**3GPP TSG RAN WG1 Meeting #104b-e R1-210xxxx**

**E-meeting, April 12th – April 20th, 2021**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #1 on 104b-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 following email discussion according to the inputs [2-8]

[104b-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)

* 1st check point: April 15
* 2nd check point: April 20

# Issues

## Support of 16-QAM for NB-IoT downlink

### Issue 1: The TBS table.

The following are proposed:

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| --- | --- |
| Sourcing | Proposals |
| [2] | Proposal 1: Confirm the following working assumption **The following TBS indices are introduced for downlink**

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| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2600 | 3240 |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | 2856 | 3624 |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 | 3112 | 4008 |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2600 | 3496 | 4264 |
| 20 | 440 | 904 | 1384 | 1864 | 2344 | 2792 | 3752 | 4584 |
| 21 | 488 | 1000 | 1480 | 1992 | 2472 | 2984 | 4008 | 4968 |

 |
| [3] | **Proposal 1: Confirm the working assumption on downlink TBS table from RAN1#104-e.** |
| [5] | ***Proposal 1: Confirm the working assumption for DL TBS table for NB-IoT 16QAM.**** ***328 bits for {I\_TBS=16, I\_SF=0}***
* ***2472 bits for { I\_TBS=21, I\_SF=4}***
 |
| [6] | **Proposal 1: Confirm the working assumption for the DL TBS table from RAN1#104-e.** |
| [8] | Observation 1 For ITBS = 16, ISF = 0 → [328, 296]: If a TBS = 328 bits is selected, then a performance crossing issue is observed with respect to the TBS = 336 bits. Observation 2 Apparently, when there are coding rates that are nearly close to each other (TBS = 328 bits → 0.58 , TBS = 336 bits → 0.59), the “soft-demapper module” and Viterbi decoding algorithms sometimes produce a non-linear response that produces an unusual performance.Observation 3 The performance crossing issue is not observed when instead of a TBS = 328 bits a TBS = 296 bits (code rate → 0.53) is utilized.Observation 4 16-QAM in principle makes possible to double the throughput with respect to QPSK. However, for 16-QAM in DL the largest TBS to be used has been agreed to be 4968 bits which does not allow to double throughput since is not exactly twice the max TBS available in Rel-16.Observation 5 If in DL the introduction of 16-QAM is meant to double the throughput, then the max TBS available in Rel-16 can be transmitted using half of the time-domain resource by selecting 2536 among the two choices for ITBS = 21, ISF = 4 → [2472, 2536], otherwise only 16-QAM in UL will be able to effectively double the throughput.Observation 6 A TBS = 2536 bits can be used for ITBS = 21, ISF = 4 without incurring in any performance issue.Proposal 1 Confirm the Working Assumption referring to the TBS indices to be introduced for downlink, including the following resolution on the TBS entries surrounded by brackets:* To avoid a performance crossing issue, between [328, 296] the TBS = 296 bits is selected.
* To transmit the max Rel-16 TBS with half of the time domain resources, between [2472, 2536] the TBS = 2536 bits is selected. Note: The TBS/MCS Table for UL accounts for this exact change, which is an ability that DL should also have.
 |

For working assumption on DL TBS, there are following proposals:

* Confirm the working assumption
	+ Huawei, HiSilicon, Nokia, NSB, ZTE, QC
* Confirm the working assumption with changes: TBS=296bits for I\_TBS=16, I\_SF=0; TBS=2536bits for I\_TBS=21, I\_SF=4
	+ Ericsson

Based on the inputs, the following is proposed:

Proposal 1: Confirm the working assumption that the following TBS indices are introduced for downlink:

|  |  |
| --- | --- |
|  |  |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | 328 | 632 | 968 | 1288 | 1608 | 1928 | 2600 | 3240 |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | 2856 | 3624 |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 | 3112 | 4008 |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2600 | 3496 | 4264 |
| 20 | 440 | 904 | 1384 | 1864 | 2344 | 2792 | 3752 | 4584 |
| 21 | 488 | 1000 | 1480 | 1992 | 2472 | 2984 | 4008 | 4968 |

Please input your comments for the above proposal:

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| Companies | Comments |
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### Issue 2: The breaking point from QPSK to 16QAM.

The following are proposed:

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| Sourcing | Proposals |
| [2] | Proposal 2: Confirm the following working assumption* **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16-QAM.**
 |
| [3] | **Proposal 2: Confirm the following working assumptions from RAN1#103-e –*** **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16-QAM.**
 |
| [4] | **Proposal1：ITBS=14 and ITBS=11 are switching point for SB/GB and IB, respectively.** |
| [5] | ***Observation 1: For NPDSCH with 1T1R antenna, 16QAM performance is about 1.8 dB better than QPSK performance at BLER =0.1 for standalone deployment when TBS 12 (2280 bits with ISF=7) is used. And the performance gap further expands when TBS 13 is used.******Observation 2: For NPDSCH with 2T1R antenna, 16QAM performance is about 0.6 dB better than QPSK performance at BLER =0.1 for standalone deployment when TBS 13 (2536 bits with ISF=7) is used.******Proposal 2: On DL breaking point, 16QAM can be used for TBS indexes from 12 to 21 for standalone and guard-band deployment.*** |
| [8] | Observation 7 For the evaluations in which 16-QAM and QPSK shared the same row (i.e., ITBS =13), 16-QAM did not outperform QPSK according with the average required SINR at 10% BLER. The same trend was observed for AWGN, ETU1, and ETU5.Observation 8 For stand-alone and guard-band deployments, the breaking-point evaluations using AWGN, ETU1, and ETU5 channels resulted in the following observations:* Regardless of whether ITBS = 13 or ITBS = 14 is used as initial index for 16-QAM, in both cases the average SINR difference for the breaking point is less than 1dB and the same trend holds for all channels (AWGN, ETU1, and ETU5).
	+ That is, the fading channels did not cause the average SINR difference for neither of the breaking points to go beyond 1dB.
* Although using either of the breaking points seems to be suitable, the range of TBS indices spanning from “I\_TBS = 14 to I\_TBS = 21” is preferred because:
	+ The range is composed by 8 indices (not 9 as the other range) which will also play a role when we begin to discuss DCI implementation.
	+ The range of ITBS indices from “I\_TBS = 14 to I\_TBS = 21” will be symmetric with respect to the range already agreed for UL.

Proposal 2 The TBS/MCS Table for stand-alone and guard-band deployments uses as breaking point ITBS = 13 as last ITBS index for QPSK and ITBS = 14 as first ITBS index for 16-QAM.Proposal 3 Confirm the Working Assumption referring to the use of 16-QAM for the TBS entries encompassed by ITBS indices between 14 and 21 for stand-alone and guard-band deployments.Proposal 4 Upon resolving the FFS on the breaking-point and the TBS entries surrounded by brackets, the TBS/MCS Table to support 16-QAM in DL for stand-alone and guard-band deployments is as follows:

|  |  |  |
| --- | --- | --- |
| Modulation Scheme |  | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| QPSK | 0 | 16 | 32 | 56 | 88 | 120 | 152 | 208 | 256 |
| 1 | 24 | 56 | 88 | 144 | 176 | 208 | 256 | 344 |
| 2 | 32 | 72 | 144 | 176 | 208 | 256 | 328 | 424 |
| 3 | 40 | 104 | 176 | 208 | 256 | 328 | 440 | 568 |
| 4 | 56 | 120 | 208 | 256 | 328 | 408 | 552 | 680 |
| 5 | 72 | 144 | 224 | 328 | 424 | 504 | 680 | 872 |
| 6 | 88 | 176 | 256 | 392 | 504 | 600 | 808  | 1032  |
| 7 | 104 | 224 | 328 | 472 | 584 | 680 | 968  | 1224  |
| 8 | 120 | 256 | 392 | 536 | 680 | 808  | 1096  | 1352  |
| 9 | 136 | 296 | 456 | 616 | 776  | 936  | 1256  | 1544  |
| 10 | 144 | 328 | 504 | 680 | 872  | 1032  | 1384  | 1736  |
| 11 | 176 | 376 | 584 | 776  | 1000  | 1192  | 1608  | 2024  |
| 12 | 208 | 440 | 680 | 904  | 1128  | 1352  | 1800  | 2280  |
| 13 | 224  | 488  | 744  | 1032 | 1256  | 1544  | 2024  | 2536  |
| 16-QAM | 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | 296 | 632 | 968 | 1288 | 1608 | 1928 | 2600 | 3240 |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | 2856 | 3624 |
| 18 | 376 | 776 | 1160 | 1544 | 1992 | 2344 | 3112 | 4008 |
| 19 | 408 | 840 | 1288 | 1736 | 2152 | 2600 | 3496 | 4264 |
| 20 | 440 | 904 | 1384 | 1864 | 2344 | 2792 | 3752 | 4584 |
| 21 | 488 | 1000 | 1480 | 1992 | 2536 | 2984 | 4008 | 4968 |

Observation 9 For in-band deployments, it has been agreed to use ITBS indices spanning from index 11 to 17, which includes one TBS entry that is surrounded by brackets (ITBS = 16, ISF = 0 → [328, 296]) according with the WA on the TBS/MCS table for DL.Proposal 5 Upon resolving the FFS on the TBS entry surrounded by brackets, the TBS/MCS Table to support 16-QAM in DL for in-band deployments is as follows:

|  |  |  |
| --- | --- | --- |
| .Modulation Scheme |  | Number of NPDSCH Subframes (NSF) |
| 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 |
| QPSK only | 0 | 16 | 32 | 56 | 88 | 120 | 152 | 208 | 256 |
| 1 | 24 | 56 | 88 | 144 | 176 | 208 | 256 | 344 |
| 2 | 32 | 72 | 144 | 176 | 208 | 256 | 328 | 424 |
| 3 | 40 | 104 | 176 | 208 | 256 | 328 | 440 | 568 |
| 4 | 56 | 120 | 208 | 256 | 328 | 408 | 552 | 680 |
| 5 | 72 | 144 | 224 | 328 | 424 | 504 | 680 | 872 |
| 6 | 88 | 176 | 256 | 392 | 504 | 600 | 808  | 1032  |
| 7 | 104 | 224 | 328 | 472 | 584 | 680 | 968  | 1224  |
| 8 | 120 | 256 | 392 | 536 | 680 | 808  | 1096  | 1352  |
| 9 | 136 | 296 | 456 | 616 | 776  | 936  | 1256  | 1544  |
| 10 | 144 | 328 | 504 | 680 | 872  | 1032  | 1384  | 1736  |
| 16-QAM only | 11 | 176 | 376 | 584 | 776  | 1000  | 1192  | 1608  | 2024  |
| 12 | 208 | 440 | 680 | 904  | 1128  | 1352  | 1800  | 2280  |
| 13 | 224  | 488  | 744  | 1032 | 1256  | 1544  | 2024  | 2536  |
| 14 | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 | 2856 |
| 15 | 280 | 600 | 904 | 1224 | 1544 | 1800 | 2472 | 3112 |
| 16 | 296 | 632 | 968 | 1288 | 1608 | 1928 | 2600 | 3240 |
| 17 | 336 | 696 | 1064 | 1416 | 1800 | 2152 | 2856 | 3624 |
| 18 | - | - | - | - | - | - | - | - |
| 19 | - | - | - | - | - | - | - | - |
| 20 | - | - | - | - | - | - | - | - |

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For the working assumptions on breaking points of standalone and guardband deployments, there are following proposals:

* Confirm the working assumption
	+ Huawei, HiSilicon, Nokia, NSB, MTK, Ericsson
* For standalone and guardband deployments, downlink TBS entries between 12 and 21 are used for 16QAM.
	+ ZTE

Based on the input, the following is proposed

Proposal 2: Confirm the working assumption:

* **For standalone and guardband deployments, the downlink TBS entries between 14 (TBS of 2856 for I\_SF=7) and 21 are used for 16QAM.**

Please input your comments for the above proposal:

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| Companies | Comments |
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## Applicability

### Issue 3: Applicability

The following are proposed:

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| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 5: 16-QAM is not supported for EDT.****Proposal 6: 16-QAM is supported for PUR.****Proposal 7: 16-QAM is supported for multi-TB scheduling.** |
| [3] | **Proposal 9: 16-QAM can be supported for PUR.****Proposal 10: 16-QAM is not supported for EDT.** |
| [5] | ***Proposal 10:16QAM could not be supported for NPDSCH and NPUSCH associated with C-RNTI from CSS.******Proposal 11: 16QAM are not supported for UL and DL transmission in PUR procedure.******Proposal 12: 16QAM is not supported in EDT for NB-IoT.*** |
| [6] | **Proposal 2: DL 16-QAM is not applicable to C-RNTI scheduled from CSS.****Proposal 3: Do not support DL 16-QAM during EDT.****Proposal 4: Do not support DL 16-QAM during PUR procedure.****Proposal 8: UL 16-QAM is not applicable to C-RNTI scheduled from CSS.****Proposal 9: Do not support UL 16-QAM during EDT.****Proposal 10: Support UL 16-QAM during PUR procedure. Include the corresponding configuration flag in *PUR-Config*.** |
| [8] | Proposal 11 Unless a concrete scenario be proposed to be investigated and proven to be beneficial, for both UL and DL 16-QAM is not applied to C-RNTI from CSS.Observation 15 In downlink, making 16-QAM applicable for EDT and PUR will imply for example having to design a channel quality reporting for idle-mode. Observation 16 Applying 16-QAM in UL for EDT and/or PUR seems to be an overdesign of the usable modulation schemes since EDT is meant to be a mechanism for transmitting small data packets during the RA procedure, whereas one of the main use-cases for PUR is related to periodic transmissions of small data from e.g., metering devices (temperature sensor).Proposal 12 Unless a concrete scenario be proposed to be investigated and evaluated, 16-QAM is not applicable in downlink nor in uplink for PUR and EDT. |

Three companies (ZTE, QC, Ericsson) propose to not support 16-QAM for C-RNTI from CSS, therefore, the following is proposed:

**Proposal 3: 16-QAM is not applied to C-RNTI from CSS.**

Seven companies (Huawei, HiSilicon, Nokia, NSB, ZTE, QC, Ericsson) propose to not support 16-QAM for EDT. Therefore, the following is proposed:

**Proposal 4: 16-QAM is not applied to EDT.**

Five companies (Huawei, HiSilicon, Nokia, NSB, QC (for UL)) propose to support PUR at least for uplink, and three companies (ZTE, QC (for DL), Ericsson) propose to not support PUR at least for downlink. In addition, Huawei and HiSilicon propose to support multi-TB scheduling for 16QAM. Therefore, the following is proposed:

**Proposal 5: FFS for PUR and multi-TB scheduling.**

Please input your comments for the above proposals, and also the reasons to support or not support PUR and multi-TB scheduling:

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| Companies | Comments |
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## DCI

### Issue 4: DCI design.

There are following proposals on power allocation

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| Sourcing | proposals |
| [2] | Proposal 3: The introduction of 16-QAM should avoid increase of DCI size.**Proposal 4: Considering variations of channel quality, the flexibility of scheduling Rel-16 QPSK TBS and repetition numbers should be supported if 16-QAM is enabled.** |
| [3] | **Proposal 7: The DCI size is not increased for 16-QAM support.****Proposal 8: When UE is configured with 16-QAM, the DCI should support all existing MCS and repetition combinations. FFS details of DCI design.** |
| [5] | ***Proposal 3: If 4-bit MCS table is adopted for DL 16QAM, it can be considered to**** ***Remove the existing 6 MCS entries and add new 8 MCS entries for guard-band and standalone deployments.***
* ***Utilize 1 bit of ‘Repetition number’ in DCI to dynamically indicate the fallback from 16QAM MCS table to legacy QPSK MCS table***

***Proposal 4: If 5-bit MCS table is adopted for DL 16QAM,*** * ***Overlapped TBS*** ***12 and 13 could be set for MCS entries with QPSK and 16QAM.***
* ***The most significant bit of ‘repetition number’ field can be repurposed to indicate MCS.***

***Proposal 6: For UL 16QAM, the most significant bit of ‘subcarrier indication’ field can be used for 5-bit MCS indication.*** |
| [6] | **Proposal 5: Enabling DL 16-QAM does not change the DCI size.****Proposal 6: If the “repetition number” field in DCI indicates 1 repetition, the MCS field indicates an entry in the DL 16-QAM MCS table. If the “repetition number” field indicates more than 1 repetition, the MCS field indicates an entry of the legacy QPSK table.** **- FFS: Details of the 16-QAM MCS table****Proposal 11: Enabling UL 16-QAM does not change the DCI size.****Proposal 12: If the “repetition number” field in DCI indicates 1 repetition and the “subcarrier indication” field indicates more than one subcarrier, the MCS field indicates an entry in the UL 16-QAM MCS table. If the “repetition number” field indicates more than 1 repetition, the MCS field indicates an entry of the legacy UL MCS table.** **- FFS: Details of the UL 16-QAM MCS table** |
| [7] | ***Proposal 1: For the DCI format N1 optimization, the joint coding of MCS and repetition number field can be considered.******Proposal 4: For the DCI format N0 optimization, the joint coding of MCS, repetition number and/or resource assignment field can be considered.*** |

The proposed schemes are diverse, and all proposed schemes seem to be aligned with the principle that the DCI size is not increased to support 16-QAM. Therefore, the following is proposed:

Proposal 6: The DCI size is not increased to support 16-QAM in uplink and downlink.

On the indication of downlink 16-QAM, there are following proposals from companies:

* MCS is increased to 5 bits, and repetition field is reduced by 1 bit;
* MCS is 4 bits, and 1 bit in repetition field is used to indicate legacy QPSK or 16QAM;
* MCS is 4 bits, and a reserved states of MCS indicates 16QAM. Repetition field indicates 16QAM MCS.
* MCS is 4 bits, 16QAM is used if repetition is indicated as one, and legacy QPSK otherwise.

Therefore, the following is proposed:

Proposal 7: It is down-selected from following options on the indication of downlink 16-QAM:

* **Option 1: MCS is increased to 5 bits, and repetition field is reduced by 1 bit;**
* **Option 2: MCS is 4 bits, and 1 bit in repetition field is used to indicate legacy QPSK or 16QAM;**
* **Option 3: MCS is 4 bits, and a reserved states of MCS indicates 16QAM. Repetition field indicates 16QAM MCS.**
* **Option 4: MCS is 4 bits, 16QAM is used if repetition is indicated as one, and legacy QPSK otherwise.**

Please input your comments for the above proposals:

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| Companies | Comments |
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## Downlink power allocation to support 16QAM

### Issue 5: Power allocation.

There are following proposals on power allocation

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| --- | --- |
| Sourcing | proposals |
| [2] | **Proposal 8: The NPDSCH EPRE in symbols with CRS can be different and can be the same with the NPDSCH EPRE in symbols with NRS and the NPDSCH EPRE in symbols without NRS and CRS.****Proposal 9:** **For standalone/guard-band deployment, if the NPDSCH EPRE in symbols with NRS is the same with the NPDSCH EPRE in symbols without NRS, the NPDSCH EPRE w/o NRS and NRS EPRE are the same.** **For in-band deployment, if the NPDSCH EPRE in symbols with NRS is same with the NPDSCH EPRE in symbols without CRS and NRS, the NPDSCH EPRE with NRS, NPDSCH EPRE without NRS and CRS, and NRS EPRE are the same. FFS power ratio of NPDSCH EPRE with CRS and NPDSCH EPRE w/o NRS.** |
| [3] | **Proposal 5: The total transmit power across OFDM symbols should be constant.****Proposal 6: The power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS (**$ρ\_{C}$**) is explicitly signaled. The other two power ratio values can be determined by the UE.**  |
| [5] | ***Observation 3: In practice, different transmit power configured between OFDM symbols may cause phase diversion.******Observation 4: The transmit power between different OFDM symbols is constant in R16 NB-IoT when a given NRS power is configured.******Proposal 7: The same total transmit power is set for each OFDM symbol for Rel-17 NB-IoT DL power allocation.******Proposal 8: A new UE-specific higher layer parameter is introduced to indicate the ratio of NPDSCH EPRE and NRS EPRE in symbols with NRS.******Proposal 9: For in-band deployment, the ratio of NRS EPRE to CRS EPRE is indicated for both same PCI and different PCI.*** |
| [6] | **Proposal 7: The UE derives the values of** $ρ\_{A}$**,** $ρ\_{B}$**,** $ρ\_{C}$ **implicitly based on*** **Power boost value for NRS**
* **NRS and CRS relative power level.**
* **Number of NRS and CRS ports.**
 |
| [7] | ***Proposal 3: Network should semi-statically configure three types of NPDSCH EPRE with assuming all the OFDM symbols with same transmission power.*** |
| [8] | Proposal 8 For the downlink power allocation of 16-QAM, the data-to-pilot power ratios are as in LTE defined in terms of the following types:Stand-alone and Guard-band:* Type A, NPDSCH in symbols without NRS: NPDSCH EPRE = NRS EPRE + ρ\_a [dB]
* Type B, NPDSCH in symbols with NRS: NPDSCH EPRE = NRS EPRE + ρ\_b [dB]

In-band:* Type A and Type B as defined for Stand-alone and Guard-band deployments.
* Type C, NPDSCH in symbols with CRS: NPDSCH EPRE = NRS EPRE + ρ\_c [dB]

Where:ρ\_a = PA [dB]PB is an index that refers to the linear ratio between ρ\_b and ρ\_a (i.e.,${10^{\left(\frac{ρ\\_b}{10}\right)}}/{10^{\left(\frac{ρ\\_a}{10}\right)}}$)PC is an index that refers to the linear ratio between ρ\_c and ρ\_a (i.e.,${10^{\left(\frac{ρ\\_c}{10}\right)}}/{10^{\left(\frac{ρ\\_a}{10}\right)}}$)Proposal 9 For the downlink power allocation of 16-QAM, down-select among the following two alternatives as to resolve the “*FFS on signaling details*” and the “*FFS for the handling on whether the PCI is different or the same*”:* Alt-1: “ρ\_a” is UE-specific signaled and the index “PB“ referring to a linear power ratio between “ρ\_b” and “ρ\_a” is cell-specific signaled as to obtain “ρ\_b”.

In addition, for in-band deployments in the case of a same PCI “nrs-CRS-PowerOffset” is used to implicitly obtain “ρ\_c”, otherwise (i.e., when different PCI) the index “PC“ referring to a linear power ratio between “ρ\_c and “ρ\_a” is cell-specific signaled as to obtain “ρ\_c”.* Alt-2: “ρ\_a” is UE-specific signaled and the index “PB“ referring to a linear power ratio between “ρ\_b” and “ρ\_a” is cell-specific signaled as to obtain “ρ\_b”.

In addition, for in-band deployments regardless of whether the PCI is the same or different the index “PC“ referring to a linear power ratio between “ρ\_c” and “ρ\_a” is cell-specific signaled as to obtain “ρ\_c”.Observation 13 For the downlink power allocation of 16-QAM, it can be pondered between a solution offering commonality for handling both “different and same PCI” (Alt-2) versus a solution that can partially re-use the existing toolbox (i.e., “nrs-CRS-PowerOffset” for same PCI) to save signaling for one out of the two PCI cases (Alt-1). |

For power allocation, several companies assumes constant transmit power between symbols. Based on this, for standalone and guard-band deployments:

* If there’s no NRS power boost, the ratio of NPDSCH EPRE to NRS EPRE is 0dB for one NRS antenna port, and -3dB for two NRS antenna ports;
* If there’s NRS power boost,
	+ Option 1: the power ratios of NPDSCH EPRE to NRS EPRE in symbols with and without NRS are signaled;
	+ Option 2: the power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS is signaled.

And for inband deployments, the power ratio of NRS EPRE to CRS EPRE is further indicated, which can reuse the existing parameter *nrs-CRS-PowerOffset.*

Based on the inputs, the following is proposed to move forward:

Proposal 8: For downlink power allocation to support 16QAM:

* **For standalone and guard-band deployments:**
	+ **If there’s no NRS power boost, the ratio of NPDSCH EPRE to NRS EPRE is 0dB for one NRS antenna port, and -3dB for two NRS antenna ports;**
	+ **If there’s NRS power boost,**
		- **Option 1: the power ratios of NPDSCH EPRE to NRS EPRE in symbols with and without NRS are signaled;**
		- **Option 2: the power ratio of NPDSCH EPRE to NRS EPRE in symbols with NRS is signaled.**
* **For inband deployments, the power ratio of NRS EPRE to CRS EPRE is signaled in addition to the signaling for standalone and guard-band deployments.**
	+ **FFS to reuse the existing parameter nrs-CRS-PowerOffset.**

Please input whether you are fine with the proposal, and the preferred option if not fine with it:

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| Companies | Comments |
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## Channel quality reporting

### Issue 6: Channel quality reporting

There are following proposals on power allocation

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| --- | --- |
| Sourcing | proposals |
| [2] | **Observation 1:** **In current NB-IoT, the channel quality reporting in Msg3 and** **connected mode are reports of NPDCCH repetition level.****Observation 2:** **For UE scheduled with 16-QAM, the NPDCCH repetition-level based channel quality reporting does not convey sufficient channel quality information.** **Proposal 10: For 16-QAM, the channel quality report is the NPDSCH MCS, when NPDCCH repetition number is 1. FFS the set of NPDSCH MCS for channel quality reporting.****Proposal 11: Re-purpose the channel quality reporting field in Msg3 and MAC CE to support CQI reporting for 16-QAM.** |
| [3] | **Proposal 3: Introduce CQI reporting for 16-QAM in the DL using the same definition for CQI as eMTC. FFS how to define CSI reference resource.****Proposal 4: Reuse Msg3 and MAC CE downlink channel quality measurement report defined in 36.133 for 16-QAM CQI reporting. FFS details.** |
| [4] | **Observation1: Aperiodic CQI reporting should be supported in NB-IOT R17.****Observation2: There is no need to define extra measurement reference resource for CQI reporting.****Observation3: The CQI table should cover both QPSK and 16QAM.****Proposal2: Reuse 1 bit from the spare bits to reach 5 bits MCS field both in DCI N0 and DCI N1.****Proposal3: Reuse 1 bit from the spare bits to indicate CQI reporting request in DCI N0.** |
| [7] | ***Proposal 2: The three unused states of CQI reporting can consider metric or values based on the same target of hypothetical NPDCCH BLER of 1%.*** |
| [8] | Proposal 6 The CQI reporting definition to support 16-QAM in DL is as in clause 7.2.3 of TS 36.213 for LTE-MTC with the corresponding updates to adapt it to NB-IoT.Observation 10 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 11 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 might be unfeasible in terms of NRS. 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 12 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.Proposal 7 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 content of channel quality report, several companies proposed to reuse LTE-MTC, but the NB-IoT channel quality report is the estimation of NPDCCH instead of data channel. Therefore, the first step should be the metric for channel quality report. The following is proposed:

Proposal 9: If 16-QAM is configured for NPDSCH, the channel quality report for 16-QAM is the MCS to achieve 10% BLER of NPDSCH.

Please input your comments for the above proposal:

|  |  |
| --- | --- |
| Companies | Comments |
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## Others

**Issue 7: Others**

There are also other proposals as below:

|  |  |
| --- | --- |
| Sourcing | proposals |
| [5] | ***Proposal 5: For NB-IoT UE with 16QAM, double RU number should be considered to improve the performance for some QPSK entries with the repetition number reduced half.*** |
| [6] | **Proposal 13: RAN1 to consider adding an additional power control parameter to allow for increased power with 16-QAM (e.g. similar to** $Δ\_{TF}$**)** |
| [8] | Observation 14 In LTE, the term ΔTF in the power control equation increases the power when the number of bits per RE is increased by a higher order modulation scheme, a similar element can be incorporated into the NB-IoT’s equation for 16-QAM in UL.Proposal 10 Incorporate into the UE’s transmit power control equation, a new term to boost the power when the number of bits per RE is increased due to the use of 16-QAM in UL. |

Two companies proposed to add a new term for power offset between different modulations, therefore, the following is proposed for discussion:

Proposal 10: FFS on an additional power control parameter for 16-QAM (e.g. similar to $Δ\_{TF}$).

Please input your comments for the above proposal, or if you think any proposal listed in this section or any other issue can be discussed in this meeting:

|  |  |
| --- | --- |
| Companies | Comments |
|  |  |
|  |  |
|  |  |

# Summary

# References

1. RP-201306, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#88e, E-meeting, June 2020.
2. R1-2102357 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2102652 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
4. R1-2102680 Switching point between QPSK and 16QAM and DCI design for 16QAM in R17 MediaTek Inc.
5. R1-2102857 Discussion on UL and DL 16QAM for NB-IoT ZTE
6. R1-2103067 Support of 16-QAM for NB-IoT Qualcomm Incorporated
7. R1-2103531 Support 16QAM for NBIoT Lenovo, Motorola Mobility
8. R1-2103723 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson