**3GPP TSG RAN WG1 Meeting #107-e R1-21xxxxx**

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

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #1 on 107-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 [2-10].

[107-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: November 15
* Final check point: November 19

# Discussion

## Uplink power control

### Issue 1: uplink power control

The proposals of companies are listed as below:

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | **Proposal 4：Confirm the working assumption of the new term** $∆\_{TF,c}$ **introduced for power control of NPUSCH for 16QAM.****Proposal 5：The new power control term can be applied to QPSK when configured with 16QAM**. |
| [3] | ***Proposal 1: Confirm the working assumption for*** $∆\_{TF,c}$ ***introduced for power control of NPUSCH.******Proposal 2: An offset can be applied on*** $∆\_{TF,c}$ ***or*** $P\_{O\\_NOMINAL\\_NPUSCH,c}$ ***to reduce the power difference between QPSK and 16QAM.**** ***The offset could be indicated by higher layers.***

***Proposal 3: Closed-loop power control could be applied to dynamically indicate power offset for 16QAM.***  |
| [4] | **Proposal 4: Confirm the working assumption to reuse LTE definition simplified for NB-IoT for the new power control term.** **Proposal 5: The new uplink power control term** $∆\_{TF,c}\left(i\right)$ **is also applied to QPSK when UE is configured with 16-QAM.** **Proposal 6: Closed-loop power control for 16-QAM is not supported in Rel-17.** |
| [5] | **Proposal 1: Confirm the following working assumption:****For the new term** $∆\_{TF,c}$ **introduced for power control of NPUSCH,*** **Reuse the LTE definition simplified for NB-IoT:** $∆\_{TF,c}\left(i\right)=10log\_{10}\left(\left(2^{BPRE∙K\_{s}}-1\right)\right)$ **for** $K\_{s}=1.25$ **and** $∆\_{TF,c}\left(i\right)=0$ **for** $K\_{s}=0$**, where** $K\_{s}$ **is given by higher layer parameter *deltaMCS-Enabled*, and** $BPRE=\frac{K}{N\_{RE}}$ **where K is the code block size.**
* **FFS: whether the new term applies to QPSK when configured with 16QAM, if it does not, whether an additional term is introduced to avoid jump between QPSK and 16QAM**

**Proposal 2: When configured with 16-QAM, the new power control parameter for NPUSCH also applies to QPSK.** |
| [6] | ***Proposal 2: The new term*** $∆\_{TF,c}$ ***introduced for power control of NPUSCH applies to QPSK and 16QAM when configured with 16QAM.*** |
| [7] | **Proposal 2: The new term** $∆\_{TF,c}$ **should apply to both 16QAM and QPSK.** |
| [8] | **Observation 8 For the new term to be introduced into UE’s transmit power control equation, even if ΔTF as in LTE were applied for NB-IoT, still there will be an issue to be solved which has to do with preventing a large power difference with respect to QPSK.** **Observation 9 The results in [4] refer to ΔTF estimates obtained using the methodology under Working Assumption, where there is a large power difference of ⁓6.4dB even between adjacent ITBS rows for QPSK and 16-QAM.****Observation 10 To prevent a large power difference between QPSK and 16-QAM derived from ΔTF, the following options were preliminary discussed as to solve the issue:*** **Apply the methodology under Working Assumption (i.e., ΔTF) also to QPSK:**

**If ΔTF is applied to QPSK, then the QPSK UL power control behavior will be different with and without 16-QAM configured and because of that is not a preferred solution.*** **Use P0\_Nominal to reduce the difference:**

**If P0\_Nominal were used to adjust ΔTF, then we will end up modifying P0\_Nominal’s range which is not the intention, since this solution can be seen the other way around where ΔTF is shifting P0\_Nominal.*** **Apply an offset on the ΔTF for 16-QAM:**

**This solution won’t lead to different behaviors nor impacts some other existing parameter. It acts directly on ΔTF as to alleviate large power difference between QPSK and 16-QAM.****Observation 11 To prevent a large power difference between QPSK and 16-QAM derived from ΔTF, applying an offset on ΔTF seems to be the most feasible solution to avoid undesired side-effects.** **Proposal 3 For the new term in the UE’s transmit power control equation, an offset is applied on the estimated ΔTF for 16-QAM to prevent a large power difference between QPSK and 16-QAM*** **Alternative 1: The offset is determined through calculating ΔTF for the QPSK at the breaking point (i.e., last ITBS row for QPSK). The Offset = [5.9dB].**
* **Alternative 2: The offset is indicated through a 2-bit higher layer parameter referring to one of the following values in the set: {[1dB], [2dB], [4dB], [6dB]} “and if this field is absent or if** $K\_{s}=0$**, then 0dB will be used”**
 |

For the following working assumption:

**Working Assumption**

**For the new term** $∆\_{TF,c}$ **introduced for power control of NPUSCH,**

* Reuse the LTE definition simplified for NB-IoT: $∆\_{TF,c}\left(i\right)=10log\_{10}\left(\left(2^{BPRE∙K\_{s}}-1\right)\right)$ for $K\_{s}=1.25$ and $∆\_{TF,c}\left(i\right)=0$ for $K\_{s}=0$, where $K\_{s}$ is given by higher layer parameter *deltaMCS-Enabled*, and $BPRE=\frac{K}{N\_{RE}}$ where K is the code block size.
* FFS: whether the new term applies to QPSK when configured with 16QAM, if it does not, whether an additional term is introduced to avoid jump between QPSK and 16QAM

Most companies support to confirm the working assumption, therefore, the following is proposed:

**Proposal 1: confirm the following working assumption.**

**For the new term** $∆\_{TF,c}$ **introduced for power control of NPUSCH,**

* Reuse the LTE definition simplified for NB-IoT: $∆\_{TF,c}\left(i\right)=10log\_{10}\left(\left(2^{BPRE∙K\_{s}}-1\right)\right)$ for $K\_{s}=1.25$ and $∆\_{TF,c}\left(i\right)=0$ for $K\_{s}=0$, where $K\_{s}$ is given by higher layer parameter *deltaMCS-Enabled*, and $BPRE=\frac{K}{N\_{RE}}$ where K is the code block size.
* FFS: whether the new term applies to QPSK when configured with 16QAM, if it does not, whether an additional term is introduced to avoid jump between QPSK and 16QAM

On the power jump between QPSK and 16QAM, companies (Huawei, HiSilicon, Nokia, NSB, QC, Lenovo, Moto, MediaTek) support to apply the new term to QPSK, companies (ZTE, Sanechips, Ericsson) support to not apply the new term to QPSK and introduce an offset uplink power control ($∆\_{TF,c}$ ***or*** $P\_{O\\_NOMINAL\\_NPUSCH,c}$).

For

* Option 1: apply the new term to QPSK
* Option 2: not apply the new term to QPSK and introduce an offset uplink power control

Then the power control values for both options are listed as below, assuming 5RUs, and that the default P0 is 0dB, and the power of 16QAM NPUSCH for option 1 and option 2 is the same.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| $$I\_{TBS}$$ | TBS | $∆\_{TF,c} $: option 1 | P0 setting for option 1 | $∆\_{TF,c} $: option 2 | Offset for option 2 | P0 setting for option 2 |
| 1 | 176 | -6.27282 | 0 | 0 | 0 | 6.5 |
| 3 | 256 | -4.42746 | 0 | 0 | 0 | 6.5 |
| 4 | 328 | -3.15198 | 0 | 0 | 0 | 6.5 |
| 5 | 424 | -1.76735 | 0 | 0 | 0 | 6.5 |
| 6 | 504 | -0.7883 | 0 | 0 | 0 | 6.5 |
| 7 | 584 | 0.083221 | 0 | 0 | 0 | 6.5 |
| 8 | 680 | 1.026534 | 0 | 0 | 0 | 6.5 |
| 9 | 776 | 1.887086 | 0 | 0 | 0 | 6.5 |
| 10 | 872 | 2.685284 | 0 | 0 | 0 | 6.5 |
| 11 | 1000 | 3.676093 | 0 | 0 | 0 | 6.5 |
| 12 | 1128 | 4.603156 | 0 | 0 | 0 | 6.5 |
| 13 | 1256 | 5.481782 | 0 | 0 | 0 | 6.5 |
| 14 | 1416 | 6.528084 | 0 | 6.528084 | -6.5 | 6.5 |
| 15 | 1544 | 7.332797 | 0 | 7.332797 | -6.5 | 6.5 |
| 16 | 1608 | 7.726365 | 0 | 7.726365 | -6.5 | 6.5 |
| 17 | 1800 | 8.878457 | 0 | 8.878457 | -6.5 | 6.5 |
| 18 | 1992 | 9.996363 | 0 | 9.996363 | -6.5 | 6.5 |
| 19 | 2152 | 10.90802 | 0 | 10.90802 | -6.5 | 6.5 |
| 20 | 2344 | 11.98355 | 0 | 11.98355 | -6.5 | 6.5 |
| 21 | 2536 | 13.04336 | 0 | 13.04336 | -6.5 | 6.5 |

The majority view is to apply the new term to QPSK also, therefore, the following is proposed:

**Proposal 2: The term** $∆\_{TF,c}\left(i\right)$ **can also be applied to NPUSCH with QPSK, when 16-QAM is configured.**

However, there’s concerns that this would have impacts to legacy, therefore, please the proponents give your comments to address this concern, and please proponents of the other option elaborate the exact impacts to legacy or other concerns:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson v002 | **Proposal 1:** Ok with confirming the WA.**Proposal 2:** We are not ok with “Proposal 2” because if ΔTF is applied to QPSK, then the QPSK UL power control behavior will be different with and without 16-QAM configured. E.g., When the radio conditions are not suitable to use 16-QAM, and the UE has to use QPSK the new term in the UE’s transmit power control equation will result in a different as compared to the one that would delivered for a UE without 16-QAM configured.To avoid undesired side-effects, applying an offset that acts on ΔTF seems to be the most feasible solution. Just as a clarification to the Moderator, we do not see “$P\_{O\\_NOMINAL\\_NPUSCH,c}$” as an offset since that will result in side effects too. By offset, we mean e.g., Alternative 1 or Alternative 2 below applied on the estimated ΔTF.* Alternative 1: The offset is determined through calculating ΔTF for the QPSK at the breaking point (i.e., last ITBS row for QPSK). The Offset = [5.9dB].
* Alternative 2: The offset is indicated through a 2-bit higher layer parameter referring to one of the following values in the set: {[1dB], [2dB], [4dB], [6dB]} “and if this field is absent or if $K\_{s}=0$, then 0dB will be used”.
 |
| ZTE, Sanechips | According to the agreement, the new term is introduced for uplink power control to support NPUSCH using 16QAM. There is no clear requirements for the case that $∆\_{TF,c} $ is applied to NPUSCH using QPSK. So we prefer that uplink power control be consistent with legacy for QPSK. And an offset is added to $∆\_{TF,c} $ to avoid the power gap between QPSK and 16QAM.When 16QAM is enabled, semi-static and dynamic power control should be supported to match variable channel and improve data rate if large SNR coverage range indicated by CQI table design is adopted. |
| Qualcomm | We are OK with both proposals. |
| Lenovo, MotoM | We are OK with both proposals (e.g., Proposal 1 and Proposal 2) |
| MTK | We are OK with both proposals. |
| Huawei, HiSilicon | We are OK with both proposals. |
| NordicSemi | We are OK with both proposals. |

## Channel quality reporting

### Issue 2: Channel quality reporting

The proposals of companies are listed as below:

|  |  |
| --- | --- |
| 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 1: Option 3 should be supported for CQI table for downlink 16-QAM CQI reporting.****Proposal 2: The use of legacy table or the new CQI table is indicated in MAC CE.****Proposal 3: Seven QPSK TBS indices and four 16QAM TBS indices should be utilized in the 16QAM CQI table.**

|  |  |  |
| --- | --- | --- |
| **CQI index** | **modulation** | **TBS index** |
| 0 | QPSK  | 0 |
| 1 | QPSK  | 2 |
| 2 | QPSK  | 4 |
| 3 | QPSK | 6 |
| 4 | QPSK  | 8 |
| 5 | QPSK | 10 |
| 6 | QPSK  | 12 |
| 8 | 16QAM  | 14 |
| 9 | 16QAM  | 16 |
| 10 | 16QAM  | 18 |
| 11 |  16QAM  | 20 |
| 12 | Reserved | Reserved |
| 13 | Reserved | Reserved |
| 14 | Reserved  | Reserved |
| 15 | Reserved  | Reserved |

 |
| [3] | ***Observation 1: For channel quality report, the switching of new table and legacy table needs to be considered for both Option 1 and Option 3 since new CQI table is introduced for NPDSCH.******Observation 2: For channel quality report, Option 1 will lead to a performance loss on CQI report for NPDSCH and a waste of feedback overhead since some CQI entries with PDCCH repetitions cannot be used for NPDSCH.******Proposal 4: Table 2 or 3 can be adopted for channel quality report for NPDSCH.***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| CQI index | modulation | TBS index | Number of repetitions | SNR at BLER of 10% (dB) | SNR gap (dB) |
| 0 | out of range |  |  |
| 1 | QPSK | 0 | 16 | -17.4 | - |
| 2 | QPSK | 0 | 8 | -14.4 | 3 |
| 3 | QPSK | 0 | 4 | -11.4 | 3 |
| 4 | QPSK | 0 | 2 | -8.4 | 3 |
| 5 | QPSK | 0 | 1 | -5.4 | 3 |
| 6 | QPSK | 2 | 1 | -3.1 | 2.3 |
| 7 | QPSK | 4 | 1 | -0.9 | 2.2 |
| 8 | QPSK | 6 | 1 | 1.0 | 1.9 |
| 9 | QPSK | 8 | 1 | 2.6 | 1.6 |
| 10 | QPSK | 10 | 1 | 4.1 | 1.5 |
| 11 | QPSK | 12 | 1 | 6.3 | 2.2 |
| 12 | 16QAM | 14 | 1 | 8.9 | 2.6 |
| 13 | 16QAM | 17 | 1 | 10.8 | 1.9 |
| 14 | 16QAM | 19 | 1 | 12.4 | 1.6 |
| 15 | 16QAM | 21 | 1 | 14.1 | 1.7 |

***or***

|  |  |  |  |
| --- | --- | --- | --- |
| CQI index | modulation | TBS index | SNR at BLER of 10% (dB) |
| 0 | out of range |  |
| 1 | QPSK | 0 | -5.4 |
| 2 | QPSK | 2 | -3.1 |
| 3 | QPSK | 4 | -0.9 |
| 4 | QPSK | 6 | 1.0 |
| 5 | QPSK | 8 | 2.6 |
| 6 | QPSK | 10 | 4.1 |
| 7 | QPSK | 12 | 6.3 |
| 8 | 16QAM | 14 | 8.9 |
| 9 | 16QAM | 15 | 9.5 |
| 10 | 16QAM | 16 | 9.7 |
| 11 | 16QAM | 17 | 10.8 |
| 12 | 16QAM | 18 | 11.7 |
| 13 | 16QAM | 19 | 12.4 |
| 14 | 16QAM | 20 | 13.0 |
| 15 | 16QAM | 21 | 14.1 |

 |
| [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).**

**Proposal 2: The eNB can configure, via higher-layer signalling, the CQI table to be used by the UE when configured with 16-QAM.**

|  |  |  |
| --- | --- | --- |
| Reported value | NPDCCH repetition level | 16-QAM |
| noMeasurement | No measurement reporting | No measurement reporting |
| candidateRep-A | 1 | N/A |
| candidateRep-B | 2 | N/A |
| candidateRep-C | 4 | N/A |
| candidateRep-D | 8 | N/A |
| candidateRep-E | 16 | N/A |
| candidateRep-F | 32 | N/A |
| candidateRep-G | 64 | N/A |
| candidateRep-H | 1 | QPSK, TBS=0 |
| candidateRep-I | 1 | QPSK, TBS=3 |
| candidateRep-J | 1 | QPSK, TBS=6 |
| candidateRep-K | 1 | QPSK, TBS=9 |
| candidateRep-L | 1 | QPSK, TBS=12 |
| candidateRep-M | 1 | 16-QAM, TBS=15 |
| candidateRep-N | 1 | 16-QAM, TBS=18 |
| candidateRep-O | 1 | 16-QAM, TBS=21 |

 |
| [5] | **Proposal 3: The new table (or modified table) for DL quality report is not captured in RAN1 specifications.*** **Send an LS to RAN2/RAN4 to capture the new DL quality report in TS 36.133 and the corresponding signaling in 36.321.**

**Proposal 4: The DL quality report includes some entries for NPDCCH repetition and some entries for NPDSCH MCS** |
| [6] | ***Proposal 1: Down select the follow options to support CQI reporting for 16QAM:**** ***Option 1: Reusing legacy CQI reporting table and extend CQI entries to 16QAM***
* ***Option 2: Follow legacy eMTC CQI table***

|  |  |  |
| --- | --- | --- |
| 　 | NPDCCH repetition level | NPDSCH |
| Modulation | Code rate x 1024 |
| noMeasurement | No measurement reporting | N/A | N/A |
| candidateRep-A | 1 | N/A | N/A |
| candidateRep-B | 2 | N/A | N/A |
| candidateRep-C | 4 | N/A | N/A |
| candidateRep-D | 8 | N/A | N/A |
| candidateRep-E | 16 | N/A | N/A |
| candidateRep-F | 32 | N/A | N/A |
| candidateRep-G | 64 | N/A | N/A |
| candidateRep-H | 128 | N/A | N/A |
| candidateRep-I | 256 | N/A | N/A |
| candidateRep-J | 512 | N/A | N/A |
| candidateRep-K | 1024 | N/A | N/A |
| candidateRep-L | 2048 | N/A | N/A |
| candidate-M | N/A | 16QAM | [429] |
| candidate-N | N/A | 16QAM | [499] |
| candidate-O | N/A | 16QAM | [549] |
| candidate-P | N/A | 16QAM | [617] |
| candidate-Q | N/A | 16QAM | [667] |
| candidate-R | N/A | 16QAM | [712] |
| candidate-S | N/A | 16QAM | [781] |

 |
| [7] | **Proposal 1: Introduce a new CQI table which excludes legacy CQI index.**

|  |  |  |  |
| --- | --- | --- | --- |
| **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 | 610 | 2.3844 |
| 10 | 16QAM | 718 | 2.8052 |
| 11 | 16QAM | 836 | 3.2684 |
| 12 | Reserved | Reserved | Reserved |
| 13 | Reserved | Reserved | Reserved |
| 14 | Reserved | Reserved | Reserved |
| 15 | Reserved | Reserved | Reserved |

 |
| [8] | Observation 1 The CQI mapping table was discussed in both RAN1# 106-e and 106bis-e without reaching any additional progress. Option 1 subject to leave as FFS e.g., “the exact table entries” and “the mechanism to interpret Table 9.1.22.15-1 as per legacy or as per Rel-17” was proposed as a middle ground solution.Observation 2 “Option 1” couldn’t be agreed “as a middle ground solution” because one company claimed that “Option 1” and “Option 2” are not in line with the “CQI reporting definition” agreed in RAN1# 104bis-e. Nonetheless, in our view the concern is not valid because:* The “CQI reporting definition” was agreed in RAN1# 104bis-e, whereas the down-selection including Option1, Option2, and Option 3 was agreed in RAN1# 105-e upon knowing the “CQI reporting definition”.
* Although the CQI report for 16-QAM is based “*on NPDSCH transport block that achieves an error probability not exceeding 10% BLER*”, the reports for 16-QAM can be incorporated into the NB-IoT’s legacy CQI Table through setting the “NPDCCH repetition level to 1” on those entries as e.g., in [4], [5].

Observation 3 Overall, a CQI report is a recommendation to hint around which I\_TBS indices a scheduling seems to be suitable, nonetheless the ultimate scheduling is up to the eNodeB. Thus, although we believe Option 2 is sufficient to accomplish this task (which requires a minor specification impact), aiming at completing the standardization of 16-QAM we will focus on Option1’s middle ground solution.Observation 4 The CQI mapping table in TS 36.133 clause 9.1.22.15 currently utilizes 13 out of 16 entries [5], however due that Option 1 will utilize more than three reports for 16-QAM it be necessary to override some legacy QPSK entries.Observation 5 The problem with overriding the legacy QPSK entries is that during the times 16-QAM is not suitable to be used, the overridden entries would be unusable, and the UE would have been left without the possibility of using the full-set of legacy QPSK reports.Observation 6 One possible way of overriding legacy QPSK entries and still having them available when required, is through interpreting Table 9.1.22.15-1 as per legacy or as per Rel-17 depending on Rmax.**Proposal 1 For 16-QAM in DL, the CQI Table is based on Option 1 (middle ground solution). Table 9.1.22.15-1 is interpreted as per legacy or as per Rel-17 depending on Rmax. That is:*** + - **A UE configured with 16-QAM should in principle be configured with a small Rmax (e.g., Rmax<= 16).**
		- **If the UE is configured with 16-QAM and Rmax <= 16, then from the middle part of Table 9.1.22.15-1 (e.g., from candidateRep-G) till the bottom of the table the entries will be interpreted as reports corresponding to re-designed QPSK reports and 16-QAM reports.**

|  |  |  |
| --- | --- | --- |
| Reported value | NPDCCH repetition level | 16-QAM CQI index with NPDSCH transport block error probability not exceeding 0.1 |
| noMeasurement | No measurement reporting | No measurement reporting |
| candidateRep-A | 1 | N/A |
| candidateRep-B | 2 | N/A |
| candidateRep-C | 4 | N/A |
| candidateRep-D | 8 | N/A |
| candidateRep-E | 16 | N/A |
| candidateRep-F | 32 | N/A |
| candidateRep-G | 1 | Guard-Band & Stand-Alone Deployments | QPSK | ITBS = [0] | In-Band Deployments | QPSK | ITBS = [0] |
| candidateRep-H | 1 | ITBS = [3] | ITBS = [2] |
| candidateRep-I | 1 | ITBS = [6] | ITBS = [4] |
| candidateRep-J | 1 | ITBS = [9] | ITBS = [8] |
| candidateRep-K | 1 | ITBS = [12] | ITBS = [10] |
| candidateRep-L | 1 | 16-QAM | ITBS = [16] | 16-QAM | ITBS = [12] |
| candidateRep-M | 1 | ITBS = [18] | ITBS = [14] |
| candidateRep-N | 1 | ITBS = [20] | ITBS = [16] |
| candidateRep-O | 1 | ITBS = [21] | ITBS = [17] |

* + - **On the other hand, If the UE is configured with 16-QAM and Rmax > 16, then all report entries in Table 9.1.22.15-1 are fully interpreted as in legacy.**

|  |  |
| --- | --- |
| Reported value | NPDCCH repetition level |
| noMeasurement | No measurement reporting |
| candidateRep-A | 1 |
| candidateRep-B | 2 |
| candidateRep-C | 4 |
| candidateRep-D | 8 |
| candidateRep-E | 16 |
| candidateRep-F | 32 |
| candidateRep-G | 64 |
| candidateRep-H | 128 |
| candidateRep-I | 256 |
| candidateRep-J | 512 |
| candidateRep-K | 1024 |
| candidateRep-L | 2048 |

 |

Companies (Nokia, NSB, QC, Lenovo, Moto, Ericsson) support or can accept a combination of NPDCCH repetitions (legacy entries) and NPDSCH MCS. And companies (Huawei, HiSilicon, ZTE, Sanechips, Nokia, NSB, Lenovo, Moto, MTK) support or can accept a table with only NPDSCH MCS.

The coding rate and efficiency of NB-IoT MCS are listed in Appendix A.1.

For the combination of NPDCCH repetitions and NPDSCH MCS, based on the evaluation results and proposals, a way forward is proposed as below.

Alt 1 (Variant of option 1): the combination of NPDCCH repetitions and NPDSCH MCS

|  |  |  |  |
| --- | --- | --- | --- |
| Reported value | NPDCCH repetition level | NPDSCH transport block error probability not exceeding 0.1 | SNR |
| Modulation | Code rate x 1024 | Efficiency |
| noMeasurement | No measurement reporting | Out of range |  |
| candidateRep-A | 1 | QPSK (TBS index 4) |  |  | -0.6 dB ([2]) |
| candidateRep-B | 2 | QPSK (TBS index 2) |  |  | -3.6 |
| candidateRep-C | 4 | QPSK (TBS index 0) |  |  | -6.6 |
| candidateRep-D | 8 | QPSK (TBS index 0, repetition 2) |  |  | -9.6 |
| candidateRep-E | 16 | QPSK (TBS index 0, repetition 4) |  |  | -12.6 |
| candidateRep-F | 32 | QPSK (TBS index 0, repetition 8) |  |  | -15.6 |
| candidateRep-G | 1 | QPSK (TBS index 6) | 336.8 | 0.6579 | 1.0 dB ([3]) |
| candidateRep-H | 1 | QPSK (TBS index 8) | 453.6 | 0.8860 | 2.6 dB ([3]) |
| candidateRep-I | 1 | QPSK (TBS index 10) | 579.4 | 1.1316 | 4.1 dB ([3]) |
| candidateRep-J | 1 | QPSK (TBS index 12) | 759 | 1.4825 | 6.3 dB ([3]) |
| candidateRep-K | 1 | 16QAM (TBS index 14) | 487.3 | 1.9035 | 8.9 dB ([3]) |
| candidateRep-L | 1 | 16QAM (TBS index 16) | 541.2 | 2.1140 | 9.7 dB ([3]) |
| candidateRep-M | 1 | 16QAM (TBS index 18) | 658 | 2.5702 | 11.7 dB ([3]) |
| candidateRep-N | 1 | 16QAM (TBS index 20) | 783.7 | 3.0614 | 13.0 dB ([3]) |
| candidateRep-O | 1 | 16QAM (TBS index 21) | 837.6 | 3.2719 | 14.1 dB ([3]) |

For a CQI table with NPDSCH MCS, the option 3 is to use eMTC table as a starting point, however, the coding rate and efficiency for NPDSCH is not exactly the same as eMTC ones, as listed in Appendix A.1. Therefore, based on the eMTC table and the evaluation results, a variant of option 3 is proposed, which tries to be as close to the eMTC table as possible, and also try to be aligned in SNR range.

Alt 2 (Variant of option 3): the combination of NPDCCH repetitions and NPDSCH MCS

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **CQI index** | **modulation** | **Repetition number** | **code rate x 1024** | **efficiency** | **SNR** |
| 0 |  |
| 1 | QPSK TBS index 0 | 2 | 80.9 | 0.0789 | -8.4 dB ([3]) |
| 2 | QPSK TBS index 0 | 1 | 80.9 | 0.1579 | -5.4 dB ([3]) |
| 3 | QPSK index 2 | 1 | 140 | 0.2737 | -3.1 dB ([3]) |
| 4 | QPSK index 4 | 1 | 221 | 0.4316 | -0.9 dB ([3]) |
| 5 | QPSK index 6 | 1 | 339.5 | 0.6632 | 1.0 dB ([3]) |
| 6 | QPSK index 8 | 1 | 458 | 0.8947 | 2.6 dB ([3]) |
| 7 | QPSK index 10 | 1 | 587.5 | 1.1474 | 4.1 dB ([3]) |
| 8 | QPSK index 12 | 1 | 760 | 1.4842 | 6.3 dB ([3]) |
| 9 | 16QAM index 14 | 1 | 477 | 1.8632 | 8.9 dB ([3]) |
| 10 | 16QAM index 16 | 1 | 541.6 | 2.1158 | 9.7 dB ([3]) |
| 11 | 16QAM index 18 | 1 | 671 | 2.6211 | 11.7 dB ([3]) |
| 12 | 16QAM index 20 | 1 | 790 | 3.0842 | 13.0 dB ([3]) |
| 13 | 16QAM index 21 | 1 | 832.7 | 3.2526 | 14.1 dB ([3]) |
| 14 | Reserved  |  | Reserved | Reserved | Reserved |
| 15 | Reserved  |  | Reserved | Reserved | Reserved |

Please input your comments on following points:

* Your preference and comments to the variants.
* The update to the variants that can address your concerns.

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson v002 | Based on previous lengthy discussions, and for the sake of constructivism (i.e., aiming at closing this issue), I think we should focus on the middle-ground solution which in this case is a design based on Opt-1.Having said that, one initial comment on the so called “Alt 1 (Variant of option 1)” is that for the in-band deployments there seem to be only two report entries available (i.e., candidateRep-K and candidateRep-L), isn’t so that one concern with other option was the few entries available? I think that aspect should be considered, e.g., as it was taken into account in [8] (see how report entries candidateRep-L to candidateRep-O are deployment-mode dependent).One other thing is that there should be a discussion on the mechanisms for switching between the CQI table under discussion and the legacy table. |
| ZTE, Sanechips | The legacy NPDCCH entries should not be remained for channel quality report for NPDSCH. For low SNR range, QPSK with repetitions can be reported for NPDSCH instead of NPDCCH repetitions. This can achieve a better CQI reporting performance for NPDSCH. Moreover, CQI table does not need to cover SNR as low as NPDCCH with 32 repetitions (-15 dB) since 16QAM is configured in high SNR scenarios. Therefore, compared with Alt 2, we do not see any benefits to support Alt 1. For the table in Alt 2 which is our preference, the two reserved entries also can be utilized to indicate more NPDSCH channel states.For the switching of CQI tables, using predefined conditions, e.g., Rmax, to switch tables will limit the flexibility of switching between legacy and new table, and also limit the application scenarios for legacy table and new table. We suggest the table switching is up to RAN2 (e.g., MAC command) |
| Qualcomm | Our preference would be to have a combination of NPDCCH repetitions and PDSCH MCS, as in Option .1 or Alt. 1 |
| Lenovo, MotoM | We are OK with either options. But here we should consider the CQI table switching for different channel condition.There is some typo for Alt2?Alt 2 (Variant of option 3): the combination of NPDCCH repetitions and NPDSCH MCS |
| MTK | We prefer Alt2. As we know 16QAM is intended for high SNR scenarios which is different from Legacy working scenarios, NPDCCH repetition indication is unnecessary for the 16QAM specific CQI table. And it’s a little bit weird to put a copy of 1~32 repetition into the new CQI table because UEs could use legacy CQI table to report all repetitions under lower SNR condition. Regarding the switching between legacy and new CQI table, we think it’s better to let UEs autonomously to decide seeing that UEs know the downlink channel status better than network. One bit might be expected in MAC CE to distinguish two tables, details leave to RAN2.  |
| Huawei, HiSilicon | We are OK with Alt.2. We do not see any additional benefits in Alt.1 compared with Alt.2. In the high SNR range for 16QAM, the designed CQI states should be targeted for NPDSCH BLER 10% and there is no need to cover NPDCCH with repetitions(>1). Thus, the CQI table for 16QAM should only cover NPDSCH MCS as a clean table. In the very low SNR range, Alt.1 removes NPDCCH repetitions > 32 CQI states do not reflect the SNR range below -15.6dB. Thus, the design of Alt-1 seems to be redundant for high SNR range and not be sufficient for low SNR range. For the switching method for legacy table and new table, we agree with ZTE that using Rmax will limit the flexibility and it is up to MAC command to do this. |
| NordicSemi | We prefer Alt1. It provides larger SNR range so that switching between the legacy and the new table are not needed so often. |

## Others

**Issue 3: Others**

The following are proposed:

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | **Proposal 6: The value range for RRC parameter power ratio of NPDSCH EPRE to NRS EPRE in symbols without NRS should be {-6, -4.77, -3, -1.77, 0, 1, 2, 3} dB.** |
| [4] | **Proposal 3: Define CSI reference resource to be used for 16-QAM CQI measurement. The definition can be up to RAN4.** |
| [8] | Observation 7 For the CSI reference resource, the comment about “*no reference resource was to be defined*”, most likely refers to the NB-IoT channel quality reporting in Rel-14, where the procedure was in IDLE mode. However, in Rel-16 for the channel quality reporting in CONNECTED mode there is a clearer definition.Proposal 2 For the channel quality reporting of 16-QAM in DL, the CONNECTED mode definition as in TS 36.133 clause 8.14.4 is re-used just replacing “reported NPDCCH repetition level” by “channel quality reported value”:* The channel quality reported value shall be derived from the channel quality measured over the NPDCCH period which carries the uplink grant of channel quality report for measurement of DL channel quality of the configured carrier.
 |
| [8] | **Observation 12 One open issue is whether the support of 16-QAM is applicable for both “FDD and TDD” or only FDD.** **Observation 13 The support of 16-QAM has been developed under the context of FDD. Supporting 16-QAM for TDD has been found to result in specification impacts, and therefore 16-QAM should only be supported for FDD operation.****Observation 14 The foreseen RAN1 impacts from supporting 16-QAM for TDD NB-IoT are:*** **In legacy TDD NB-IoT, NPDSCH can be transmitted on DwPTS.**
* **For NPDSCH without repetition, rate matching is used for the Resource Element (RE) mapping into the special subframe.**
* **The RE mapping on special subframes including rate matching aspects would have to be discussed for supporting 16-QAM in TDD NB-IoT.**

**Observation 15 The foreseen RAN4 impacts from supporting 16-QAM for TDD NB-IoT are:*** **Define dedicated UE demodulation requirements for 16QAM in TDD NB-IoT in TS 36.101.**
* **Define a BS conformance test (Test Model) for 16-QAM in TDD NB-IoT in TS 36.141.**

**Proposal 4 Conclusion: In Rel-16, 16-QAM for unicast in UL and DL for NB-IoT is only supported for FDD operation.** |

# Summary

# References

1. RP-211340, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#92e, E-meeting, June 2021.
2. R1-2110857 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2111070 Discussion on 16QAM for NB-IoT ZTE, Sanechips
4. R1-2111133 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
5. R1-2111449 Support of 16-QAM for NB-IoT Qualcomm Incorporated
6. R1-2112001 Support 16QAM for NBIoT Lenovo, Motorola Mobility
7. R1-2112300 Discussion on CQI table and NPUSCH power control parameter for 16QAM MediaTek Inc.
8. R1-2112361 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
9. R1-2111939 Further considerations on Rel-17 NB-IoT and eMTC enhancements Huawei, HiSilicon
10. R1-2112363 On the support of 16-QAM for unicast in UL and DL in TDD NB-IoT Ericsson

# Appendix A

## A.1 The coding rate and efficiency

Assuming 2 NRS ports in standalone deployment, then the coding rate and efficiency for QPSK and 16QAM MCS are summarized in the following table, assuming repetition number is one

|  |  |  |
| --- | --- | --- |
| Modulation | I\_TBS | I\_sf |
| 0 | 1 | 2 | 3 |
| TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency |
| BPSK | 0 | 16 | 107.7894737 | 0.105263158 | 32 | 107.7894737 | 0.105263158 | 56 | 125.754386 | 0.122807018 | 88 | 148.2105263 | 0.144736842 |
| QPSK | 1 | 24 | 80.84210526 | 0.157894737 | 56 | 94.31578947 | 0.184210526 | 88 | 98.80701754 | 0.192982456 | 144 | 121.2631579 | 0.236842105 |
| BPSK | 2 | 32 | 215.5789474 | 0.210526316 | 72 | 242.5263158 | 0.236842105 | 144 | 323.3684211 | 0.315789474 | 176 | 296.4210526 | 0.289473684 |
| QPSK | 3 | 40 | 134.7368421 | 0.263157895 | 104 | 175.1578947 | 0.342105263 | 176 | 197.6140351 | 0.385964912 | 208 | 175.1578947 | 0.342105263 |
| QPSK | 4 | 56 | 188.6315789 | 0.368421053 | 120 | 202.1052632 | 0.394736842 | 208 | 233.5438596 | 0.456140351 | 256 | 215.5789474 | 0.421052632 |
| QPSK | 5 | 72 | 242.5263158 | 0.473684211 | 144 | 242.5263158 | 0.473684211 | 224 | 251.5087719 | 0.49122807 | 328 | 276.2105263 | 0.539473684 |
| QPSK | 6 | 88 | 296.4210526 | 0.578947368 | 176 | 296.4210526 | 0.578947368 | 256 | 287.4385965 | 0.561403509 | 392 | 330.1052632 | 0.644736842 |
| QPSK | 7 | 104 | 350.3157895 | 0.684210526 | 224 | 377.2631579 | 0.736842105 | 328 | 368.2807018 | 0.719298246 | 472 | 397.4736842 | 0.776315789 |
| QPSK | 8 | 120 | 404.2105263 | 0.789473684 | 256 | 431.1578947 | 0.842105263 | 392 | 440.1403509 | 0.859649123 | 536 | 451.3684211 | 0.881578947 |
| QPSK | 9 | 136 | 458.1052632 | 0.894736842 | 296 | 498.5263158 | 0.973684211 | 456 | 512 | 1 | 616 | 518.7368421 | 1.013157895 |
| QPSK | 10 | 144 | 485.0526316 | 0.947368421 | 328 | 552.4210526 | 1.078947368 | 504 | 565.8947368 | 1.105263158 | 680 | 572.6315789 | 1.118421053 |
| QPSK | 11 | 176 | 592.8421053 | 1.157894737 | 376 | 633.2631579 | 1.236842105 | 584 | 655.7192982 | 1.280701754 | 776 | 653.4736842 | 1.276315789 |
| QPSK | 12 | 208 | 700.6315789 | 1.368421053 | 440 | 741.0526316 | 1.447368421 | 680 | 763.5087719 | 1.49122807 | 904 | 761.2631579 | 1.486842105 |
| QPSK | 13 | 224 | 754.5263158 | 1.473684211 | 488 | 821.8947368 | 1.605263158 | 744 | 835.3684211 | 1.631578947 | 1032 | 869.0526316 | 1.697368421 |
| 16QAM | 14 | 256 | 431.1578947 | 1.684210526 | 552 | 464.8421053 | 1.815789474 | 840 | 471.5789474 | 1.842105263 | 1128 | 474.9473684 | 1.855263158 |
| 16QAM | 15 | 280 | 471.5789474 | 1.842105263 | 600 | 505.2631579 | 1.973684211 | 904 | 507.5087719 | 1.98245614 | 1224 | 515.3684211 | 2.013157895 |
| 16QAM | 16 | 296 | 498.5263158 | 1.947368421 | 632 | 532.2105263 | 2.078947368 | 968 | 543.4385965 | 2.122807018 | 1288 | 542.3157895 | 2.118421053 |
| 16QAM | 17 | 336 | 565.8947368 | 2.210526316 | 696 | 586.1052632 | 2.289473684 | 1064 | 597.3333333 | 2.333333333 | 1416 | 596.2105263 | 2.328947368 |
| 16QAM | 18 | 376 | 633.2631579 | 2.473684211 | 776 | 653.4736842 | 2.552631579 | 1160 | 651.2280702 | 2.543859649 | 1544 | 650.1052632 | 2.539473684 |
| 16QAM | 19 | 408 | 687.1578947 | 2.684210526 | 840 | 707.3684211 | 2.763157895 | 1288 | 723.0877193 | 2.824561404 | 1736 | 730.9473684 | 2.855263158 |
| 16QAM | 20 | 440 | 741.0526316 | 2.894736842 | 904 | 761.2631579 | 2.973684211 | 1384 | 776.9824561 | 3.035087719 | 1864 | 784.8421053 | 3.065789474 |
| 16QAM | 21 | 488 | 821.8947368 | 3.210526316 | 1000 | 842.1052632 | 3.289473684 | 1480 | 830.877193 | 3.245614035 | 1992 | 838.7368421 | 3.276315789 |

|  |  |  |
| --- | --- | --- |
| Modulation | I\_TBS | I\_sf |
| 4 | 5 | 6 | 7 |
| TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency |
| BPSK | 0 | 120 | 161.6842105 | 0.157894737 | 152 | 170.6666667 | 0.166666667 | 208 | 175.1578947 | 0.171052632 | 256 | 172.4631579 | 0.168421053 |
| QPSK | 1 | 176 | 118.5684211 | 0.231578947 | 208 | 116.7719298 | 0.228070175 | 256 | 107.7894737 | 0.210526316 | 344 | 115.8736842 | 0.226315789 |
| BPSK | 2 | 208 | 280.2526316 | 0.273684211 | 256 | 287.4385965 | 0.280701754 | 328 | 276.2105263 | 0.269736842 | 424 | 285.6421053 | 0.278947368 |
| QPSK | 3 | 256 | 172.4631579 | 0.336842105 | 328 | 184.1403509 | 0.359649123 | 440 | 185.2631579 | 0.361842105 | 568 | 191.3263158 | 0.373684211 |
| QPSK | 4 | 328 | 220.9684211 | 0.431578947 | 408 | 229.0526316 | 0.447368421 | 552 | 232.4210526 | 0.453947368 | 680 | 229.0526316 | 0.447368421 |
| QPSK | 5 | 424 | 285.6421053 | 0.557894737 | 504 | 282.9473684 | 0.552631579 | 680 | 286.3157895 | 0.559210526 | 872 | 293.7263158 | 0.573684211 |
| QPSK | 6 | 504 | 339.5368421 | 0.663157895 | 600 | 336.8421053 | 0.657894737 | 808 | 340.2105263 | 0.664473684 | 1032 | 347.6210526 | 0.678947368 |
| QPSK | 7 | 584 | 393.4315789 | 0.768421053 | 680 | 381.754386 | 0.745614035 | 968 | 407.5789474 | 0.796052632 | 1224 | 412.2947368 | 0.805263158 |
| QPSK | 8 | 680 | 458.1052632 | 0.894736842 | 808 | 453.6140351 | 0.885964912 | 1096 | 461.4736842 | 0.901315789 | 1352 | 455.4105263 | 0.889473684 |
| QPSK | 9 | 776 | 522.7789474 | 1.021052632 | 936 | 525.4736842 | 1.026315789 | 1256 | 528.8421053 | 1.032894737 | 1544 | 520.0842105 | 1.015789474 |
| QPSK | 10 | 872 | 587.4526316 | 1.147368421 | 1032 | 579.3684211 | 1.131578947 | 1384 | 582.7368421 | 1.138157895 | 1736 | 584.7578947 | 1.142105263 |
| QPSK | 11 | 1000 | 673.6842105 | 1.315789474 | 1192 | 669.1929825 | 1.307017544 | 1608 | 677.0526316 | 1.322368421 | 2024 | 681.7684211 | 1.331578947 |
| QPSK | 12 | 1128 | 759.9157895 | 1.484210526 | 1352 | 759.0175439 | 1.48245614 | 1800 | 757.8947368 | 1.480263158 | 2280 | 768 | 1.5 |
| QPSK | 13 | 1256 | 846.1473684 | 1.652631579 | 1544 | 866.8070175 | 1.692982456 | 2024 | 852.2105263 | 1.664473684 | 2536 | 854.2315789 | 1.668421053 |
| 16QAM | 14 | 1416 | 476.9684211 | 1.863157895 | 1736 | 487.2982456 | 1.903508772 | 2280 | 480 | 1.875 | 2856 | 481.0105263 | 1.878947368 |
| 16QAM | 15 | 1544 | 520.0842105 | 2.031578947 | 1800 | 505.2631579 | 1.973684211 | 2472 | 520.4210526 | 2.032894737 | 3112 | 524.1263158 | 2.047368421 |
| 16QAM | 16 | 1608 | 541.6421053 | 2.115789474 | 1928 | 541.1929825 | 2.114035088 | 2600 | 547.3684211 | 2.138157895 | 3240 | 545.6842105 | 2.131578947 |
| 16QAM | 17 | 1800 | 606.3157895 | 2.368421053 | 2152 | 604.0701754 | 2.359649123 | 2856 | 601.2631579 | 2.348684211 | 3624 | 610.3578947 | 2.384210526 |
| 16QAM | 18 | 1992 | 670.9894737 | 2.621052632 | 2344 | 657.9649123 | 2.570175439 | 3112 | 655.1578947 | 2.559210526 | 4008 | 675.0315789 | 2.636842105 |
| 16QAM | 19 | 2152 | 724.8842105 | 2.831578947 | 2600 | 729.8245614 | 2.850877193 | 3496 | 736 | 2.875 | 4264 | 718.1473684 | 2.805263158 |
| 16QAM | 20 | 2344 | 789.5578947 | 3.084210526 | 2792 | 783.7192982 | 3.061403509 | 3752 | 789.8947368 | 3.085526316 | 4584 | 772.0421053 | 3.015789474 |
| 16QAM | 21 | 2472 | 832.6736842 | 3.252631579 | 2984 | 837.6140351 | 3.271929825 | 4008 | 843.7894737 | 3.296052632 | 4968 | 836.7157895 | 3.268421053 |