**3GPP TSG RAN WG1 #101 R1-20xxxxx**

**e-Meeting, May 25th – June 5th, 2020**

**Source: Moderator (NTT DOCOMO, INC.)**

**Title:** **Summary on [101-e-LTE-UEFeatures-eMTC-01]**

**Agenda Item:** **6.2.5.1**

**Document for:** **Discussion and Decision**

1. Introduction

This contribution summarizes the following email discussion/approval regarding UE features for additional MTC enhancements.

[101-e-LTE-UEFeatures-eMTC-01] Email discussion/approval on remaining issues on UE features for eMTC (25th – 29th May) – (DCM, Hiroki)

* Discuss and decide prerequisite feature groups of FG1-17
* Discuss and decide applicability of FG1-34 to CE mode B
* Discuss and decide any other necessary update for the UE features list for eMTC based on identified issues/proposals in R1-2004378
* Note that all the LTE-MTC/NB-IoT alignment issues will be discussed in [101-e-LTE-UEFeatures-NBIoT-01] and agreed change(s) for LTE-MTC UE features list will be confirmed in this email discussion/approval

1. Discussion on UE features for additional MTC enhancements

## 2.1 FG1-17

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-17 | Multi-TB unicast UL early termination | 1. UL early termination for multi-TB unicast scheduling | 1-12 [and 1-25],  or 1-13 [and 1-26] | Yes | N/A | Multi-TB unicast will not use UL early termination. | Per UE | Yes | N/A |  | Optional with capability signalling |

* **Prerequisite feature groups**
  + **Remove 1-25 and 1-26: [2], [3], [4], [5]**
* **Note**
  + **Add “For HD-FDD, the necessary UL gaps can be created using feature groups 1-25 and 1-26”: [5]**

Above remaining issues and proposals are identified based on following feedbacks provided in contributions for the RAN1#101-e meeting.

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| [2] | Unclear why we have a dependency on resource reservation – propose to remove.   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 1-17 | Multi-TB unicast UL early termination | 1. UL early termination for multi-TB unicast scheduling | 1-12,  or 1-13 | Yes | N/A | Multi-TB unicast will not use UL early termination. | Per UE | Yes | N/A |  | Optional with capability signalling | |
| [3] | Currently, it is suggested that 1-25 'subframe level resource reservation for UL in CEmodeA' and 1-26 'subframe level resource reservation for UL in CEmodeB' could be the prerequisite of UL early termination for multi-TB unicast scheduling. However, UE early termination should be independent of resource reservation  ***Proposal 1: For 1-17 'Multi-TB unicast UL early termination' remove 1-25/26 in the prerequisite fields.*** |
| [4] | FD-FDD or TDD BL/CE UEs can transmit UL data and receive MPDCCH simultaneously, therefore, the subframe-level resource reservation is not needed to perform early termination. For HD-FDD UEs in CEMode B, the early termination can be realized via the UL transmission gap. For HD-FDD UEs in CEMode A, the repetition number is small and the benefits for early termination is trivial. Therefore, there is no need to have the subframe-level resource reservation as the perquisite of UL multi-TB unicast with early termination.  Proposal 1: Feature groups 1-25 and 1-26 are not the prerequisite for feature groups 1-17. |
| [5] | In the RAN1 UE feature list for Rel-16 LTE-MTC in [1], it is FFS whether support for sub-frame level UL resource reservation (1-25/1-26) should be a prerequisite for the multi-TB UL early termination feature (1-17). The rationale for tying the two features to each other is that without means for creating a gap in the UL transmission, it would not be possible for eNB to indicate to the UE that it should terminate its UL transmission. However, that rationale only holds for HD-FDD. In FD-FDD and TDD, it may be possible to transmit the DL indication without a gap in the UL transmission. Therefore, it seems to make sense to remove 1-25/1-26 from the prerequisites for 1-17 and consider adding a note about the HD-FDD case.   1. For 1-17, remove 1-25 and 1-26 from Prerequisites. 2. For 1-17, insert an informative Note stating that “For HD-FDD, the necessary UL gaps can be created using feature groups 1-25 and 1-26”. |

Based on above, following FL proposals are made.

### **FL proposal 1:**

* **Prerequisite feature groups for FG1-17**
  + **Remove 1-25 and 1-26**
* **Note for FG1-17**
  + **Add “For HD-FDD, the necessary UL gaps can be created using feature groups 1-25 and 1-26”**

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-17 | Multi-TB unicast UL early termination | 1. UL early termination for multi-TB unicast scheduling | One of {1-12, 1-13} | Yes | N/A | Multi-TB unicast will not use UL early termination. | Per UE | Yes | N/A | **For HD-FDD, the necessary UL gaps can be created using feature groups 1-25 and 1-26** | Optional with capability signalling |

Companies are encouraged to check above FL proposals and to provide feedback if any in below.

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| Company | Comment |
| Qualcomm | This change is OK for us. |
| Ericsson | This change is OK for us. |
| Huawei, HiSilicon | We are fine with the change. |
| Sony | OK with change. We agree with the argumentation in [5]. From [4], we agree that UL transmission gaps could be used for early termination in HD-FDD CE Mode B, but prefer the note in the table above, since we think that it is more useful to align the early termination across UEs, which is more easily done via the resource reservation approach.  In any case, we area OK with the change proposed in the table above. |
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## 2.2 FG1-34

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-34 | MPDCCH performance improvement with reciprocity-based candidates in TDD | 1. MPDCCH performance improvement with reciprocity-based candidates in TDD | 1-31 or 1-32 | Yes | N/A | MPDCCH performance improvement does not use reciprocity-based candidates in TDD. | Per UE | TDD only | N/A | FFS: whether it can apply to CE mode B | Optional with capability signalling |

* **FG name and components**
  + **Add “for CE mode A”: [2], [3], [4], [5]**
* **Prerequisite feature groups**
  + **Remove 1-32: [2], [3], [4], [5]**
* **Note**
  + **Remove FFS: [2], [3], [4], [5]**

Above remaining issues and proposals are identified based on following feedbacks provided in contributions for the RAN1#101-e meeting.

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| [2] | SRS is not supported in CE mode B, so the usefulness of this feature would be limited.   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 1-34 | MPDCCH performance improvement with reciprocity-based candidates in TDD in CEmodeA | 1. MPDCCH performance improvement with reciprocity-based candidates in TDD for CE mode A | 1-31 | Yes | N/A | MPDCCH performance improvement does not use reciprocity-based candidates in TDD. | Per UE | TDD only | N/A |  | Optional with capability signalling | |
| [3] | For FG 1-34, currently it is suggest to FFS whether it can apply to CE mode B. From practical deployment scenario, for majority of CE mode B UE, the SNR of the measurement channel is low therefore the measurement accuracy is usually the problem. Moreover, with long repetition for CE mode B, the delay in CSI measurement is large. Considering also the UE complexity it is suggested not to support this FG in CE mode B.  ***Proposal 2: FG 1-34 'MPDCCH performance improvement with reciprocity-based candidates in TDD' only applies to CE mode A.***   * ***Add 'in CEMode A' in FG name*** * ***Remove FFS*** * ***Remove 1-32 in the prerequisite field*** |
| [4] | There is an FFS for feature group 1-34 stating that whether MPDCCH performance improvement with reciprocity-based candidates in TDD can apply to CE mode B. With reciprocity based candidates, the eNB will measure the SRS to estimate the DMRS precoding used for MPDCCH. However, as SRS is not supported for CEMode B UEs, it is impossible to support reciprocity-based candidates in TDD for MPDCCH performance improvement.   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 1-34 | MPDCCH performance improvement with reciprocity-based candidates in TDD | 1. MPDCCH performance improvement with reciprocity-based candidates in TDD | 1-31 or 1-32 | Yes | N/A | MPDCCH performance improvement does not use reciprocity-based candidates in TDD. | Per UE | TDD only | N/A | FFS: whether it can apply to CE mode B | Optional with capability signalling |   Proposal 2：MPDCCH performance improvement with reciprocity-based candidates in TDD is not applied to CE mode B in feature group 1-34. |
| [5] | In the RAN1 UE feature list for Rel-16 LTE-MTC in [1], it is FFS whether MPDCCH performance improvement with reciprocity-based candidates in TDD (1-34) can apply to CE mode B. Since there is no SRS support in CE mode B, it seems reasonable to limit the support of this feature to CE mode A.   1. For 1-34, add “for CE mode A” in the Feature group and Components columns. 2. For 1-34, change Prerequisites from “1-31 or 1-32” to “1-31”. |

Based on above, following FL proposals are made.

### **FL proposal 2:**

* **FG name and components for FG1-34**
  + **Add “for CE mode A”**
* **Prerequisite feature groups for FG1-34**
  + **Remove 1-32**
* **Note for FG1-34**
  + **Remove FFS**

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-34 | MPDCCH performance improvement with reciprocity-based candidates in TDD for CE mode A | 1. MPDCCH performance improvement with reciprocity-based candidates in TDD for CE mode A | 1-31 | Yes | N/A | MPDCCH performance improvement does not use reciprocity-based candidates in TDD. | Per UE | TDD only | N/A |  | Optional with capability signalling |

Companies are encouraged to check above FL proposals and to provide feedback if any in below.

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| --- | --- |
| Company | Comment |
| Qualcomm | This change is OK for us. |
| Ericsson | This change is OK for us. |
| Huawei, HiSilicon | We are fine with the change. |
| Sony | OK with change |

## 2.3 FG1-35

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-35 | CSI-RS-based feedback for non-BL UE | 1. CSI-RS-based feedback for non-BL UE in CEmodeA | *tm9-CE-ModeA-r13* | Yes | N/A | CSI feedback will be based on CRS. | Per UE | Yes | N/A |  | Optional with capability signalling |

* **FG name**
  + **Add “for CE mode A”: [5]**

Above remaining issue and proposal are identified based on following feedbacks provided in contributions for the RAN1#101-e meeting.

|  |  |
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| [5] | In the RAN1 UE feature list for Rel-16 LTE-MTC in [1], for feature groups that are restricted to only one of the two CE modes, the applicable CE mode is indicated already in the Feature group column. CSI-RS-based feedback for non-BL UE (1-35) is only applicable to CE mode A, as can be seen in the Components column, but it is not indicated in the Feature group column.   1. For 1-35, add “for CE mode A” in the Feature group column. |

Based on above, following FL proposals are made.

### **FL proposal 3:**

* **FG name for FG1-35**
  + **Add “for CE mode A”**

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-35 | CSI-RS-based feedback for non-BL UE for CE mode A | 1. CSI-RS-based feedback for non-BL UE in CEmodeA | *tm9-CE-ModeA-r13* | Yes | N/A | CSI feedback will be based on CRS. | Per UE | Yes | N/A |  | Optional with capability signalling |

Companies are encouraged to check above FL proposals and to provide feedback if any in below.

|  |  |
| --- | --- |
| Company | Comment |
| Qualcomm | This change is OK for us. |
| Ericsson | This change is OK for us. |
| Huawei, HiSilicon | We are fine with the change. |
| Sony | OK with change. |

## 2.4 Others

* **Discuss and decide on updates to align descriptions for LTE-MTC and NB-IoT: [5]**

Above remaining issue and proposal are identified based on following feedbacks provided in contributions for the RAN1#101-e meeting.

|  |  |
| --- | --- |
| [5] | In the RAN1 UE feature list for Rel-16 LTE in [1], the descriptions differ more than necessary for some of the features that are common or similar for LTE-MTC and NB-IoT.   1. Discuss and decide on updates to align descriptions for LTE-MTC and NB-IoT. |

As clarified in the scope of this email discussion/approval, all the LTE-MTC/NB-IoT alignment issues are handled in another email discussion/approval.

1. Conclusion

**FL proposal 1:**

* **Prerequisite feature groups for FG1-17**
  + **Remove 1-25 and 1-26**
* **Note for FG1-17**
  + **Add “For HD-FDD, the necessary UL gaps can be created using feature groups 1-25 and 1-26”**

**FL proposal 2:**

* **FG name and components for FG1-34**
  + **Add “for CE mode A”**
* **Prerequisite feature groups for FG1-34**
  + **Remove 1-32**
* **Note for FG1-34**
  + **Remove FFS**

**FL proposal 3:**

* **FG name for FG1-35**
  + **Add “for CE mode A”**

Reference

[1] R1-2003196 Summary on email discussion [100b-e-LTE-UEFeatures-Remaining] Moderators (AT&T, NTT DOCOMO, INC.)

[2] R1-2003787 UE features for eMTC Qualcomm Incorporated

[3] R1-2003799 Discussion on UE features for additional MTC enhancements ZTE

[4] R1-2004169 Rel-16 UE features for LTE-MTC Huawei, HiSilicon

[5] R1-2004661 On the RAN1 UE feature list for Rel-16 LTE-MTC Ericsson

Appendix: latest version of UE features list for additional MTC enhancement [1]

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| **Features** | **Index** | **Feature group** | **Components** | **Prerequisite feature groups** | **Need for the eNB to know if the feature is supported** | **Need for the UE to know if the feature is supported (only for V2X WI, where the PC5-RRC capability signalling is delivered between the UEs)** | **Consequence if the feature is not supported by the UE** | **Type**  **(the ‘type’ definition from UE features should be based on the granularity of 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | **Need of FDD/TDD differentiation** | **Capability interpretation for mixture of FDD/TDD** | **Note** | **Mandatory/Optional** |
| 1. LTE\_eMTC5 | 1-1 | Group WUS without group resource alternation | 1. Group WUS without group resource alternation | Rel-15 MWUS | Yes | N/A | The UE will be paged with Rel-15 MWUS or without MWUS instead of Group WUS. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-2 | Group WUS with group resource alternation | 1. Group WUS with group resource alternation | 1-1 | Yes | N/A | If UE does not support group resource alternation and the eNB enables group resource alternation, UE falls back to Rel-15 MWUS when Rel-15 MWUS is configured or no MWUS when Rel-15 MWUS is not configured. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-3 | PUR for full-PRB in CEmodeA | 1. PUR for full-PRB in CEmodeA | CEmodeA | Yes | N/A | UL data transmission will use EDT or connected mode instead of PUR in CEmodeA. | Per UE | Yes | N/A | RAN2 has agreed that PUR with UP and CP solutions have separate indications, but this is not captured in this RAN1 UE feature list. | Optional with capability signalling |
| 1-3a | Combination of PUR for full-PRB in CEmodeA with max UL TBS 2984 bits | 1. Combination of PUR for full-PRB in CEmodeA with max UL TBS 2984 bits | 1-3,  and *ce-PUSCH-NB-MaxTBS* | Yes | N/A | PUR transmission will not use the larger UL TBS. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-4 | PUR for full-PRB in CEmodeB | 1. PUR for full-PRB in CEmodeB  2. Potential UE-specific cyclic shift for DMRS | 1-3,  and CEmodeB | Yes | N/A | UL data transmission will use EDT or connected mode instead of PUR in CEmodeB. | Per UE | Yes | N/A | RAN2 has agreed that PUR with UP and CP solutions have separate indications, but this is not captured in this RAN1 UE feature list. | Optional with capability signalling |
| 1-5 | PUR for sub-PRB in CEmodeA | 1. PUR for sub-PRB in CEmodeA | 1-3,  and UL sub-PRB | Yes | N/A | PUR will not use sub-PRB allocation in CEmodeA. | Per UE | Yes | N/A | RAN2 has agreed that PUR with UP and CP solutions have separate indications, but this is not captured in this RAN1 UE feature list. | Optional with capability signalling |
| 1-6 | PUR for sub-PRB in CEmodeB | 1. PUR for sub-PRB in CEmodeB | 1-4,  and UL sub-PRB | Yes | N/A | PUR will not use sub-PRB allocation in CEmodeB. | Per UE | Yes | N/A | RAN2 has agreed that PUR with UP and CP solutions have separate indications, but this is not captured in this RAN1 UE feature list. | Optional with capability signalling |
| 1-7 | PUR serving cell RSRP TA validation | 1. Serving cell RSRP for TA validation for PUR | 1-3 | Yes | N/A | PUR will not use serving cell RSRP for TA validation. | Per UE | Yes | N/A | TA validation mechanisms based on ‘Serving cell changes’ and ‘TA timer for idle mode’ (and ‘TA always valid’) are mandatory for PUR UEs. | Optional with capability signalling |
| 1-8 | PUR frequency hopping | 1. Frequency hopping for PUR | 1-3 | Yes | N/A | PUR will not use frequency hopping. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-9 | PUR L1 ACK | 1. L1 ACK for PUR | 1-3 | Yes | N/A | PUR will not use L1 ACK. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-10 | Multi-TB unicast for DL in CEmodeA | 1. Multi-TB unicast scheduling for DL in CEmodeA | CEmodeA | Yes | N/A | Each DCI will schedule a single TB instead of multiple TBs in DL in CEmodeA. | Per UE | Yes | N/A | Following legacy capabilities are reused to support combinations.  o Rel-14 feature for 2984 bits max UL TBS in 1.4 MHz in CE mode A  o Rel-14 feature for new numbers of repetitions for PUSCH in CE mode A  o Rel-14 feature for modulation restrictions for PDSCH/PUSCH in CE mode A  o Rel-15 features for flexible starting PRB for PDSCH/PUSCH in CE mode A/B | Optional with capability signalling |
| 1-11 | Multi-TB unicast for DL in CEmodeB | 1. Multi-TB unicast scheduling for DL in CEmodeB | CEmodeB | Yes | N/A | Each DCI will schedule a single TB instead of multiple TBs in DL in CEmodeB. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-12 | Multi-TB unicast for UL in CEmodeA | 1. Multi-TB unicast scheduling for UL in CEmodeA | CEmodeA | Yes | N/A | Each DCI will schedule a single TB instead of multiple TBs in UL in CEmodeA. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-13 | Multi-TB unicast for UL in CEmodeB | 1. Multi-TB unicast scheduling for UL in CEmodeB | CEmodeB | Yes | N/A | Each DCI will schedule a single TB instead of multiple TBs in UL in CEmodeB. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-14 | Multi-TB unicast TB interleaving | 1. TB interleaving for multi-TB unicast scheduling | 1-10 or 1-11 or 1-12 or 1-13 | Yes | N/A | Multi-TB unicast will not use TB interleaving. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-15 | Multi-TB unicast HARQ bundling | 1. DL HARQ bundling for multi-TB unicast scheduling | 1-10 | Yes | N/A | Multi-TB unicast will not use HARQ bundling. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-16 | Multi-TB unicast UL sub-PRB | 1. UL sub-PRB allocation for multi-TB unicast scheduling | 1-12 or 1-13,  and UL sub-PRB | Yes | N/A | Multi-TB unicast will not use UL sub-PRB. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-17 | Multi-TB unicast UL early termination | 1. UL early termination for multi-TB unicast scheduling | 1-12 [and 1-25],  or 1-13 [and 1-26] | Yes | N/A | Multi-TB unicast will not use UL early termination. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-18 | Multi-TB unicast DL 64QAM for CE mode A | 1. DL 64QAM for multi-TB unicast scheduling for CE mode A | 1-10,  and DL 64QAM | Yes | N/A | Multi-TB unicast will not use DL 64QAM. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-19 | Multi-TB unicast frequency hopping | 1. Frequency hopping for multi-TB unicast scheduling | 1-10 or 1-11 or 1-12 or 1-13 | Yes | N/A | Multi-TB unicast will not use frequency hopping. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-21 | Multi-TB SC-MTCH in CEmodeA | 1. Multi-TB SC-MTCH scheduling in CEmodeA  2. Potential scheduling gaps for multi-TB SC-MTCH scheduling in CEmodeA | CEmodeA,  and SC-PTM | Up to RAN2 | N/A | UE will not be able to receive SC-PTM transmissions using multi-TB scheduling in CEmodeA. | Per UE | Yes | N/A | The basic multicast (SC-PTM) functionality was introduced for LTE-M/NB-IoT in Rel-14 without capability signaling. | Up to RAN2 |
| 1-22 | Multi-TB SC-MTCH in CEmodeB | 1. Multi-TB SC-MTCH scheduling in CEmodeB  2. Potential scheduling gaps for multi-TB SC-MTCH scheduling in CEmodeB | CEmodeB,  and SC-PTM | Up to RAN2 | N/A | UE will not be able to receive SC-PTM transmissions using multi-TB scheduling in CEmodeB. | Per UE | Yes | N/A | The basic multicast (SC-PTM) functionality was introduced for LTE-M/NB-IoT in Rel-14 without capability signaling. | Up to RAN2 |
| 1-23 | Subframe level resource reservation for DL in CEmodeA | 1. Subframe-level time-domain resource reservation in DL in CEmodeA  2. RBG-level frequency-domain resource reservation in DL in CEmodeA | CEmodeA | Yes | N/A | Whole DL subframe(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-23a | Slot/symbol level resource reservation for DL in CEmodeA | 1. Slot/symbol-level time-domain resource reservation in DL in CEmodeA  2. RBG-level frequency-domain resource reservation in DL in CEmodeA | 1-23 | Yes | N/A | Whole DL PRB pair(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-24 | Subframe level resource reservation for DL in CEmodeB | 1. Subframe-level time-domain resource reservation in DL in CEmodeB  2. RBG-level frequency-domain resource reservation in DL in CEmodeB | CEmodeB | Yes | N/A | Whole DL subframe(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-24a | Slot/symbol level resource reservation for DL in CEmodeB | 1. Slot/symbol-level time-domain resource reservation in DL in CEmodeB  2. RBG-level frequency-domain resource reservation in DL in CEmodeB | 1-24 | Yes | N/A | Whole DL PRB pair(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-25 | Subframe level resource reservation for UL in CEmodeA | 1. Subframe-level time-domain resource reservation in UL in CEmodeA | CEmodeA | Yes | N/A | Whole UL subframe(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-25a | Slot/symbol-level resource reservation for UL in CEmodeA | 1. Slot/symbol-level time-domain resource reservation in UL in CEmodeA | 1-25 | Yes | N/A | Whole UL PRB pair(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-26 | Subframe level resource reservation for UL in CEmodeB | 1. Subframe-level time-domain resource reservation in UL in CEmodeB | CEmodeB | Yes | N/A | Whole UL subframe(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-26a | Slot/symbol-level resource reservation for UL in CEmodeB | 1. Slot/symbol-level time-domain resource reservation in UL in CEmodeB | 1-26 | Yes | N/A | Whole UL PRB pair(s) may need to be configured as invalid in order to avoid NR collision. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-27 | Subcarrier puncturing for DL in CEmodeA | 1. Subcarrier puncturing for DL in CEmodeA | CEmodeA | Yes | N/A | The UE will suffer a slight DL performance degradation if eNB punctures anyway. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-28 | Subcarrier puncturing for DL in CEmodeB | 1. Subcarrier puncturing for DL in CEmodeB | CEmodeB | Yes | N/A | The UE will suffer a slight DL performance degradation if eNB punctures anyway. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-29 | DL quality report in Msg3 in Idle | 1. Using 2 bits in Msg3 in Idle  2. Using 4 bits in Msg3 in Idle | CEmodeA | Up to RAN2 | N/A | The eNB will have to rely on other information, e.g. CSI reports if available. | Per UE | Yes | N/A | It is up to RAN2 whether to have separate capabilities for CE mode A and B. | Up to RAN2 |
| 1-30 | DL quality report in Connected | 1. DL quality report using 4 bits in Connected | CEmodeA | Up to RAN2 | N/A | The eNB will have to rely on other information, e.g. CSI reports if available. | Per UE | Yes | N/A | It is up to RAN2 whether to have separate capabilities for CE mode A and B. | Up to RAN2 |
| 1-31 | MPDCCH performance improvement with precoder cycling in CEmodeA | 1. MPDCCH performance improvement with precoder cycling in CEmodeA | CEmodeA | Yes | N/A | MPDCCH demodulation will rely on DMRS only (not CRS) in CEmodeA. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-32 | MPDCCH performance improvement with precoder cycling in CEmodeB | 1. MPDCCH performance improvement with precoder cycling in CEmodeB | CEmodeB | Yes | N/A | MPDCCH demodulation will rely on DMRS only (not CRS) in CEmodeB. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-33 | MPDCCH performance improvement with CSI-based mapping for CE mode A | 1. MPDCCH performance improvement with CSI-based mapping for CE mode A | 1-31 | Yes | N/A | MPDCCH performance improvement does not use CSI-based mapping. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-34 | MPDCCH performance improvement with reciprocity-based candidates in TDD | 1. MPDCCH performance improvement with reciprocity-based candidates in TDD | 1-31 or 1-32 | Yes | N/A | MPDCCH performance improvement does not use reciprocity-based candidates in TDD. | Per UE | TDD only | N/A | FFS: whether it can apply to CE mode B | Optional with capability signalling |
| 1-35 | CSI-RS-based feedback for non-BL UE | 1. CSI-RS-based feedback for non-BL UE in CEmodeA | *tm9-CE-ModeA-r13* | Yes | N/A | CSI feedback will be based on CRS. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-35a | Codebook subset restriction for CSI-RS-based feedback for non-BL UE in CEmodeA | 1. Codebook subset restriction for CSI-RS-based feedback for non-BL UE in CEmodeA | 1-35 | Yes | N/A | CSI feedback will be based CSI-RS without codebook subset restriction (or on CRS). | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-36 | ETWS/CMAS indication in connected mode for non-BL UE in CEmodeA | 1. ETWS/CMAS indication in connected mode for non-BL UE in CEmodeA | CEmodeA | Yes | N/A | UE will need to be released to idle mode before it can receive the ETWS/CMAS indication. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-37 | ETWS/CMAS indication in connected mode for non-BL UE in CEmodeB | 1. ETWS/CMAS indication in connected mode for non-BL UE in CEmodeB | CEmodeB | Yes | N/A | UE will need to be released to idle mode before it can receive the ETWS/CMAS indication. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-38 | LTE control region use for MPDCCH in CEmodeA | 1. LTE control region use for MPDCCH in CEmodeA | CEmodeA | Yes | N/A | MPDCCH reception will rely only on symbols transmitted in the LTE data region. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-39 | LTE control region use for MPDCCH in CEmodeB | 1. LTE control region use for MPDCCH in CEmodeB | CEmodeB | Yes | N/A | MPDCCH reception will rely only on symbols transmitted in the LTE data region. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-40 | LTE control region use for PDSCH in CEmodeA | 1. LTE control region use for PDSCH in CEmodeA | CEmodeA | Yes | N/A | PDSCH reception will rely only on symbols transmitted in the LTE data region. | Per UE | Yes | N/A |  | Optional with capability signalling |
| 1-41 | LTE control region use for PDSCH in CEmodeB | 1. LTE control region use for PDSCH in CEmodeB | CEmodeB | Yes | N/A | PDSCH reception will rely only on symbols transmitted in the LTE data region. | Per UE | Yes | N/A |  | Optional with capability signalling |
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