**3GPP TSG RAN WG1 Meeting #106bis-e R1-21xxxxx**

**e-Meeting, October 11th – October 19th, 2021**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #1 on 106bis-e-LTE-Rel17-NB-IoT-eMTC-01**

**Document for: Discussion and Decision**

# Introduction

The WID for Rel-17 enhancements for NB-IoT and LTE-MTC [1] includes an objective to support 16-QAM for unicast in UL and DL in NB-IoT.

* *Specify 16-QAM for unicast in UL and DL, including necessary changes to DL power allocation for NPDSCH and DL TBS. This is to be specified without a new NB-IoT UE category. For DL, increase in maximum TBS of e.g. 2x the Rel-16 maximum, and soft buffer size will be specified by modifying at least existing Category NB2. For UL, the maximum TBS is not increased. [NB-IoT] [RAN1, RAN4]*
  + *Extend the NB-IoT channel quality reporting based on the framework of Rel-14—16, to support 16-QAM in DL. [NB-IoT] [RAN2, RAN1, RAN4]*

This documents provides the proposals and summary of discussions of the corresponding email discussion according to the inputs [2-9].

[106bis-e-LTE-Rel17-NB-IoT-eMTC-01] Email discussion on support of 16-QAM for unicast in UL and DL for NB-IoT – Yubo (Huawei)

# Discussion

## Applicability

### Issue 1: Applicability

The following are proposed:

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| Sourcing | proposals |
| [2] | **Proposal 5: Support 16-QAM for NPDSCH in PUR procedure.**   * **CSI report is not supported/expected during PUR procedure.** |
| [4] | **Proposal 8: Support 16-QAM for NPDSCH in PUR procedure. CSI report is not expected during PUR procedure.**  **Proposal 9: For supporting 16-QAM in PUR procedure,**   * **One IE is introduced in pur-PhysicalConfig to enable the use of 16-QAM in NPUSCH**   + **The field multiTone in npusch-MCS in PUR NPUSCH configuration is modified to include MCS 0-21.** * **One IE is introduced in pur-PhysicalConfig to enable the use of 16-QAM in NPDSCH**   + **Power ratios of NRS and NPDSCH are given in pur-PhysicalConfig** |
| [8] | Observation 11 The applicability of 16-QAM in DL for PUR is less transparent and the use-case less evident than 16-QAM in UL for PUR. Therefore, the pre-configuration of 16-QAM for PUR should decouple UL and DL.  Observation 12 Given that the potential agreements touching upon the applicability of 16-QAM in DL for PUR were lengthy discussed and they address observation 11, we are ok with agreeing on them.  Proposal 6 Support 16-QAM for NPDSCH in PUR procedure   * CSI report is not supported/expected during PUR procedure   Proposal 7 To support 16-QAM for NPDSCH and NPUSCH in PUR procedure,   * 16-QAM can be enabled/disabled by UE specific RRC signaling in *PUR-Config-NB* for NPDSCH and NPUSCH separately.   + When 16-QAM is enabled for NPUSCH, the MCS indices, RU indices and UL power control parameter are indicated in *PUR-Config-NB*.     - Note1: It’s up to RAN2 whether a new parameter or the legacy parameter is used to indicate the RU indices.     - Note 2: There may be additional parameters if agreed.   + When 16-QAM is enabled for NPDSCH, the DL power allocation is indicated in *PUR-Config-NB*. |

On the support of 16-QAM for NPDSCH in PUR procedure, all companies with inputs proposed to support it without enhancement of CSI reporting. Therefore, the following is proposed:

Proposal 1: Support 16-QAM for NPDSCH in PUR procedure

* CSI report is not supported/expected during PUR procedure.

The details of RRC parameters can be discussed in the dedicated email thread for RRC parameters.

Please input your comments for the above proposal:

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## DCI

### Issue 2: DCI design

The following are proposed:

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| Sourcing | proposals |
| [2] | **Proposal 1: The reserved state to indicate the use of 16QAM in DCI format N0 and DCI format N1 should be “1111”.** |

There’s only one proposal for the DCI design, regarding the reserved state for indication of 16-QAM. To complete the remaining issue, the following is proposed:

**Proposal 2: The reserved state to indicate the use of 16QAM in DCI format N0 and DCI format N1 should be “1111”.**

Please input your comments regarding the above proposal:

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## Power allocation and power control

### Issue 3: downlink power allocation

The following are proposed:

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| Sourcing | proposals |
| [2] | **Proposal 3: Confirm the WA of the DL power allocation for in-band deployments.**  **Working Assumption**  **For downlink power allocation to support 16QAM:**   * **For inband deployments, a power ratio is signaled in addition to the signalling for standalone and guard-band deployments which in this case applies to “symbols with NRS” and “symbols without NRS nor CRS”.**    + **the power ratio between NPDSCH EPRE and NRS EPRE in symbols with CRS is signalled**   + **the signalling is UE specific**   **Note: “symbols with NRS” and “symbols without NRS nor CRS” have the same power.** |
| [3] | **Proposal 1: Confirm the following working assumption:**  **For downlink power allocation to support 16QAM:**   * **For inband deployments, a power ratio is signaled in addition to the signalling for standalone and guard-band deployments which in this case applies to “symbols with NRS” and “symbols without NRS nor CRS”.**    + **the power ratio between NPDSCH EPRE and NRS EPRE in symbols with CRS is signalled**   + **the signalling is UE specific**   **Note: “symbols with NRS” and “symbols without NRS nor CRS” have the same power.** |
| [4] | **Proposal 4: Confirm the working assumption on downlink power allocation for in-band deployment.** |
| [5] | ***Proposal 2: Confirm the working assumption for DL power allocation for inband case.*** |
| [6] | ***Proposal 1: Confirm the working assumption for downlink power allocation for inband deployments.*** |
| [8] | Observation 9 If the WA for In-band deployments is confirmed:   * The power ratio to be signalled does not have a dependency on the PCI case. * The deployment modes will all use the same DL power allocation framework based on signalling power ratios. * The in-band case will not be different in terms of complexity, specification impact and nature than the recently confirmed Working Assumption for Stand-alone and Guard-band deployments.   Proposal 4 Confirm the following Working Assumption from RAN1# 106-e related the DL power allocation for in-band deployments. |

All companies with inputs proposed to confirm the working assumption, therefore, the following is proposed:

**Proposal 3: confirm the following working assumption:**

**Working Assumption**

**For downlink power allocation to support 16QAM:**

* **For inband deployments, a power ratio is signaled in addition to the signalling for standalone and guard-band deployments which in this case applies to “symbols with NRS” and “symbols without NRS nor CRS”.** 
  + **the power ratio between NPDSCH EPRE and NRS EPRE in symbols with CRS is signalled**
  + **the signalling is UE specific**

**Note: “symbols with NRS” and “symbols without NRS nor CRS” have the same power.**

Please input your comments regarding the above proposal:

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### Issue 4: uplink power control

The following are proposed:

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| [2] | **Proposal 4：Option 1 should be supported for uplink power control for 16QAM.** |
| [3] | **Proposal 2: Include a configuration flag in *PUR-Config* to enable 16-QAM (row 6 in RRC parameter list).**  **Proposal 3: For uplink power control, introduce the following specification changes:**   * **Add a correction term in the power control equation following the same definition as in LTE (Option 1).** * **Add a configuration parameter *deltaMCS-Enabled*** * **Add the definition of BPRE as in LTE.** |
| [4] | **Proposal 5: A new uplink power control term is introduced in the uplink power control as follows**  **and enabled via RRC configuration.**  **Proposal 6: For the new uplink power control term, select one of the options below –**   * **Option 1: Reuse the LTE definition simplified for NB-IoT: for and for , where is given by higher layer parameter *deltaMCS-Enabled*, and where K is the code block size.** * **Option 2: is given in table based on MCS index if enabled, 0 otherwise.**   **Proposal 7: Close-loop power control for 16-QAM is not supported in Rel-17.** |
| [5] | Similar as defined in LTE, is determined as:  for and for , where is given by higher layers parameter.   * where is the code block size and is the number of resource elements determined as where , , are defined in TS36.211, and is defined in section 16.5.1.1 in TS36.213.   ***Proposal 3: Introduce parameter ΔTF to uplink power control enhancement in NBIoT.*** |
| [6] | ***Observation 1: Option 5 for UL power allocation only provides a fixed power offset for 16-QAM.***  ***Observation 2: For UL power allocation, compared with option 2, option 1 provides a finer power offset for different TBS under the same MCS.***  ***Observation 3: For UL power allocation, option 1 may cause a larger performance gap between QPSK and 16-QAM due to the power offset.***  ***Proposal 2: Option 4 from Cat 1 can be considered for open loop UL power allocation.***  ***Proposal 3: Closed-loop power control should be adopted for 16-QAM***   * ***The most significant bit of ‘subcarrier indication’ filed can be utilized to enable the dynamic power control.*** * ***If dynamic power control is enabled, the “Repetition number” field in DCI Format N0 is utilized to indicate the TBS indices for 16-QAM and the MCS can be utilized to indicate the power offset.*** |
| [7] | **Proposal 2: Take option 1/option 2 as stating point and make final decision at this meeting.** |
| [8] | Observation 10 On the additional power control parameter for 16-QAM in UL, in summary:   * Category 1:   + Opt-1 re-uses the ΔTF expression and the definition of *BPRE*, and as a result it provides a single ΔTF regardless of the ITBS index being used. While re-using the ΔTF expression seems suitable, reusing the legacy definition of *BPRE* seems to be an unnecessary overcomplication. The exact resulting value of ΔTF in dB from Opt-1 has not been provided by the proponent.   + Opt-2 provides one ΔTF per ITBS index. That is, 8 different ΔTFs would be introduced as to cover the ITBS indices spanning from 14 to 21. It is unclear from the proponent the methodology that will be used to determine a ΔTF per ITBS index.   + Opt-4 aims at defining a set of values, from which ΔTF is selected and delivered to the UE through an RRC parameter, if this RRC parameter is absent then ΔTF = 0dB will be used. This option can be made to encompass other options, e.g., the resulting numeric values from Opt-1 and/or Opt-5 can be included in the set to be used by Opt-4.   + Opt-5 re-uses the ΔTF expression as in LTE and redefines *BPRE* as “*BPRE* = CodeRatemax\*Qm” in order to simplify it. As result Opt-3 provides a single ΔTF regardless of the ITBS index being used (The estimated value is ΔTF = 7.2545 dB). * Category 2:   + Opt-3 aims at introducing a “TPC command” which is to be dynamically signaled via DCI rather than semi-statically signaled as ΔTF. The purpose of the new term in the UE transmit power control equation is to compensate for the fact that 16-QAM will have more bits per RE than QPSK, rather than compensating for the channel variations as it is the purpose of a TPC command. The “TPC command” serves a different purpose than was is intended to be achieved through ΔTF.   Proposal 5 For the introduction of the new term “ΔTF” into the uplink power control of NPUSCH using 16-QAM, Category 1 is used along with Option 4 as follows:   * ΔTF is indicated through a 2-bit HL parameter referring to one of the following values in the set: {2dB, 4dB, [Opt-5Result\_dB], [Opt-1Result\_dB]} “and if this field is absent then dB0 will be used”. |

In last meeting, the following has been achieved:

Agreement

Down-select one option from Cat 1 as starting point

* Cat 1: Option 1, Option 2/Option 4, Option 5

FFS Cat 2: Option 3, for close-loop power control

* Option 1: Reuse the LTE definition simplified for NB-IoT: for and for , where is given by higher layer parameter *deltaMCS-Enabled*, and where K is the code block size.
* Option 2: is given in table based on MCS index if enabled, 0 otherwise.
* Option 3: A TPC command is introduce to indicate the power offset for NPUSCH with 16-QAM.
* Option 4: is configured by high layer parameter.
* Option 5: ΔTF = for *Ks* = 1.25 or ΔTF = 0 for *Ks* = 0, where BPRE =. is the highest code rate in the TBS/MCS table used for the Modulation Scheme, and is the number of bits per M-ary symbol of the Modulation Scheme.

On the down-selection of open loop power control term, companies (Huawei, HiSilicon, Qualcomm, Nokia, NSB, Lenovo, Motorola, MTK) support option 1, companies (Nokia, NSB, MTK) support option 2, and companies (ZTE, Sanechips, Ericsson) support option 4.

Based on majority view, the following is proposed:

**Proposal 4: For the new term**  **introduced for power control of NPUSCH,**

* Reuse the LTE definition simplified for NB-IoT: for and for , where is given by higher layer parameter *deltaMCS-Enabled*, and where K is the code block size.

For closed loop power control, there are not many companies showing their opinions. So the following is proposed to collect more views.

**Proposal 5: Further study on support of Cat 2: Option 3, for close-loop power control.**

Please input your comments regarding the above proposal, and give your view on closed loop power control.

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## Channel quality reporting

### Issue 5: Channel quality reporting

The following are proposed:

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| Sourcing | proposals |
| [2] | **Observation 1: The SNR gap between the legacy entry with largest SNR (NPDCCH repetition 1) and the 16-QAM TBS with smallest SNR (TBS index 14 with 16QAM) is significant (>>3dB).**  **Proposal 2: Option 3 should be supported for CQI table for downlink 16-QAM CQI reporting, i.e., a new CQI table is defined for 16-QAM based on the eMTC table (CQI Tables in 36.213) as a starting point.** |
| [4] | **Proposal 1: For 16-QAM CQI table, our preferences are**   * **First preference – Option 3: A new CQI table is defined for 16-QAM based on the eMTC table (CQI Tables in 36.213) as a starting point** * **Second preference – Option 1: More than three candidate values for 16-QAM are added in the legacy table by replacing candidates with high repetition values (e.g. candidateRep-J to candidateRep-L).** |
| [5] | ***Proposal 1: Remove some of the legacy CQI reporting values and add more than 3 CQI reporting values for support 16QAM in DL or report the subset of CQI reporting values determined by channel condition.*** |
| [6] | ***Observation 4: For option 1 and 2 of CQI table,***   * ***The limited number of CQI states with 16QAM cannot adequately match the variety of channel conditions.*** * ***There is large SNR gap between the adjacent two CQI indices with NPDCCH repetition 1 and 16QAM TBS.***   ***Observation 5: For CQI table, option 1 and option 2 are not aligned with the agreement, i.e. the channel quality report for 16-QAM is based on NPDSCH transport block that achieves an error probability not exceeding 10% BLER.***  ***Observation 6:*** ***The channel quality for NPDSCH and NPDCCH can be reported separately based on different tables.***  ***Observation 7: The existing MAC CE can be reused to report 4-bit CQI for NPDSCH if the UE receives a NPDSCH CQI command and 4-bit number of repetitions for NPDCCH if the UE receives a NPDCCH CQI command.***  ***Proposal 4: A new 4-bit CQI table should be defined for downlink 16QAM.*** |
| [7] | **Proposal 1: Support Option3 and take Table1 as starting point to make final decision at this meeting.**  **Table 1: 4-bit CQI Table for 16QAM**   |  |  |  |  | | --- | --- | --- | --- | | **CQI index** | **modulation** | **code rate x 1024** | **efficiency** | | 0 | out of range | | | | 1 | QPSK | 40 | 0.0781 | | 2 | QPSK | 78 | 0.1523 | | 3 | QPSK | 120 | 0.2344 | | 4 | QPSK | 193 | 0.3770 | | 5 | QPSK | 308 | 0.6016 | | 6 | QPSK | 449 | 0.8770 | | 7 | QPSK | 602 | 1.1758 | | 8 | 16QAM | 480 | 1.8788 | | 9 | 16QAM | 524 | 2.0472 | | 10 | 16QAM | 610 | 2.3844 | | 11 | 16QAM | 718 | 2.8052 | | 12 | 16QAM | 836 | 3.2684 | | 13 | Reserved | Reserved | Reserved | | 14 | Reserved | Reserved | Reserved | | 15 | Reserved | Reserved | Reserved | |
| [8] | Observation 3 In relation with the CQI mapping table, the WID states: “Extend the NB-IoT channel quality reporting based on the framework of Rel-14—16, to support 16-QAM in DL”  Observation 4 Based on the WID, the selected option should be incorporated into the legacy CQI mapping Table in TS 36.133 clause 9.1.22.15 as to re-use the NB-IoT’s framework and provide backward compatibility.  Observation 5 The legacy CQI mapping table in TS 36.133 clause 9.1.22.15 currently uses 13 out of 16 entries, hence the three unused fields could be utilized to incorporate the channel quality reporting for 16-QAM in DL.  Observation 6 For the TBS/MCS table for DL, the step-size between ITBS indices is in most cases smaller than 1dB, which is a level of granularity that is not feasible from a measurement accuracy perspective even in the static condition because of the limited number of NRS symbols. Today the channel quality reporting is specified for each repetition level 1, 2, 4, 8, …, which means that in legacy the step size is 3dB.  Observation 7 In Rel-17, the full range of ITBS indices (14 to 21 and 11 to 17 depending on the deployment mode) can be covered using only three candidate reports (i.e., candidateRep-M, candidateRep-N, or candidateRep-O) as to have a feasible level of granularity with step-sizes larger than 1dB.  Observation 8 Encompassing the full-range of I\_TBS indices using three reports is suitable, since the report is just a recommendation on what seems to be suitable to use. Hence, it is sufficient to hint around which I\_TBS indices a scheduling is suitable since anyhow the ultimate scheduling is up to the eNodeB  Proposal 3 The three unused entries in the legacy CQI mapping Table in clause 9.1.22.15 of TS 36.133 (i.e., Table 9.1.22.15-1) are used for the CQI reporting of 16-QAM in DL.   |  |  |  | | --- | --- | --- | | Reported value | NPDCCH repetition level | 16-QAM CQI index with NPDSCH transport block error probability not exceeding 0.1 | | candidateRep-M | 1 | 0 | | candidateRep-N | 1 | 1 | | candidateRep-O | 1 | 2 |  |  |  |  | | --- | --- | --- | | **CQI Index** | **ITBS index** | | |  | Guard-band and Stand-alone deployments | In-band deployments | | 0 | [17] | [13] | | 1 | [20] | [16] | | 2 | [21] | [17] | |

On the CQI table for downlink 16-QAM, 4 companies (Nokia, NSB (2nd preference), Lenovo, Moto) prefer option 1, 1 company (Ericsson) prefers option 2, and 7 companies (Huawei, HiSilicon, Nokia, NSB (1st preference), ZTE, Sanechips, MTK) prefer option 3.

Agreement

For CQI table for downlink 16-QAM, down-select between following options in RAN1#106-e:

* Option 1: More than three candidate values for 16-QAM are added in the legacy table.
  + FFS: Which of the legacy entries are removed
* Option 2: Three candidate values for 16-QAM are added in the legacy table.
* Option 3: A new CQI table is defined for 16-QAM based on the eMTC table (CQI Tables in 36.213) as a starting point

The concerns to support option 1 include: limited number of MCS entries for 16-QAM for efficient CQI reporting, “dB” step size granularity, increased size of legacy table, no backward compatible, and more UE complexity on hypothetical decoding of both NPDCCH and NPDSCH.

The concerns to support option 2 include: large SNR gap between NPDCCH repetition 1 and 16QAM TBS, more UE complexity on hypothetical decoding of both NPDCCH and NPDSCH, and limited number of MCS entries for 16-QAM for efficient CQI reporting.

The concerns to support option 3 include: not backward compatible, out of scope of WID, and additional signaling.

Based on the number of supporting companies, the following is proposed to move forward:

**Proposal 6: For CQI table for downlink 16-QAM, down-select between following options:**

* **Option 1: More than three candidate values for 16-QAM are added in the legacy table.**
  + **FFS: Which of the legacy entries are removed**
* **Option 3: A new CQI table is defined for 16-QAM based on the eMTC table (CQI Tables in 36.213) as a starting point**

Please input your comments regarding the above proposal:

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| Companies | Comments |
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### Issue 6: Measurement reference resource

The following are proposed:

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| [4] | **Proposal 2: Define CSI reference resource to be used for 16-QAM CQI measurement.**  **Proposal 3: The CSI reference resource is given by a set of the last *R*CSI subframes used for NPDCCH monitoring by the BL/CE UE in the corresponding narrowband before *n*-*nCQI\_ref*.** |
| [6] | ***Proposal 5: There is no need to specify measurement reference resource for CQI report for NB-IoT 16QAM.*** |
| [8] | Observation 1 It is needed to define the reference resource to estimate the CQI.  Observation 2 The reason why RAN1 did not specify the measurement resource in previous releases is because RAN4 specified it in TS 36.133 (e.g., see TS 36.133 clause 6.6.2.6). Since RAN4 has no plan to discuss the core part on 16 QAM CQI report, RAN1 needs to define the reference resource in TS 36.213.  Proposal 2 In Rel-17 for 16-QAM in DL, NRS symbols are used as reference resource for CQI measurement. |

Based on the inputs, companies still have different views on the introduction of measurement reference resources, therefore, the following is proposed to collect more views and discussions:

**Proposal 7: Further study on the specification of measurement reference resource.**

Please input your comments regarding whether to specify the measurement reference resource.

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## Others

**Issue 6: Others**

The following are proposed:

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| Sourcing | proposals |
| [8] | Proposal 1 To clarify that the “*inbandCarrierInfor*” is not only signalled in SIB, the “/UE specific signaling” is appended to related agreement from RAN1# 106-e as follows:  “For the UE configured with 16-QAM for NPDSCH, the deployment of the carrier is signaled by *operationModeInfo* in MIB or *inbandCarrierInfo* in SIB/UE specific signaling” |
| [9] | Observation 1 The WID left open the applicability of 16-QAM for unicast in UL and DL for both FDD and TDD, hence it needs to be investigated whether the agreements we have reached to support 16-QAM hold for TDD and what would be the impact in other Working Groups.  Observation 2 A preliminary assessment on RAN1 aspects touching upon TBS/MCS tables, DCI designs, DL power allocation, UL power control term, channel quality reporting, etc, seem to indicate that there won’t be any incompatibility issue with TDD.  Observation 3 Nonetheless, it seems that from a RAN4 perspective there might be a need to add another Test Model (in the BS conformance specs) and NPDSCH demodulation requirements for supporting 16-QAM in TDD.  Observation 4 Operators, UE vendors, Network vendors and other interested parties should discuss the relevance of supporting 16-QAM for TDD NB-IoT, especially if supporting it results in an extra impact in any of the Working Groups involved.  Proposal 1 Discuss whether the agreements we have reached to support 16-QAM in UL and DL hold for TDD and what are the impacts in other Working Groups.  Proposal 2 Decide whether 16-QAM for unicast in UL and DL is applicable for both FDD and TDD. |

As discussed in last meeting, regarding the proposal that the *inbandCarrierInfo* can also be signaled by UE specific signaling, the following is proposed:

**Proposal 8: the agreement below is updated as**

Agreement

**For the UE configured with 16-QAM for NPDSCH, the deployment of the carrier is signaled by *operationModeInfo* in MIB or *inbandCarrierInfo* in SIB/UE specific signaling.**

Please input your comments to the above proposal, and also your views on the support of 16-QAM for FDD and TDD:

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| Companies | Comments |
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# Summary

# References

1. RP-211340, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#92e, E-meeting, June 2021.
2. R1-2108777 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2109174 Support of 16-QAM for NB-IoT Qualcomm Incorporated
4. R1-2109314 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
5. R1-2109320 Support 16QAM for NBIoT Lenovo, Motorola Mobility
6. R1-2109337 Discussion on UL and DL 16QAM for NB-IoT ZTE, Sanechips
7. R1-2109559 Remaining Issues on supporting 16QAM in NB-IOT R17 MediaTek Inc.
8. R1-2110316 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
9. R1-2110318 On the support of 16-QAM for unicast in UL and DL for TDD NB-IoT Ericsson