**3GPP TSG RAN WG1 Meeting #108-e R1-22xxxxx**

**e-Meeting, February 21 – March 3, 2022**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #1 on 108-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 [2-11].

[108-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 companies’ proposals are listed in the table below

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | **Proposal 2：The new power control term can be applied to NPUSCH with QPSK when configured with 16QAM.** |
| [3] | ***Observation 1: For legacy QPSK, there is no clear requirements to introduce the new term***  ***for uplink power control in NB-IoT.***  ***Observation 2: For NPUSCH with QPSK and TBS 1-6, uplink power reduction caused by will lead to a performance loss if is applied to QPSK.***  ***Proposal 1: An offset can be applied on to reduce the power difference between QPSK and 16QAM.***   * ***The offset could be indicated by higher layers.*** |
| [4] | **Proposal 2: The new uplink power control term is also applied to QPSK when UE is configured with 16-QAM.** |
| [5] | **Proposal 2: The new term also applies to QPSK, when configured with 16-QAM.** |
| [6] | ***Proposal 2: The new term introduced for power control of NPUSCH applies to QPSK and 16QAM when configured with 16QAM.*** |
| [7] | **Proposal 2: The new term should apply to both 16QAM and QPSK, no offset needed.** |
| [8] | **Observation 7 A new term (ΔTF) for 16-QAM in UL was introduced as to account for the larger number of bits per RE that this higher order modulation scheme introduces.**  **Observation 8 Due to the introduction of ΔTF, it was pointed out the possibility of introducing a way to prevent a large power difference between QPSK and 16-QAM.**  **Observation 9 Two proposals remained considered to alleviate the power difference between QPSK and 16-QAM: 1) “Introducing ΔTF for QPSK” and 2) “Introducing an Offset acting on ΔTF for 16-QAM”.**  **Observation 10 “Introducing ΔTF for QPSK” has as a side effect QPSK resulting in an UL power control behavior that will be different with and without 16-QAM configured.**  **Observation 11 Due that it was not possible to reach a consensus towards 1) or 2), at some point one company commented that “in terms of open loop such jump up to 6.5dB is very common, perhaps we could let it go”.**  **Observation 12 In our view, the WID’s objective was about introducing 16-QAM for NB-IoT and therefore we should not create side effects (i.e., different behaviors) from making modifications touching upon legacy modulation schemes.**  **Observation 13 Based on observation 12, any solution intended to alleviate the power difference between QPSK and 16-QAM should be based on a solution acting on 16-QAM elements (i.e., offset acting on ΔTF), otherwise is preferred to deal with a power difference between QPSK and 16-QAM.**  **Proposal 3 If the power difference between QPSK and 16-QAM is to be alleviated, it should be based on a solution acting on 16-QAM elements (i.e., offset acting on ΔTF), otherwise is preferred to live with such a power difference between modulation schemes.** |

The following has been agreed in last meeting:

**Agreement**

**The following working assumption is confirmed.**

**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.
* 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 FFS part, based on the comments, it will be down-selected from the following options:

* Option 1: The term can also be applied to NPUSCH with QPSK, when 16-QAM is configured.
* Option 2: An offset to is configured from a set of {[1dB], [2dB], [4dB], [6dB]}, when 16-QAM is configured.

For information, the calculated are summarized in the following table:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Modulation |  |  |  | | | | | | | |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| QPSK | 13 | TBS | 224 | 488 | 744 | 1032 | 1256 | 1544 | 2024 | 2536 |
|  | 4.546765 | 5.238875 | 5.374201 | 5.708471 | 5.481782 | 5.686359 | 5.542038 | 5.562083 |
| 16QAM | 14 | TBS | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |

And 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.

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

The company positions for the two options are as following:

* Option 1: The term can also be applied to NPUSCH with QPSK, when 16-QAM is configured.
  + Huawei, HiSilicon, Nokia, NSB, Qualcomm, MediaTek,
* Option 2: An offset to is configured from a set of {[1dB], [2dB], [4dB], [6dB]}, when 16-QAM is configured.
  + ZTE, Sanechips, Ericsson

As this issue has discussed for several meetings without consensus, please input your comments of following:

* technical concerns that the option not preferred could not work
* any update to the option not preferred so that it’s acceptable to you.

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | The technical concern we have with Option 1 is that we should not only see the issue from the perspective of UEs supporting 16-QAM, but also from the perspective of the co-existence of UEs supporting 16-QAM and UEs not supporting this feature. For those UEs configured with 16-QAM the QPSK transmissions will account for an extra parameter, which won’t be the case for the QPSK transmissions of UEs not supporting 16-QAM.  Thus, if the power difference between QPSK and 16-QAM is to be alleviated, it should be based on a solution acting on 16-QAM elements (e.g., an offset acting on ΔTF as per Option 2), otherwise is preferred to live with such a power difference between modulation schemes. |
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## Channel quality reporting

### Issue 2: Configuration and switching of CQI table

The companies’ proposals are listed in the table below

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [2] | **Proposal 1: The use of legacy table or the new CQI table is indicated by UE in MAC CE, if 16QAM is configured.** |
| [3] | ***Proposal 2: When DL 16QAM is configured, UE indicates the use of legacy or new CQI table via MAC CE.*** |
| [4] | **Proposal 1: On the use of legacy measurement reporting table, our preferences are –**   * **1st preference: The eNB can configure, via higher-layer signalling, the CQI table to be used by the UE when configured with 16-QAM.** * **2nd preference: If 16-QAM in DL is configured, then the UE should use the 16-QAM CQI table, otherwise the UE will use the legacy table.** |
| [5] | **Proposal 4: The UE uses the 16-QAM CQI table if it is configured with 16-QAM, otherwise it uses the QPSK table.** |
| [6] | ***Proposal 1: When 16QAM is configured, the new CQI table is used. UE determines the legacy or new CQI table based on Rmax, or eNB indicates the use of legacy or new CQI table via MAC CE or RRC configuration.*** |
| [7] | **Proposal 1: switching of CQI table should down selected from following two options.**   * + **Option 1: UE indicates the use of legacy or new CQI table via MAC CE.**   + **Option 2: eNB indicates the use of legacy or new CQI table via MAC CE.** |
| [8] | Observation 1 Towards the end of RAN1# 107-e, the possibility of switching between the Rel-17 CQI table and the legacy CQI table was discussed.  Observation 2 There were several proposals for performing the CQI Table switching such as using MAC CE, Rmax, RRC configuration, and “if 16QAM in DL is configured in msg4, then the UE should use the 16QAM CQI table, otherwise the UE will use the legacy table”.  **Observation 3 During RAN1# 107-e, it was mentioned that the designed Rel-17 CQI table should be sufficient as to do not require a switching to the legacy table since UEs should be configured with a small Rmax value, and the radio conditions of such UEs cannot change so drastically as to require reports tied to a very large number of repetitions.**  Observation 4 16-QAM was designed to be used with 1 repetition, if due to a change in the radio conditions were necessary to switch to QPSK, it seems that the Rel-17 CQI Table covers a reasonable margin of NPDCCH repetitions (up to 32 repetitions).  Observation 5 We need to consider that going beyond the number of repetitions (> 32 repetitions) covered by the Rel-17 CQI table, may even result in an RLF for a UE configured with a small Rmax value.  Observation 6 Thus, for a scenario requiring a large number of repetitions (i.e., > 32) a CQI table switching mechanism may result to be irrelevant, since in those scenarios a larger Rmax would need to be configured.  Proposal 1 Based on the Rel-17 CQI table design which covers up to 32 repetitions for QPSK, introducing a table switching mechanism is no longer necessary. |

On configuration and switching of the CQI table, the company positions are summarized as below:

* + Option 1: UE indicates the use of legacy or new CQI table via MAC CE.
    - Huawei, HiSilicon, ZTE, Sanechips, MediaTek
  + Option 2: eNB indicates the use of legacy or new CQI table via MAC CE.
    - MediaTek, Lenovo, Moto
  + Option 3: eNB configures the use of legacy or new CQI table via RRC configuration
    - Nokia, NSB (1st), Lenovo, Moto
  + Option 4: if Rmax<=16, the new CQI table is used, otherwise, the legacy CQI table is used.
    - Lenovo, Moto
  + Option 5: the 16-QAM CQI table is used if DL 16-QAM is configured, otherwise the legacy CQI table is used
    - Nokia, NSB (2nd), Qualcomm, Ericsson

As the views are still very diverse, it is proposed to down-select from the two options with support of most number of companies, i.e., option 1 and option 5.

**Proposal 1: When 16QAM is configured, the new CQI table is used. On use of the legacy CQI table, it’s down-selected from following options:**

* + **Option 1: UE indicates the use of legacy or new CQI table via MAC CE.**
  + **Option 5: the 16-QAM CQI table is used if DL 16-QAM is configured, otherwise the legacy CQI table is used**

Please input your preference regarding the two options.

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| --- | --- |
| Companies | Comments |
| Ericsson | Given the final design of the Rel-17 CQI table, we think that there is no need of introducing any CQI table switching mechanism. Hence, Option 5 is our preference which in our understanding does not need any specification statement since it is an inherent fact for the feature. |
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## Text proposals

### EPRE for 16-QAM

In section 1 of [5], it is proposed to replace the description of constant power between symbols by equations, with the following text proposal

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| --- |
| TP1 (TS 36.213)  16.2.2 Downlink power allocation  **[…]**  If a UE is configured with higher layer parameters *npdsch-16QAM-Config* and *nrs-PowerRatio*, - if higher layer parameter *operationModeInfo* indicates '10' or '11', - the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs (not applicable to NPDSCH REs with zero EPRE) is given by the parameter *nrs-PowerRatio* in symbols without NRS, and  - the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs in symbols with NRS is given by , where is given by the parameter *nrs-PowerRatio*, and for a cell with two NRS antenna ports and for a cell with one NRS antenna port  - otherwise,  - the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs (not applicable to NPDSCH REs with zero EPRE) is given by the parameter *nrs-PowerRatio* in symbols without NRS and CRS, and  - the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs (not applicable to NPDSCH REs with zero EPRE) is given by the parameter *nrs-PowerRatioWithCRS* in symbols with CRS, and  - the ratio of NPDSCH EPRE to NRS EPRE among NPDSCH REs in symbols with NRS is given by , where is given by the parameter *nrs-PowerRatio*, and for a cell with two NRS antenna ports and for a cell with one NRS antenna port  . |

Please input your comments regarding the above text proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Math-wise the proposed TP seems to be correct, the only thing that needs to be amended is the following variable “ for a cell with two NRS antenna ports and for a cell with one NRS antenna port”. |
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### Configuration for PUR

In section 2 of [5], it is proposed that the configuration/behavior of 16-QAM for downlink is as following:

* If 16 QAM is enabled in PUR, and the DCI is mapped to the search space by PUR-RNTI, and MCS=’1111’, or
* If 16QAM is enabled in UE-specific RRC, and the DCI is mapped to the search space by C-RNTI and MCS = ‘1111’, then
  + Use 16-QAM as the modulation order.

And it is proposed to endorse the following text proposal:

|  |
| --- |
| TP 3(TS 36.213):  16.4.1.5 Modulation order and transport block size determination  To determine the modulation order in the NPDSCH, the UE shall  - if the UE is configured with higher layer parameter *npdsch-16QAM-Config* and the DCI is mapped onto the UE specific search space and the 4-bit "modulation and coding scheme" field () in the DCI is set to ‘1111’, or if the UE is configured with higher layer parameter *pur-DL-16QAM-Config* and the DCI is mapped onto the UE specific search space given by PUR-RNTI and the 4-bit "modulation and coding scheme" field () in the DCI is set to ‘1111’,  - use modulation order, **=** 4  - otherwise  - use modulation order, **=** 2. |

In section 2.2 of [8], the same issue is discussed, and the following text proposal is proposed:

|  |
| --- |
| ------------------------------------------------------- Text Start ----------------------------------------------------------- 16.4.1.5 Modulation order and transport block size determination To determine the modulation order in the NPDSCH, the UE shall  - if the UE is configured with higher layer parameter *npdsch-16QAM-Config* and the DCI is mapped onto the UE specific search space given by C-RNTI or if the UE is configured with higher layer parameter *pur-DL-16QAM-Config* and the DCI is mapped onto the UE specific search space given by PUR-RNTI, and the 4-bit "modulation and coding scheme" field () in the DCI is set to ‘1111’,  - use modulation order, **=** 4  - otherwise  - use modulation order, **=** 2.  ------------------------------------------------------- Text End ----------------------------------------------------------- |

Please input your comments regarding the above two text proposals:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Either of the two TPs above are ok. Perhaps we slightly prefer the one at the bottom due that it is a bit shorter, but if the one on the top were adopted it seems that we would need to add “given by C-RNTI” before the track changes start. |
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### Support of 16-QAM in TB processing of NPUSCH

In section 3.2.1, it is proposed to capture the missed part of 16-QAM in TB processing of NPUSCH, with the following text proposal:

|  |
| --- |
| --------------------------------------------------------- Text Start ---------------------------------------------------------6.3.2 Uplink shared channel Figure 6.3.2-1 shows the processing structure for the UL-SCH transport channel. Data arrives to the coding unit in the form of a maximum of one transport block over a number of resource units per UL cell. The number of resource units is scheduled according to [3]. The following coding steps can be identified:  - CRC attachment  - Channel coding  - Rate matching    Figure 6.3.2-1: Transport block processing for UL-SCH  The CRC attachment, channel coding, and rate matching are performed according to clauses 5.2.2.1, 5.2.2.3, and 5.2.2.4, respectively, with the following differences:  - In clause 5.1.4.1.2 in the calculation of  , *Qm* is 1 for π/2-BPSK, 2 for π/4-QPSK and 4 for 16QAM, and *rvidx* = 0 or 2.  In addition, after rate matching interleaving is applied per resource unit according to clauses 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where the input sequence to 5.2.2.7 is the portion of *e* for a resource unit instead of *f*, and where  is the number of SC-FDMA symbols for NPUSCH in a UL resource unit as given in clause 10.1.2.3 of [2].  ------------------------------------------------------- Text End ----------------------------------------------------------- |

Please input your comments regarding the above text proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | OK with the TP. It seems needed, since now 16QAM is supported. |
|  |  |
|  |  |

### Uplink power control for PUR NPUSCH with 16QAM

In section 3.2.2.1 of [8], it is proposed to add the uplink power control for NPUSCH with 16-QAM, with following text proposal:

|  |
| --- |
| ------------------------------------------------------- Text Start ----------------------------------------------------------16.2.1.1.1 UE behaviour The setting of the UE Transmit power for a Narrowband Physical Uplink Shared Channel (NPUSCH) transmission is defined as follows. For FDD, if the UE is capable of enhanced random access power control [12], and it is configured by higher layers, and for TDD, enhanced random access power control shall be applied for a UE which started the random access procedure in the first or second configured NPRACH repetition level. ------------------------------------------------------- Text Omitted ------------------------------------------------------- - If NPUSCH (re)transmissions with 16QAM or NPUSCH (re)transmission corresponding to preconfigured uplink resource with 16QAM,  - for and for where  is given by the parameter *deltaMCS-Enabled* provided by higher layers for serving cell , and  - where is the code block size and is the number of resource elements determined as where , , are defined in [3], and is defined in section 16.5.1.1  - otherwise .  ------------------------------------------------------- Text End ----------------------------------------------------------- |

Please input your comments regarding the above text proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Ok with the TP. The new term in the UE’s transmit power control equation is also applicable for PUR, nonetheless since the statement “NPUSCH (re)transmissions with 16QAM” does not encompass PUR, then an explicit statement about PUR needs to be added. |
|  |  |
|  |  |

### The indices of MCS for PUR NPUSCH

In section 3.2.2.2 of [8], it is proposed to clarify how the indices of MCS for PUR NPUSCH is provided, with the following text proposal:

|  |
| --- |
| ------------------------------------------------------- Text Start ----------------------------------------------------------16.5.1.2 Modulation order, redundancy version and transport block size determination To determine the modulation order, redundancy version and transport block size for the NPUSCH, the UE shall first  - read the "modulation and coding scheme" field () in the DCI or configured by higher layers for NPUSCH transmission using preconfigured uplink resource, and  - read the "redundancy version" field () in the DCI or initiate with for NPUSCH transmission using preconfigured uplink resource, and  - read the "resource assignment" field () in the DCI or configured by higher layers for NPUSCH transmission using preconfigured uplink resource, and  - compute the total number of allocated subcarriers (), number of resource units (), and repetition number () according to Clause 16.5.1.1. ------------------------------------------------------- Text Omitted ------------------------------------------------------- The UE shall use (,) and Table 16.5.1.2-2 to determine the TBS to use for the NPUSCH. is given in Table 16.5.1.2-1 if , or if NPUSCH with 16QAM except for NPUSCH transmission using preconfigured uplink resource in which case the corresponding indices are provided in *PUR-Config-NB*,  otherwise. is the value of the "modulation and coding scheme for 16QAM" in the DCI.  ------------------------------------------------------- Text End ----------------------------------------------------------- |

Please input your comments regarding the above text proposal:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | Ok with the TP, since it is not captured from where the information is obtained in the case of NPUSCH transmission using preconfigured uplink resources. |
|  |  |
|  |  |

## Others

There are also following proposals:

|  |  |
| --- | --- |
| Sourcing | Proposals |
| [6] | ***Proposal 3: DL 16QAM in PUR is configured only in condition that DL 16QAM in connected mode is configured*** |

Please input your comments regarding the above proposal, or any other critical issues you think should be discussed:

|  |  |
| --- | --- |
| Companies | Comments |
| Ericsson | In our view there is no need to tie idle-mode to connected-mode for the 16-QAM feature. PUR has its own toolbox to perform adjustments (e.g., ways of determining if the UE requires a PUR re-configuration) and therefore there is no need of conditioning the usage of 16-QAM for PUR based on a configuration for connected-mode, since the PUR feature should maintain its autonomy. |
|  |  |
|  |  |

# Summary

# References

1. RP-211340, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#92e, E-meeting, June 2021.
2. R1-2200976 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2201135 Discussion on remaining issues for NB-IoT 16QAM ZTE, Sanechips
4. R1-2201407 Support of 16-QAM for unicast in UL and DL for NB-IoT Nokia, Nokia Shanghai Bell
5. R1-2201650 Support of 16-QAM for NB-IoT Qualcomm Incorporated
6. R1-2201968 Support 16QAM for NBIoT Lenovo, Motorola Mobility
7. R1-2202076 Remaining issue for support 16QAM in NB-IOT R17 MediaTek Inc.
8. R1-2202277 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
9. R1-2202280 Clarification on the support of 16-QAM for NB-IoT in TS 36.212 Ericsson
10. R1-2202281 Clarification on the support of 16-QAM for NB-IoT in TS 36.213 Ericsson
11. R1-2202477 Further considerations on Rel-17 NB-IoT and eMTC enhancements Huawei, HiSilicon