity) and the frequency domain (with LTE RBG level granularity) for unicast MPDCCH/PDSCH/PUSCH/PUCCH transmissions in connected mode in CE mode A/B. The resource reservation patterns are configurable using parameter combinations based on bitmaps, periodicities and offsets. For PDSCH/PUSCH, the DCI can indicate that the resource reservation should be overridden, in which case the PDSCH/PUSCH transmission becomes continuous.
* **DL subcarrier puncturing**: In order to achieve PRB alignment between LTE-MTC and NR, a possibility to puncture 1 or 2 DL subcarriers at the lower or higher edge of each 6-PRB narrowband is introduced. The puncturing affects MPDCCH/PDSCH transmissions in connected mode in CE mode A/B. The performance loss from the puncturing should typically be insignificant.

#### 2.8 Connection to 5GC

In Rel-16, support for connecting LTE-MTC UEs to 5GC is introduced. It resembles the Rel-15 functionality for connecting LTE UEs to 5GC. The RRC\_INACTIVE state is supported and additionally the User Plane CIoT 5GS optimisation is supported in RRC\_IDLE (similar to the corresponding EPC feature). Some features, such as EDT and PUR are supported only in RRC\_IDLE using the UP-optimisation solution and are not supported in RRC\_INACTIVE. Long extended DRX in RRC\_IDLE is supported, and RAN paging cycles of 5.12 s and 10.24 s are supported in RRC\_INACTIVE.

### 3 References

[1] [RP-192875](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_86/Docs/RP-192875.zip), Rel-16 LTE-MTC work item description

[2] [RP-200819](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-200819.zip), Rel-16 LTE-MTC work item status report

[3] [RP-192647](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_86/Docs/RP-192647.zip) & [RP-192648](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_86/Docs/RP-192648.zip) & [RP-200196](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_87e/Docs/RP-200196.zip) & [RP-200698](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-200698.zip), RAN1 CR packs

[4] [RP-200360](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_87e/Docs/RP-200360.zip) & [RP-201192](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-201192.zip) & [RP-201193](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-201193.zip), RAN2 CR packs

[5] [RP-201086](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-201086.zip) & [RP-201087](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-201087.zip), RAN3 CR packs

[6] [RP-193023](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_86/Docs/RP-193023.zip) & [RP-200418](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_87e/Docs/RP-200418.zip) & [RP-200962](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_88e/Docs/RP-200962.zip), RAN4 CR packs